PDHonline Course C612 (10 PDH)

Hoover Dam: Conqueror of the Colorado

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2020

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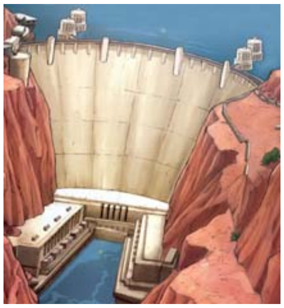
HOOVER DAM



Conqueror of the Colorado

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Part 1

To Harness a River

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"…Blackest night above, inferno below…It is the fiery pit of haunted dreams, aglow with light and colorful reflections that bounce back and forth between the narrow walls like an echo. Dazzling searchlights, groping, restless; headlamps streaming out of nowhere…Your ears pick out the hiss of steam, roaring motors, muffled subterranean thunder, the rapid-fire of air-driven tools, the whir, the swish, the chug of giant scoops biting into earth, the river's rumbling overtones – sounds magnified to satanic proportions as they climb aloft to you some 700-feet above…And this is the beginning of Hoover Dam – a test of man, machinery and engineering without precedent in all the history of the world"

***Popular Mechanics*, June 1932**

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Left: nighttime view looking downstream into *Black Canyon* from *Lookout Point*
Above: daytime view looking downstream into Black Canyon from Lookout Point

5

View looking down into dam foundation from near Lookout Point on the Nevada rim (700-feet above the river)

6

"…Yonder to the north lies the great basin which will be more than one hundred miles long, and will be the biggest artificial body of water in the world. It will hold enough water to cover the state of Kentucky to a depth of one foot. It is a vast area of rugged mountain peaks hewn to fantastic outlines by erosion, splotched with unbelievable color, cleft by great canyons and sandy washes…"
Popular Mechanics, **June 1932**

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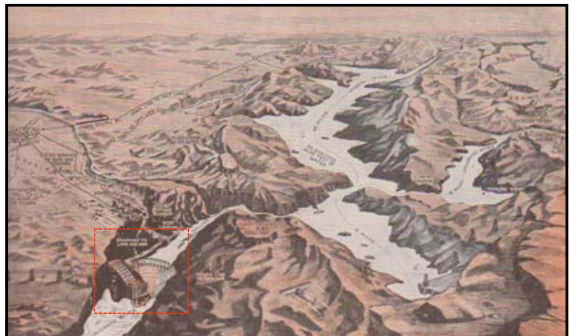

"Drawing of the Boulder-Dam country, showing where the dam and other proposed improvements will be situated; the entire project, including erection of the dam and power house, installation of machinery and building of a canal, will cost $165 million"
Popular Mechanics, **June 1932**

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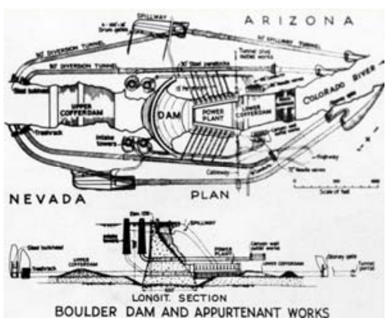

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Desert scene south of Boulder City, Nevada (May 1932)

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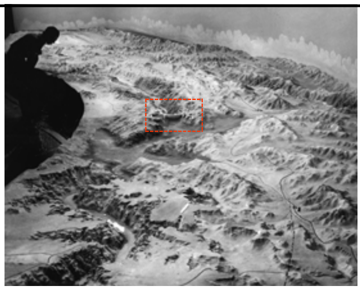
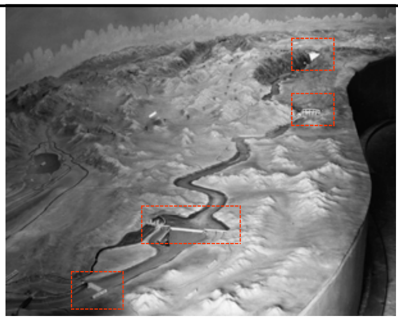
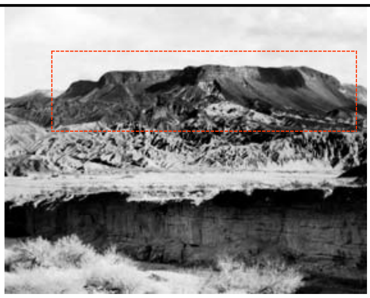


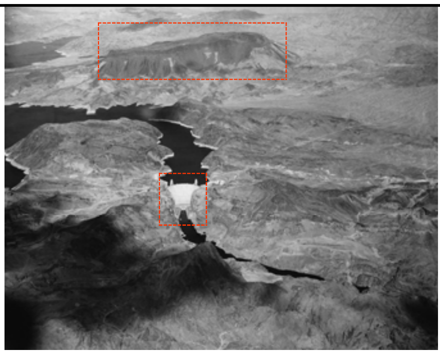
View looking downstream of the ***Exhibit Building*** model showing the ***Grand Canyon***, ***Lake Mead*** and Hoover Dam area. Hydraulic engineering models were used by the USBR to study/resolve engineering issues. The extensive hydraulic modeling/testing was performed at ***Colorado State University*** laboratories (in Fort Collins, CO) and on the USBR's ***Uncompahgre Project*** (in western Colorado). 13



Model of Hoover Dam and the Southwest area (on permanent display in the Exhibit Building at Hoover Dam). In this view (looking upstream, from bottom to top); *Laguna Dam, Imperial Dam, Parker Dam* and *Hoover Dam*. 14

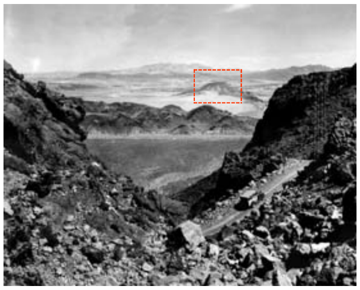


View of *Fortification Hill*, a prominent landmark in this area. Geologists state that the entire Hoover Dam area was once covered with a cap of *Basalt* (which was entirely eroded away) except on this commanding butte. The Basalt cap can be plainly seen in the photograph, overlying the *Andesite* which is of earlier volcanic origin. 15



View looking upstream: Fortification Hill (top) / Hoover Dam (bottom) 16

Panorama from *Observation Point*, overlooking *Hemenway Wash* and the reservoir which was created when Hoover Dam was completed. The range of hills in the foreground were submerged, the flat-topped hill in the left-center formed a small island. The site of the gravel pit is in the direct center. 17



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Rigger/Rodman working with topography survey party in *Black Canyon* on the Nevada side. Rodman was lowered over the canyon rim on rope and gave points which were recorded with horizontal and vertical angle by two transit parties. The dam's foundation and abutments are rock of volcanic origin geologically called *Andesite Breccia*. The rock is hard and very durable.

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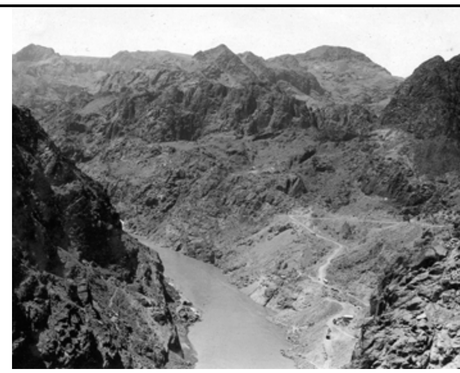
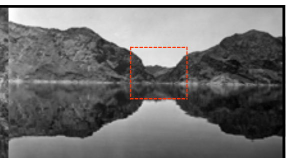
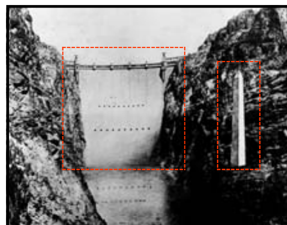
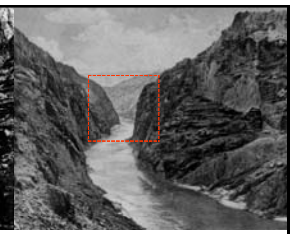


Colorado River (looking downstream from Hoover Dam site) 20



Left: *Boulder Canyon*. The original site for Hoover Dam. The dam site was moved to Black Canyon for its greater geological stability and proximity to logistical support. The USBR made the final decision as to the dam's location.
Above: reflected perfectly in the mirror-like waters of Lake Mead is the entrance to Boulder Canyon. This canyon (eighteen miles above the actual site of Hoover Dam) was once considered strongly as the most feasible site for the dam. From the canyon, even though the dam was built in Black Canyon, came the name "Boulder Dam" by which the dam was known (until 1947 when it officially became "Hoover Dam"). 21





Left: *"Damsite of proposed Boulder (Hoover) Dam and Washington Monument for comparison of heights. Monument 555-feet, Dam 560-feet from river level to crest."* (January 1923)
Right: Hoover Dam site (Black Canyon) prior to initiation of construction activities (photograph taken prior to 1929)

22

"…In building the dam, enough material must be moved to furnish foundations for the homes of 80K persons. This will be followed by the placing of upward of 4.2 million cubic yards of concrete and 35 million pounds of reinforcing steel. Every miracle that modern science and inventive genius have created has been mustered for this tremendous undertaking, the cost of which has been put at approximately $165 million…"
***Popular Mechanics*, June 1932**

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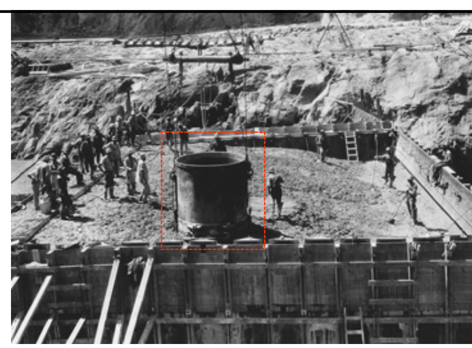

Placing concrete in block at mid-section of Hoover Dam site. Note the eight cubic-yard bucket (handled by cableway) in use 24

Wild Precise Theodolite **(mounted on concrete pedestal on canyon wall). Used for survey to determine temperature and load movements in dam**

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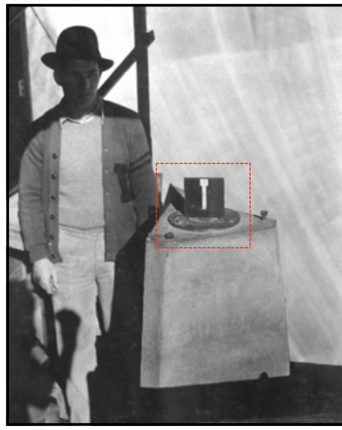

Target (mounted on concrete pedestal) used for triangulation measurement in precise survey to determine temperature and load movements in dam

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Left: Operator holding *Plumbing Telescope* (used to observe temperature and load movements in dam through elevator shafts; December 1935)
Above: Operator making observation through telescope of *Prismatic Tilt Meter* (used in measuring temperature and load movement in dam; December 1935)

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Angle Meter

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Surveying Transit

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Seismic Device (with prisms)

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Oscillograph

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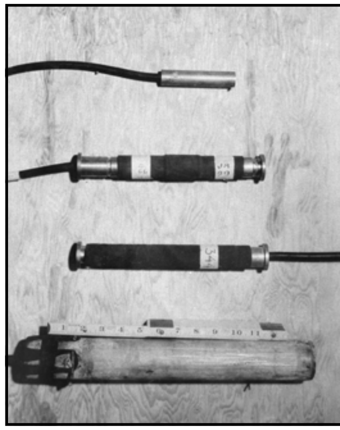

From top to bottom; *Resistance Thermometer, Joint Meter, Strain Meter* (ready for installation), *Strain Meter* (in field case).

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One (of two) time frequency control clocks

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"… And here, at Hoover Dam, are the modern pioneers. Rugged stalwarts all, true sons of the fathers who wrote romantic history at Plymouth Rock, in Kentucky wildernesses, along the muddy Missouri, through the golden Feather River rush of '49. No aliens here, by congressional direction, but a picturesque army of native Americans who today as builders of the world's greatest engineering project are reviving in dramatic fashion the traditions of the old west…"

***Popular Mechanics,* June 1932**

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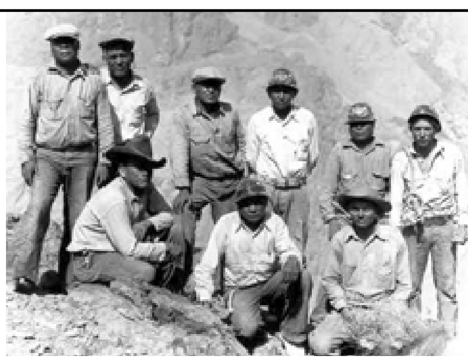

Native-American Work Crew

35

Form Stripping Crew

36

Family Living in Tent (in "Ragtown")

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"…There is no more spectacular boom town of record than Boulder City, capital of the new realm. Less than a year ago, nothing but a mirage in the desert sun, a desolate stretch of cactus-strewn, wind swept hillside. Now a typical, hustling town of 5,200 people, with paved streets, elaborate public utility systems, fine new buildings, churches, theaters and other good living facilities. It materialized magically, overnight. Not helter-skelter, but to exact plan – a city precise to the last detail before a nail was tapped…"
***Popular Mechanics*, June 1932**

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607 “F” Street, Boulder City, Nevada

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Exterior view/s of rear (left) and side (right) of *Guest House*, which occupied a commanding knoll overlooking Boulder City and the mountains beyond. The Guest House was the home of *Six Companies* directors when they were visiting Boulder City. General Superintendent *Frank Crowe* told Edgar Kaiser (son of Six Companies Chairman *Henry Kaiser*) many years later that the most difficult part of building Hoover Dam was the Guest House. First there was the issue of where it should be located that wasted valuable time and then there were the guests themselves. One company director would show up at the guest house one week issuing specific instructions and the following week another director would show up with an entirely different set of instructions. *Felix Kahn* – Manager of the Boulder City Company, realized the difficult situation their man Crowe was in stating: *“A Board of Directors can establish policy, but it can’t build a dam.”* The board voted to create a four-man Executive Committee inclusive of Henry Kaiser, Felix Kahn, *Stephen Bechtel* (Director of Purchasing, Auditing and Warehousing) and Crowe confidant *Charles Shea* (Director of Construction) to establish clear lines of communications with Frank Crowe.

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Front view of the Guest House showing the covered veranda which afforded a view of scenic grandeur across Hemenway Wash and the reservoir which was created when Hoover Dam was completed

48

The majestic panorama of rugged peaks as seen from the Six Companies' Guest House. Beyond Hemenway Wash (in foreground) can be seen the Colorado River. 49

Interior of the Living Room (looking toward the sleeping quarters). The Guest House contained six bedrooms arranged en-suite, four on the first floor and two on the second floor (with bathrooms between). 50

Interior view of the Guest House Living Room
(looking towards the Dining Room) 51

Guest House Dining Room 52

Six Companies *Office Club* (corner of *Birch* and *Cherry*), Boulder City

53

"…It unquestionably is the driest community in America. At the reservation entrance all cars and their occupants must pass the inspection of the eagle-eyed United States marshals. Try and get a drink in Boulder City! It is also the healthiest city, both from the standpoint of climate and sanitation as well as from the angle of personal safety. Weapons are taboo, there are no two-gun men, no gangsters, no gambling, no vice…"
Popular Mechanics, **June 1932**

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Drawing of *Administration Building* at Boulder City

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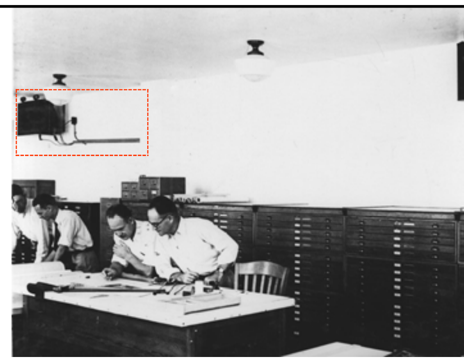
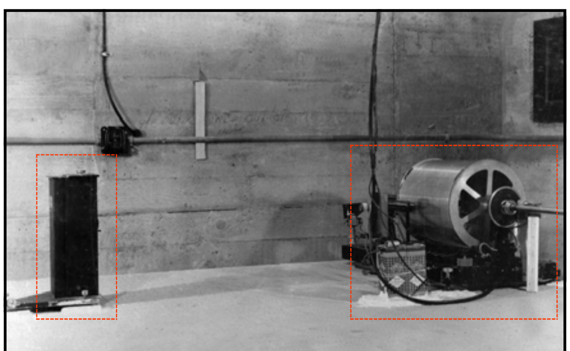
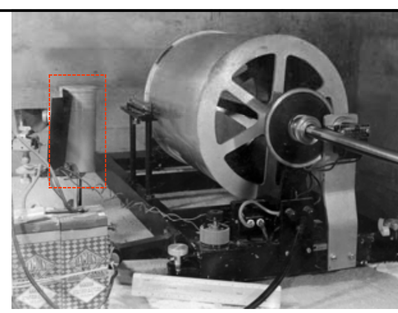


Cooling units installed in the office engineer's drafting room at the Government Administration Building, Boulder City 58



Single, east-west component - *Wood-Anderson* seismograph, Administration Building, Boulder City. Seismometer on the left and recorder on the right. 59



End view of *Wood-Anderson* seismograph recorder. Synchronous AC motor, (right of shaft) drove the drum at a constant speed (one millimeter per second). The source of light for operation was enclosed in the can-like container (at left). Each minute, the light source beam was given a slight deviation by the magnet pulling a small pane into the light. 60

The *Annex Building* (of the Main Administration Building) in Boulder City

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Drawing of *Municipal Building and Post Office* at Boulder City

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Drawing of *Dormitory and Guest House* at Boulder City

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Boulder Dam Hotel

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Interior of the Boulder Dam Hotel

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Recreation Hall **(operated by the *Boulder City Co*mpany)**

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Looking up *Nevada Boulevard* in Boulder City. Government Administration Building on the hill in the distance. Boulder City Co. Department Store and Business District in the foreground

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Drug Department of Boulder City Company Department Store

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Men's Furnishing Department of the Boulder City Department Store

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Boulder City School

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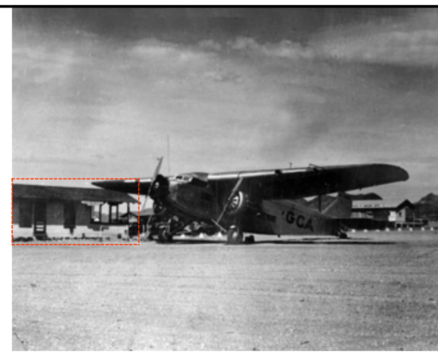

Ford tri-motor airplane used by *Grand Canyon Airways* in Boulder City. The plane is at the field in Boulder City (waiting room at left).

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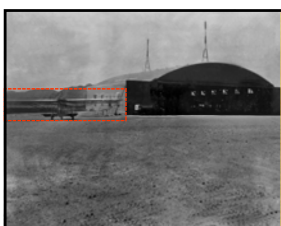

<u>Left</u>: Grand Canyon Airways, Inc. Hangar (plane used for scenic trips over Hoover Dam)
<u>Right</u>: *Grand Canyon-Boulder Dam Tours, Inc*. map indicating tours by automobile, boat and airplane of "Two Wonders of the World" (Grand Canyon and Boulder/Hoover Dam)

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"…But on the other hand there is an undeniable swagger about Boulder City; something in the bravado, the high spirit, good nature and devil-may-care attitude of the old cow and mining towns. It's an up-and-coming place, and really resembles nothing so much as a war-time cantonment…"
Popular Mechanics, **June 1932**

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Six Companies Bunkhouses under construction at Boulder City

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***Babcox & Wilcox Company Dormitory*, Boulder City**

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"…there are a hundred phases of construction wholly without precedent. 'Hoover Dam carries all previous engineering knowledge and experience one step further,' according to one authority. Here are a few of the special problems: All concrete generates heat during the hydration or drying-out process. In small blocks, this is dissipated naturally. But it would take 250 years for this projected mass to cool unless artificially treated. So they are going to put Hoover Dam literally 'on ice.' Some 152 miles of pipe and a complete cold-storage plant will be required for the job…"
Popular Mechanics, **June 1932**

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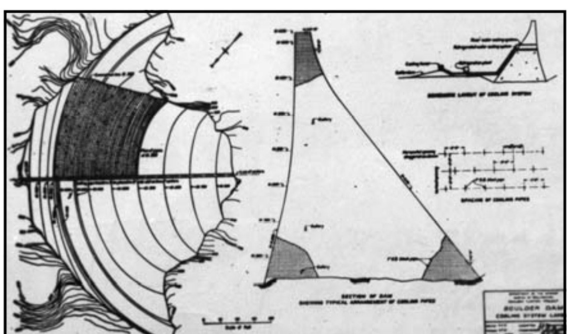

A drawing describing the "Cooling System Layout" for Hoover Dam

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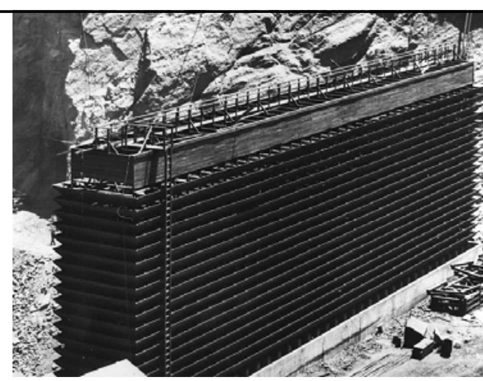

Evaporation Tower for concrete cooling system

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From its founding in 1902, the *U.S.* (Department of the Interior) *Bureau of Reclamation* (USBR) had learned much about the chemical interactions between cement, aggregate and water; the building blocks of concrete. At the *Belle Fourche Project* (in western South Dakota, 1905-1916), much of the original concrete required replacement within fifteen years due to alkaline reactions. A major issue facing USBR on the *Boulder Canyon Project* (BCP) was removing the *Heat of Hydration* resultant from the mass of concrete curing. Left to cool by itself, expansion and/or contraction over the long cool-down period that would be required (+100 years) would cause cracks resulting in the dam's failure. During the construction of the *Owyhee Dam* (1928-1932), USBR engineers experimented in their Denver labs with a refrigeration system that would remove the heat generated by the curing concrete thus preventing undesirable expansion/contraction. By the time of the BCP, USBR engineers were aware of the dangers and their specifications for Hoover Dam's concrete was custom-fit to local aggregate and water quality/supply conditions.

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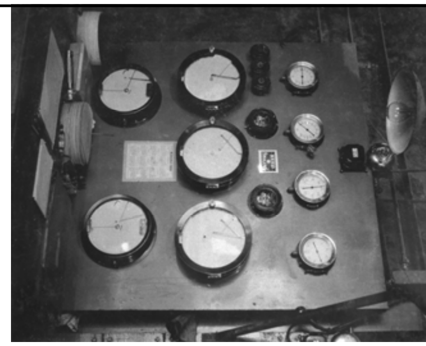

Instrument Panel; Hoover Dam cooling system (compressor house)

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"…Then there are the giant diversion tunnels through which the river will flow while the dam itself is under construction. There are four of these, each three-quarters of a mile long and fifty-six feet in diameter. That means the height of a four-story building. Nothing so gigantic in tunneling ever before has been attempted…"
Popular Mechanics, **June 1932**

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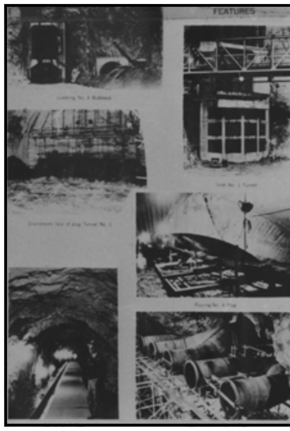

A group of pictures showing some of the various features in the construction of the four diversion tunnels

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"…One of the most dangerous tasks of the entire project is scaling down of the canyon walls that tower almost a sheer thousand feet above the river. Suspended from above by ropes anchored to steel bars driven into the rock, jackhammer men, riggers and scalers toiled for days on overhanging projections. Huge masses had to be drilled and blown down with dynamite. Every loose fragment for a mile up and down the river on both sides of the 350-foot gorge had to be cleared for protection of the workmen below…"
Popular Mechanics, **June 1932**

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"High-Scalers" perched on a bench 1K-feet above the river prepare anchorages from which workmen will be suspended by ropes in scaling the canyon walls

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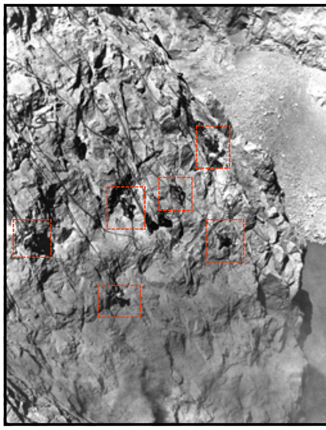

High-Scalers at work

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High-Scaler's *Bosom Chair*

92

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Preparing dynamite

94

Safety signs put up by insurance company (August 1931)

95

"…Never has so great an enterprise been confined and restricted to so small an area. Another handicap to be overcome was, and is, climate. It isn't the humidity here, it's the heat. Only Death Valley, the famous California inferno, knows higher temperatures. For more than ninety days last summer, the average daily temperature in the lower Colorado basin was 119.8 degrees Fahrenheit, while on many days the maximum thermometer registered 128 degrees. Although it is true that 110 degrees of this dry heat is comparable to ninety in New York or Chicago, 128 degrees on any man's thermometer spells H-O-T…"

Popular Mechanics, **June 1932**

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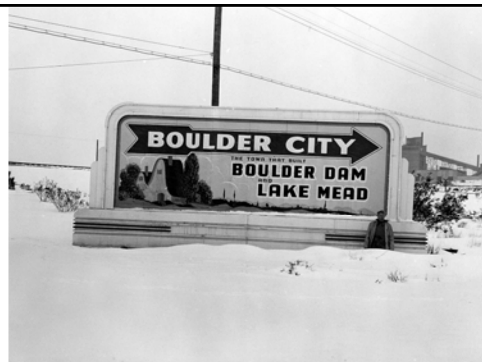
"Covered Wagons" (each having a capacity of forty-eight men) were used to transport workmen from Boulder City to Black Canyon. The trucks' canvas-covered side curtains could be raised during hot weather. 97

Indicative of the wide range of temperatures at Boulder City (which reaches 115-degrees in the summer), this photograph shows what was officially reported as the third snowstorm in seventeen years. The temperature dropped to 24-degrees (November 1931). 98

Rear view of the Administration Building covered with a four-inch blanket of snow (February 1939) 99



January 1945 100

"…And last, but not least, is the river itself. With a flow velocity of from eight to thirty miles an hour, it is regarded as the world's most dangerous stream. In flash flood it will often rise sixty feet in six hours. This is the only river in the world whose volume is less than half water. Some sixty percent is sand and gravel in suspension…"
Popular Mechanics, **June 1932** 101

Black Canyon (view looking downstream toward Hoover Dam site) 102

Government engineers on boat trip down the Colorado near dam site (September 1930). During the summer of 1931, the temperatures in Black Canyon reached 140-degrees. When winter arrived, icy winds whipped through the canyon and temperatures dropped to below freezing. 103

***R.F. Walter*, Chief Engineer of the Reclamation Service (left) and *Dr. Elwood Mead*, Commissioner of the Bureau of Reclamation (right) at the dam site (September 1930)** 104

Old *Ring Bolt* anchored in rocks on the Arizona shore of the Colorado River (near *Jumbo Wash,* below Hoover Dam). These rings were used by early navigators as cable anchors to assist the boats through swift waters. The bolt was probably set shortly after the end of the Civil War.

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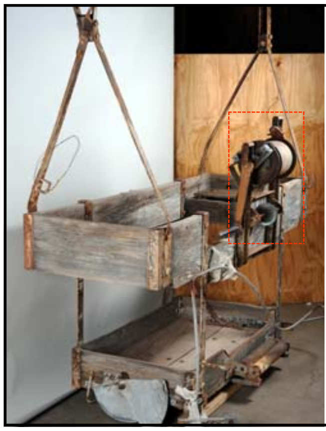

Cable car with *Canfield Reel* (used downstream of the dam to measure river flow)

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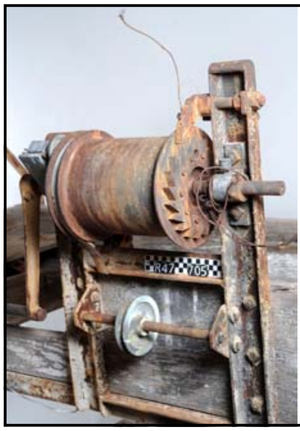

Close-up of the Canfield Reel

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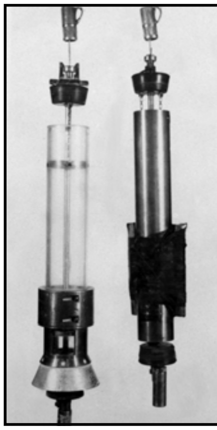
Close-up view of the dividing line of silt and clear water. The muddy water plunges down and under at this point. These is a sharp change in temperature here as well. 108



Foerst Water Sampler **(at right)**
(lucite model at left)

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Water Lab

110

Too Thick to Drink, Too Thin to Plow

111

"…In forty years the Colorado has pushed back the Gulf of California 150 miles. And here's what it will take to stop that river; A dam two city blocks thick at the base, tapering to forty-five feet on top; 727 feet, or one-eighth of a mile, high. That's just twice as tall as any other dam on earth. It means enough concrete spread into a twenty-foot highway to reach from Los Angeles to Chicago."
***Popular Mechanics,* June 1932**

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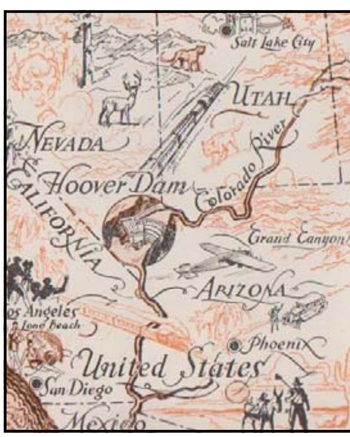

"The Geographic area affected by the Hoover Dam project"
***Popular Mechanics,* June 1932**

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Colorado River flowing through Boulder Canyon (April 1932) 114

Part 2

Fortune Favors the Bold

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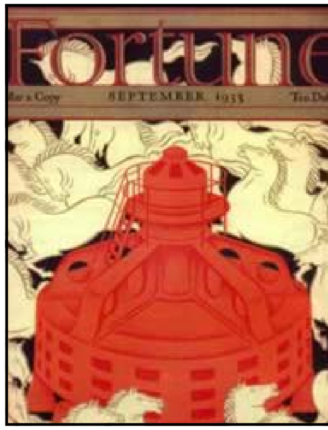

"Boulder Dam will probably be the biggest dam, perhaps the biggest man-made thing in the whole wide world. But since engineering is a craft in which men hold their jobs by being exactly right, even the dam engineers make no flat claim for their colossus. They tell you there are other canyons and other rivers which could take greater dams. But below these other rivers there are no dried out wastes of potential farm land wide enough for their prisoned floods to water; and, as populations are now settling, no cities are at hand to burn their power. Probably they won't be built."

Fortune **magazine, Sept. 1933**

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"Colorado River Basin Below Boulder Dam" (September 1929)

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"Boulder Dam was, first of all, a vision in the desert. It was the vision primarily of Arthur Powell Davis of the U.S. Reclamation Service (now called the Bureau of Reclamation). A month before he died, Arthur Powell Davis was appointed Consulting Engineer on the dam project. And thereby hangs a nicely ironic tale. Mr. Davis had his vision back in 1902. His uncle, John Wesley Powell, made the first foolhardy explorations of the Grand Canyon of the Colorado in the late 1860s and 1870s. The awful gorges of the Colorado were common gossip in the Powell-Davis families. And in 1902 Arthur Powell Davis, having taken a civil engineering degree at Columbian (now George Washington) University, and having spent several years as Hydrographer with the abortive Nicaragua Canal Commission, began to make his own rich contribution to the Colorado's history. He studied the endless, mud-swishing Gulliver sprawled across the sun-scorched wastes of the Southwest. How it moved in perpetual twilight under precipices as terrifying as the cliffs of dream. How it wound into remorseless sunlight between lonely rock horizons upon whose brows you half expected to see the stain of perspiration. Near the southern tip of Nevada the river entered Black Canyon. The walls of Black Canyon are considerably higher than the Woolworth Building and they diverge enough to be thoroughly baked by the sun. There is no hotter or more desolate scene on the Colorado - a turgid stream in a towering furnace of stone, a parching parody of all that the sweet word river has meant to the poets..."

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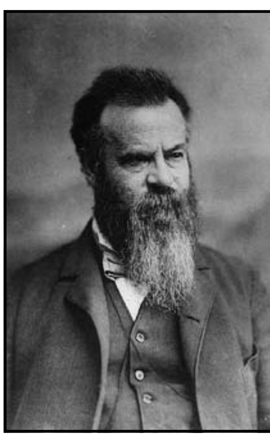

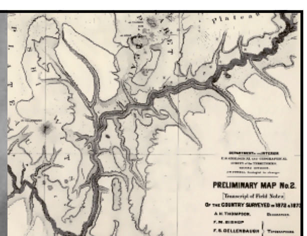

Left: Major John Wesley Powell (1834-1902)

Above: Portion of an early topographic map from the *J.W. Powell Expedition* (ca. 1872)

119

"The Spanish explorers Domingues and Escalante discovered the Lee's Ferry area in 1776. Jacob Hamblin, Mormon missionary to the Hopis, used the crossing in 1869, on his seventh expedition. During Major John Wesley Powell's second canyon voyage in 1871-72, Lee's Ferry became a layover and supply depot. John D. Lee, one of Utah's great pioneers, had been excommunicated from the Mormon Church because of his involvement in the Mountain Meadows Massacre during the Utah War of 1857-58. Lee, henceforth an exile, nevertheless followed instructions to establish a ferry at the mouth of the Paria River. He established his 'Lonely Dell' ranch and home in 1871 and began ferry operations with Powell's abandoned river boat the 'Nellie Powell.' He built the 'Colorado,' soon lost to the river…"

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Left: map of the lower Colorado River; from ***Lee's Ferry*** to the ***Gulf of California***
Above: early drawing of a sailboat on the Colorado River

121

John Wesley Powell Memorial **(West Rim Drive)**
(between *Grand Canyon Village* & *Hermit Rest*, Grand Canyon, Coconino Cty., AZ

122

Arthur Powell Davis
1861-1933

123

"…There in Black Canyon Arthur Powell Davis had his vision. For twenty succeeding years he gave his finest energies to the notion of the dam. Boulder Dam became a local and then a national issue. It involved scores of prominent Americans in disputes political, financial, and technical. But in the jagged valleys of the Colorado or in Washington or anywhere else there was no dispute about one fact: Boulder Dam was fundamentally the conception of Arthur Powell Davis; it was everlastingly based on his monumental engineering report. In 1923 the wrangling got so hectic in the office of Secretary of the Interior Hubert Work that Mr. Davis resigned his positions as Director and Chief Engineer to the Reclamation Service. Gray and gentle and disillusioned, he went to California, where he worked on local aqueducts, and to Turkestan, where he was the Soviets' Chief Consulting Engineer on irrigation…"
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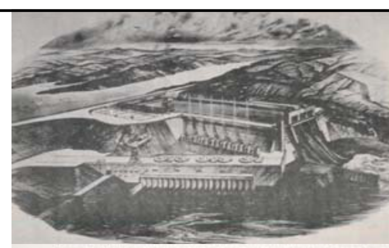
Mrs. Arthur Powell Davis beneath bronze plaque of her famous husband. Members of the Davis family were honored guests at the dedication of *Davis Dam* which was named in his honor (December 1952).

125



The Bureau of Reclamation has since 1904 conducted studies in the Colorado River Basin directed toward a comprehensive plan for the conservation and utilization of the waters of the main stream and tributaries. These studies, together with those of other agencies, have resulted in the construction of a series of dams on the lower river: Boulder, Parker, Headgate Rock, Imperial, and Laguna. Davis Dam will complete the development below Boulder Dam. It is named in honor of the late Arthur Powell Davis--long a member of the Society and President during 1920. Mr. Davis, as one of the builders of the old Reclamation Service and the Director from 1914 to 1923, laid the foundation for the planned development of the Colorado River.

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United States Reclamation Service **(U.S.R.S.) Bronze plaque. The reclamation service's name was changed (in 1923) to the *U.S. Bureau of Reclamation* (U.S.B.R.)**

127

"…For ten years Boulder Dam proceeded without him. The money was at long last appropriated, actual blasting was begun. In California, far from these detonations, Mr. Davis' health began to fail. The Prosperity Party changed the name of the project to Hoover Dam. Mr. Davis' name, which had never had much advertisement in the first place, dropped out of memory as quickly as that of any ill and retired American. On June first of this year the first buckets of concrete were poured into the hugest mold ever conceived; the Colorado already writhed helplessly in a strait-jacket of stone and steel. At length in mid-July the forgotten Mr. Davis received his own particular New Deal. The new Administration concluded perhaps that just dues were better late than never, and Mr. Davis' appointment as consulting Engineer on Boulder Dam was announced by Secretary Ickes. And at seventy-two Arthur Powell Davis returned, or was returned, to his vision. His health was too delicate to permit much actual field work in the Molochian jaws of Black Canyon. But on the Washington records he was back at what any of the boys on the canyon will be first to admit was his job. By 1936, seventeen months or better ahead of schedule, Mr. Arthur Powell Davis' vision will stand materialized across the broken back of the Colorado, a barrier so vast that few men without seeing it will be able to sense its size…"

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Construction Stiffs

129

"…Arthur Powell Davis is the chief unsung hero of Boulder Dam. The others are the men who sweat out their days, and many of their nights, in Black Canyon. The Boulder Dam worker of 1933 is a national type of some importance. He is a tough itinerant American - the 'construction stiff.' His average age is thirty-three. His average wage is sixty-eight cents an hour. He is taller and heavier than the average U. S. soldier, runs a greater risk of losing his life, and has passed a more drastic physical examination. He has been in most of the states of the Union and can find his way in a dozen different kinds of unskilled and semi-skilled labor - a hoist in a Pennsylvania coal mine, a saw in Oregon, a shovel on a dozen road jobs. He has boiled a string of mules in Bluejacket, Oklahoma - followed a pipe line as it crept across a prairie, a few yards a day, toward a town invisible behind a hill range. He is inured to ceaseless, frightful heat - and fearful cold, too, for that matter. Four or five of him in an old car can always get to a row of lights on Saturday night and if some four-flusher cops his roll or his girl it may be a fight or a laugh – what's the difference? He has earned $10 a day rough-necking on top of 110 foot oil rigs, driven a steam shovel, been slashed in a dance-hall fight, thought a lot about getting married…."

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"…He is sentimental, moody, and literate; he does not believe he will ever be anything better than what he is, and isn't trying, regardless of the schoolbooks, the adage to 'make your spare time pay,' and the example of Abe Lincoln. He leaves some money every week or so in Block Sixteen, Las Vegas (legalized prostitution), but has enough left to send a money order to somebody somewhere once a month. He shares the universal superstition of miners that if a woman ever walks into a tunnel where you are working you'd better get out quick because there's going to be a cave-in. He keeps washed. He smokes a pack of cigarettes a shift. When he travels, he rides freights. He knows how to live in jungles, but has never begged. The most he ever had in his life was $5,000 after the pipe-line job but he hung it on a wrong deal and lost it. He likes hunting better than baseball, horse racing better than either. He'll pick a grudge, or smell bad luck, mosey out and hit the road or the rails, but while he works he is inspired with a devil of loyalty, shrewdness, and skill. He wears Friendly Five shoes, and sleeps seven hours a day. He is the man, as much as General Superintendent Crowe and U. S. Engineer-in-Charge Young, who is putting up this dam faster than anyone thought it could possibly be done…"

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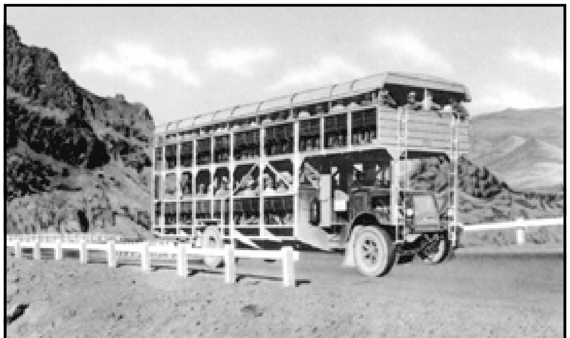

A 150-person capacity "Jitney Bus" (worker transport)

133

Miners and workmen leaving Boulder City for the canyon

134

"…Year in, year out, Crowe and Young and their 200-odd inspectors and foremen and their labor gang battle the Colorado twenty-four hours a day. The day shift comes on at 7:00 AM and knocks off at 3:00 PM. Swing shift from 3:00 PM to 11:00 PM. Graveyard from 11:00 PM to 7:00 AM. The inevitably ribald slang of the construction camp has coined for the wives of the night workers the name of 'Graveyard Widows.' At night Black Canyon is lighted like a theatre with incredible clusters of sun arcs, bought from a bankrupt San Francisco ball park. The men come to work in covered lorries wearing paper-mache safety helmets that look like AEF tin hats. (The American Expeditionary Force was deployed to Europe in World War I). These serve to protect them from falling rock - the greatest danger of the canyon work. Despite this precaution, in addition to a doctor and a field hospital at the base of the dam, over fifty men had given their lives to Boulder Dam by mid-summer last (1932)…"

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Workmen loading-out for the canyon on the day shift (in front of the Six Companies' Mess Hall, Dormitories in background)

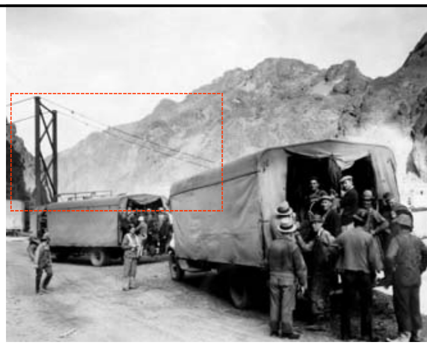
136

Night construction (June 1934)

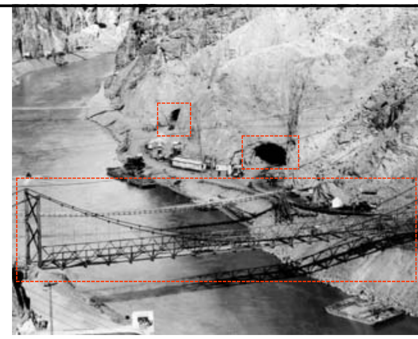
137

Hoover Dam construction at night (as seen from Lookout Point; September 1934).

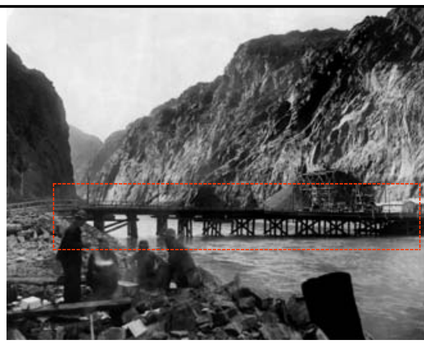
138



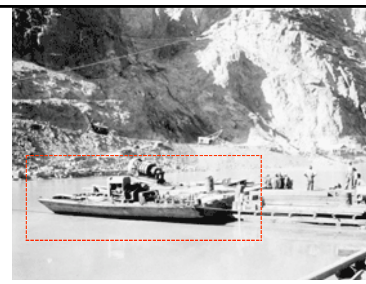
Day shift workmen entering the transports (at the upper Diversion Tunnel/s portal/s) for their return journey to Boulder City ten miles away (note the steel suspension bridge in background) 139



The steel suspension bridge (immediately below the lower portals of the diversion tunnels). Lower portal Diversion Tunnels Nos. 3 and 4 in the background. 140



Prior to the completion of the steel suspension bridge, a temporary pile and trestle bridge was erected to enable the removal of excavated rock from the upper portals of the Arizona diversion tunnels. 141



Before the bridges, barges were used to transport materials across the river (September 1931, pictured above). Initially, there were no roads into the canyon, so all the workers and equipment had to be brought in by boat. In time, roads were built into the canyon, and catwalks were strung across the river so the workmen could get across the river (after arriving by truck transport). 142

Industrial Fatalities

143

The “official” number of fatalities involved in building Hoover Dam is 96. These were men who died at the dam site and were classified as “Industrial Fatalities” from such diverse causes as drowning, blasting, falling rocks, falls from the canyon walls, being struck by heavy equipment, truck accidents, etc. Industrial fatalities did not include deaths from heat, pneumonia, heart trouble, etc. As well, the official number of fatalities does not include deaths that occurred prior to authorization of the BCP (i.e. surveyors *J.G. Tierney* and *Harold Connelly* who drowned while conducting geological surveys in December 1922). A total of 21K men worked on the dam with an average of 3,500 and a maximum of 5,218 daily, which occurred in June 1934. The average monthly payroll was $500K 144

What Are They Building?

145

"…What are they building? Boulder Dam, named for the abandoned Boulder Canyon site twenty miles up river, is a concrete-arch, gravity-type dam which will tower 730 feet from canyon bedrock - almost as high as the aforementioned Woolworth Building. The base width will equal two city blocks. It will measure not much less than a quarter-mile across the top. The concrete used would build a standard sixteen-foot highway from Pensacola to Seattle - if you can visualize that. When complete it will back up the largest artificial body of water in the world, sufficient to cover Connecticut to a depth of ten feet. This will form a grimly beautiful lake 115 miles long and full of tourist steamboats…"

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What is it For?

147

"…What is it for? **Boulder Dam has four purposes:**

1. ***Flood control*****. The yellow Colorado water has for many years watered the rich desert farms of southern California and western Arizona. Often it flooded them, sweeping away budding crops, farmers' fords, and the farmers themselves. Boulder Dam will not only block the largest flood on record but it will hold almost two full years' flow behind its bulk, releasing a normal stream throughout the year. A sub-purpose is silt removal, whereby the muddy content will precipitate above the dam, simplifying and cheapening distribution to irrigation lands. Flood and silt have cost Southwest ranchers an estimated $2,000,000 yearly. This bill will have been paid for the last time when the Colorado, for the first time in thousands of years, flows evenly and clear to the Gulf…"**

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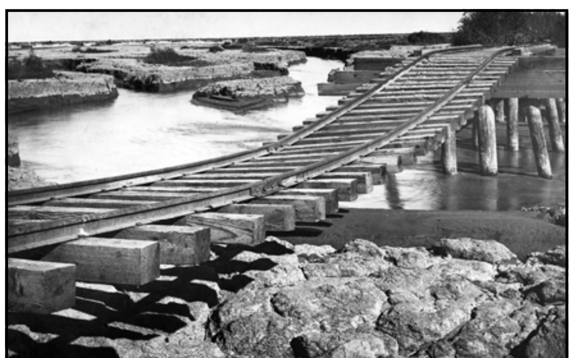
Cut banks in the new river canyon (at the ferry four miles northeast of Brawley, California). The photo above shows the Colorado River when it was out of it's banks and flowing across *Imperial Valley* to form the *Salton Sea* (August 1906)

149



View shows where the *Southern Pacific* railroad tracks were cut into and washed out (September 1906)

150

Left: Salton Sea map location – formed by the flooding of the Colorado River (1933)
Above: location map

151

"...2. Water conservation. Below the dam the Colorado now irrigates 660,000 acres of land. This acreage is limited by the low water (summer, fall, and winter) flow. By storing spring floods, from five to seven times as much water will be available in summer, permitting irrigation on about 1,500,000 acres of new land (2,160,000 acres in all). Principally planted will be alfalfa, cantaloupes, lettuce, barley, corn, milo maize, small fruits, and cotton. This new acreage is roughly half as much as all new land opened to date by all government irrigation projects, totaling twenty-nine…"
***Fortune* magazine, September 1933**

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An aerial view of a section of the *Coachella Valley* near Indio, CA, (looking northwest; February 1948). This photo shows some of the older developed portions of the valley as well as some of the raw desert that has not yet been developed. The valley began to develop at an accelerated rate as the completion of the "Boulder Canyon Project" (BCP) neared.

153

A field of (capped) Canteloupes in the Yuma Valley (January 1956)

154

"…3. Domestic water supply. The Metropolitan Water District, comprising many cities and towns in southern California - principally Los Angeles - has contracted to take about a billion gallons daily from the river to wash southern California faces and water southern California lawns. For this purpose the district will build a $220,000,000 aqueduct. For this water the district will pay the U. S. about $250,000 yearly…"
***Fortune* magazine, September 1933**

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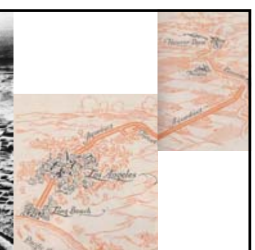


Left: view of the *All-American Canal*, California (Region 3; ca. 1940)
Above: "Map view of the (proposed) aqueduct serving the Los Angeles area" (*Popular Mechanics*, Sept. 1933)

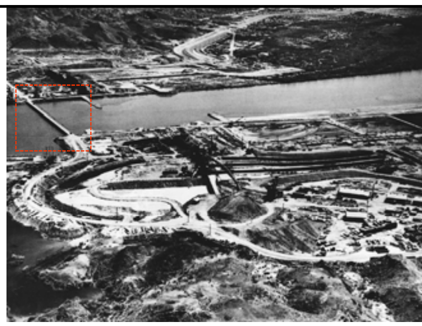
156

The All-American Canal, authorized as a part of the Boulder Canyon project, conveys water to some 425,000 acres in the rich Imperial Valley of California. About 78,000 acres in the equally rich Coachella Valley eventually will receive water from the All-American's major branch, the Coachella Canal. When the Gila project is completed, the Gila Cavity Main Canal will serve 115,000 acres near Yuma, Arizona. In addition, thousands of acres on the Yuma project, the Yuma Auxiliary project, the Palo Verde Valley, and the and the Colorado River Indian Reservation near Parker, Arizona, are irrigated with Colorado River water.

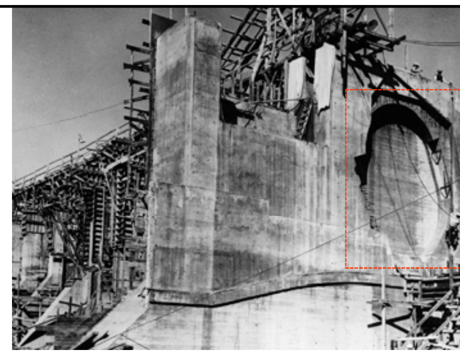
With river flow stabilized, the Parker Dam was built to provide a forebay for diversion of water to 35 incorporated cities and to extensive, unincorporated areas in southern California

157

All-American Canal (Station 3330 to Station 3343; May 1940) 158

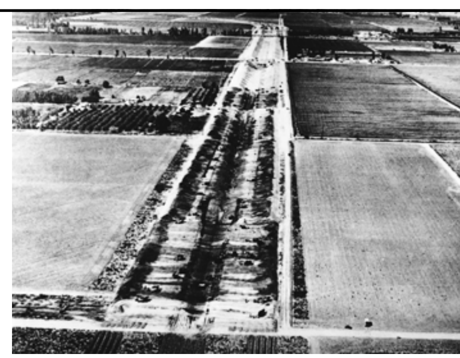


***Imperial Dam*, looking across the Colorado River toward the Arizona All-American Canal Headworks, with division walls of concrete sheet piling which separate the diversion channels to the Desilting works extending to the right (March 1937).** 159

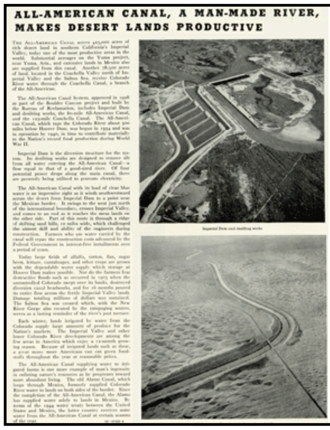


Pier No. 1 of the All-American Canal Headworks (showing recess for idling end of 75-foot roller gate; November 1936) 160

Looking upstream along the All-American Canal (from near Station 85 during construction; March 1937) 161



Looking west down the All-American Canal. Beginning the excavation at Station 3634 (curve in distance at Station 3738; March 1937) 162



All-American Canal (from brochure printed by the U.S. Department of the Interior)

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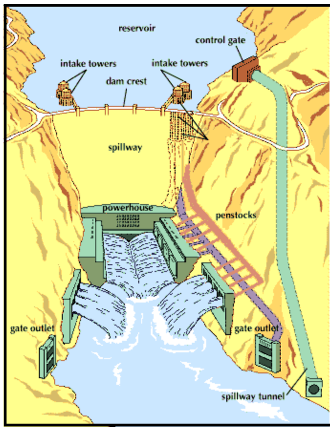
164



"…4. Power. Under the mighty shadow of the dam will be built the biggest power-plant in the world. This will develop 1,800,000 horsepower four times Niagara's power, thrice the ultimate capacity of Muscle Shoals. Already the electricity has been sold on fifty-year contracts to the city of Los Angeles and the Southern California Edison Co., which in turn subcontract 79 percent of it (on percentages fixed by law) to Arizona, Nevada, the Metropolitan Water District, and smaller California valley towns…"

***Fortune* magazine, Sept. 1933**

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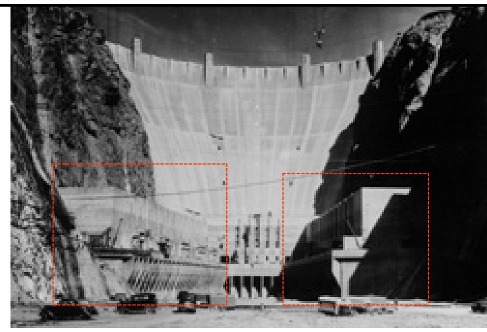

Nevada (left) and Arizona (right) wings of Powerhouse at dam base

166

A portion of the 287.5KW transformers and roof take-off structure along the Arizona wing wall of the Powerhouse

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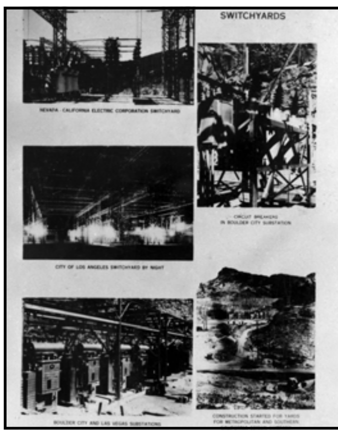

A group of pictures showing several of the Switchyards in and around the Boulder Canyon Project

168

One of many transmission towers comprising the *City of Los Angeles'* 287,500 volt transmission line

169

Hoover Dam transmission towers passing through the desert

170

"Panoramic Perspective of Hoover Dam and Related Features" (showing power transmission lines)

171

What Does it Cost?

172

"…What does it cost? The Boulder Canyon Project Act authorized federal appropriations not to exceed $165,000,000. They were apportioned as follows:
Dam and reservoir $70,600,000
Power development 38,200,000
All-American Canal 38,500,000
Interest during construction 17,700,000
The All-American Canal is a subproject by which water will be carried to southeastern California's Imperial and Coachella valleys. There is at present a canal feeding these territories which is dug partly in Mexico. Mexico is not famed for administrative efficiency; Mexico is not devoted to these United States; Mexico has revolutions. A new canal, all-American, was deemed sage insurance. From the figures it might be estimated, roughly, that Boulder Dam will cost every man, woman, and child in the land $1.25. Actually, the promise is that it will cost no man, woman, or child a cent. Sale of power plus sale of domestic water is budgeted to repay the entire cost of the dam in fifty years - plus a 100 percent profit…"
Fortune **magazine, September 1933**

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United States Code

TITLE 43 - PUBLIC LANDS
CHAPTER 12A - BOULDER CANYON PROJECT
SUBCHAPTER I - BOULDER CANYON PROJECT ACT

Sec. 617. Colorado River Basin; protection and development; dam, reservoir, and incidental works; water, water power, and electrical energy; eminent domain

For the purpose of controlling the floods, improving navigation, and regulating the flow of the Colorado River, providing for storage and for the delivery of the stored waters thereof for reclamation of public lands and other beneficial uses exclusively within the United States, and for the generation of electrical energy as a means of making the project herein authorized a self-supporting and financially solvent undertaking, the Secretary of the Interior subject to the terms of the Colorado River compact hereinafter mentioned in this chapter, is authorized to construct, operate, and maintain a dam and incidental works in the main stream of the Colorado River at Black Canyon or Boulder Canyon adequate to create a storage reservoir of a capacity of not less than twenty million acre-feet of water and a main canal and appurtenant structures located entirely within the United States connecting the Laguna Dam, or other suitable diversion dam, which the Secretary of the Interior is authorized to construct if deemed necessary or advisable by him upon engineering or economic considerations, with the Imperial and Coachella Valleys in California, the expenditures for said main canal and appurtenant structures to be reimbursable, as provided in the reclamation law, and shall not be paid out of revenues derived from the sale or disposal of water power or electric energy at the dam authorized to be constructed at said Black Canyon or Boulder Canyon, or for water for potable purposes outside of the Imperial and Coachella Valleys: Provided, however, that no charge shall be made for water for the use, storage, or delivery of water for irrigation or water for potable purposes in the Imperial or Coachella Valleys; also to construct and equip, operate, and maintain at or near said dam, or cause to be constructed, a complete plant and incidental structures suitable for the fullest economic development of electrical energy from the water discharged from said reservoir; and to acquire by proceedings in eminent domain, or otherwise, all lands, rights-of-way, and other property necessary for said purposes.

RE: excerpt from the *Boulder Canyon Project Act* (1928)

174

"…One hundred and sixty is fair candy money, even for Washington. And particularly when forty-five states in the Union are not getting so much as a gumdrop. The sullen watchfulness of eastern, southern, northern, and mid-western Congressmen made a waste-proof spending plan imperative. Two set-ups were possible. The dam could be government built (cries of 'No! No! The government will lose money!'). The dam could be built on private contract (cries of 'No! No! The government will lose money!'). The problem was solved by compromise. The dam is under the direct supervision of the Washington and Denver offices of the U.S. Government's Bureau of Reclamation; actual designs of all its features are made in the Denver office. It is being built by a group of western contractors, calling themselves the Six Companies…"

Fortune **magazine, September 1933**

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Dr. Elwood Mead**, Commissioner of Reclamation (at top) and *****R.F. Walter*****, Chief Engineer, signing the contract with the *****Six Companies, Inc.***** for the construction of Hoover Dam, Power Plant, and Appurtenant works; Boulder Canyon Project.**

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Construction Engineer *****Walker R. Young*** with his Boulder City office force posing in front of the Administration Building; Bureau of Reclamation, Boulder Canyon Project**

177

Executives of the Bureau of Reclamation, Boulder Canyon Project. Left to right: (standing); *****Earle R. Mills***, Chief Clerk; *****J.R. Alexander*****, District Counsel; *****Sims Ely*****, City Manager of Boulder City / (seated); *****John C. Page*****, Office Engineer; *****Walker R. Young*****, Construction Engineer, *****Ralph Lowery*****, Field Engineer.**

178

"…When Washington announced it had the job for somebody, a sudden low scribbling was heard in the land. This was the sound of estimating. Most of it died very quickly, as contractors realized the job was too huge even to bid on. But in San Francisco, Salt Lake City, Boise, and Portland, telephones jangled and very quickly the hard heads of Bechtel & Kaiser and MacDonald & Kahn (San Francisco), Morrison-Knudson Co. (Boise), Utah Construction Co. (Salt Lake City), and Portland's J.F. Shea and the Pacific Bridge Co. were put together. They set up a joint corporation capitalized for $8,000,000, called it the Six Companies, scribbled, estimated, and bid $48,890,995, bonded the contract for $5,000,000 in cash. They got the job…"

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Six Companies Executives. All the principals of the Six Companies were experienced and proven construction men, each with an area of specialization; headstrong and determined to have their own way. For example, *****Harry Morrison*** was an "equipment-man" thinking in terms of major equipment (i.e. steam shovels). *****Henry Kaiser***** was an "efficiency-man" emphasizing maximum efficiency of men and machines. *****Felix Kahn***** was an "organization-man" focusing on money and organizational issues. *****Charlie Shea***** was a "manpower-man" focusing on labor issues. Six Companies was allowed seven years (starting April 20th 1931) to build the dam, power plant, and appurtenant works, but all features were substantially complete by March 1st 1936.**

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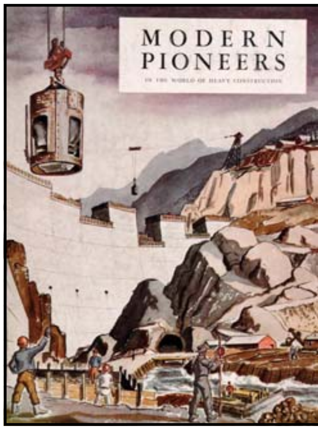

For their $48,890,995 the Six Companies must foot all construction bills - for dynamite, for trucks, for digging mud and dumping mud, for bosses' salaries, and for labor's wage. The Six companies do not pay for construction raw material - for the 5,500,000 barrels of cement consumed, or the 55,000 tons of steel plates and castings, or the turbines and generators in the power plant, or any of the permanent operating machinery of the dam.
***Fortune* magazine, September 1933**

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"…It is not feasible to detail a month's or even a year's statement of the Six Companies, since their expenses vary enormously. They were out of pocket $3,500,000 for preliminary work before they received a government penny. Until half the work was done they received only ninety cents on the dollar. The holdback is around $2,000,000, which they will receive at the end - like an ice-cream cone for being good. It suffices perhaps to say that during the first five months of 1933 the government paid an average monthly bill from the Six Companies of $1,513,000. Out of this the corporation must pay items such as a half-million a month payroll, $48,000 for gas and oil, $40,000 for electricity. At one time when the roads were roughest, they were spending $500 a day for truck and automobile tires. When the last bills are paid and the turbines begin to turn, the Six companies will have turned a profit estimated at $7,000,000 and upward for all their work…"
***Fortune* magazine, September 1933**

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Six Companies constructed muck roads and spoil dumps (June 1932)

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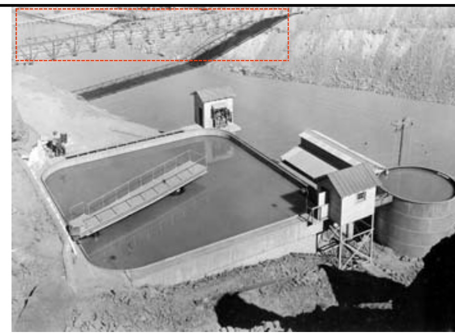
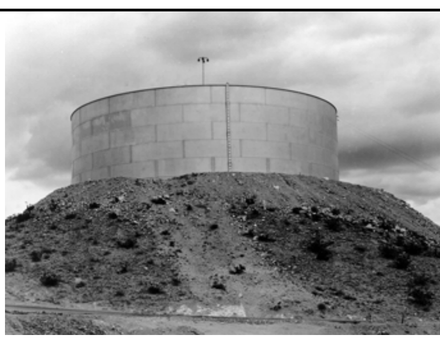


Six Companies built pre-sedimentation tank (at river intake to Boulder City water supply). View looking upstream from road above (suspension bridge across river above; February 1932)

184



Boulder City water supply tank (May 1932)

185

Interior view of Six Companies' garage and automobile repair shop in Boulder City. Complete facilities were installed for overhauling all classes of equipment (August 1932).

186

Highballing

187

"…This profit, which must be understood as a highly unofficial estimate, is the insurance premium the U.S. pays for efficiency. If the contractors spent all their money, botched the job, and went broke, the government might have to finish the dam to the tune of a great many millions. The U.S. is willing to pay a good profit for a good dam built rapidly. Thus far the scheme is paying fat dividends in speed. One of the few complaints of the men on the job is that the bosses are 'highballing' - labor slang for forcing work to the limit. Their contract started April 20, 1931. To date they have 'highballed' the job to a point seventeen months ahead of schedule. This speed has cost the Six Companies money in many operations - money which will be more than saved by finishing the dam an estimated year and a half before its appointed birthday, April 20, 1938…"
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Group of notables who witnessed the pouring of the first concrete in Hoover Dam. Left to right: *H.J. Lawler* - Director, Six Companies Inc.; *Walker R. Young* - Construction Engineer, U.S.B.R.; *Frank T. Crowe* - General Superintendent, Six Companies Inc.; *C.A. Shea* - Director of Construction, Six Companies Inc.; *W.A. Betchel* - President, Six Companies Inc.; *R.F. Walter* - Chief Engineer, U.S.B.R.; *Theodore A. Walters* - First Assistant Secretary of the Interior; *Ed Clark* and *C.P. Squires* - members of the original *Colorado River Commission*.

189

Night work at the dam site

190

"…Clearly, such speed requires a traffic cop. He is on duty, a government inspector, who reports the contents of every batch of cement, the blast of every dynamite barrage, the loads on the cableways, and the depth of every hole. He even goes down the canyon wall on ropes to outline the rock to be moved, then later to report the tons of rock chipped off by high scalers. Over 150 men are paid government money to stick their noses into the contractor's business. Not until they are satisfied that the work conforms in the minutest detail to rigid U.S. specifications do the Six Companies get Washington's check for the preceding month's payroll and expenses…"
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Gravel Testing Laboratory; Las Vegas, Nevada (November 1929)

192

<u>Left</u>: Gravel Testing Lab exhibit (January 1931)
<u>Above</u>: Gravel Testing Laboratory exhibit (*Rattler Tests*; January 1931)

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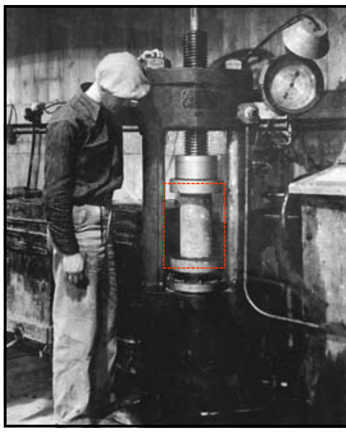
Concrete Testing Laboratory (erected by the Bureau of Reclamation in Black Canyon). The bridge (at right) connected the laboratory with the Six Companies' low level concrete mixing plant (April 1932).

194



Compressive strength testing machine in concrete laboratory at high-level concrete mixing plant (January 1935)

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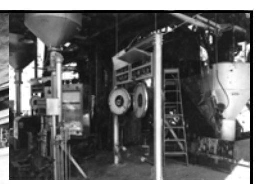
Six Companies' high level concrete mixing plant showing loading, mixing and control decks with cement storage silos above (March 1933)

196



<u>Left</u>: fully suspended batching scales for coarse and fine aggregate located on batching and Control Deck (under aggregate storage bins) at the Six Companies' high level concrete mixing plant (April 1933)
<u>Above</u>: Control Deck at Six Companies' high level concrete mixing plant. Seen are; water batchers, auto electric recording devices, batching scales, cement batcher and mixer hopper (April 1933)

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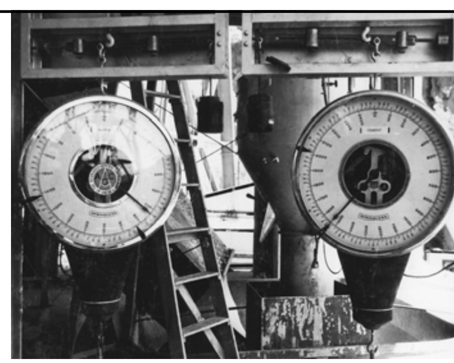

Fully suspended batching scales at Six Companies Inc. high level concrete mixing plant (April 1933)

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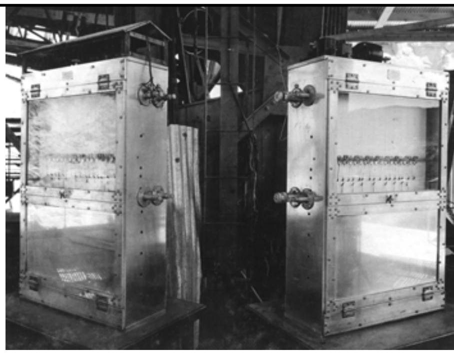
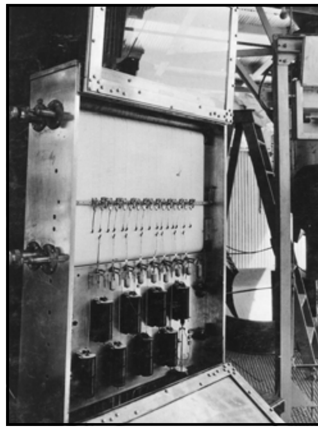


Dual installation of *C.S. Johnson* auto recording devices on control deck at Six Companies' high level concrete mixing plant (April 1933) 199



C.S. Johnson auto recording device on Control Deck at the Six Companies' high level concrete mixing plant (doors open up to show scribers and mechanism; April 1933)

200

***Southwark* testing machine (for making tension and compression tests on weld specimens), *Babcock and Wilcox Company* plant. Capacity of machine is 3K-pounds per square inch (October 1933)**

201

Display board showing pipe weld specimens (prepared by the Babcock and Wilcox Company; November 1934)

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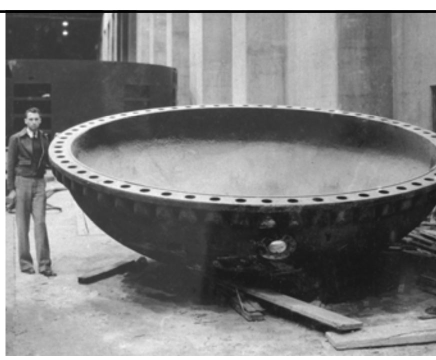
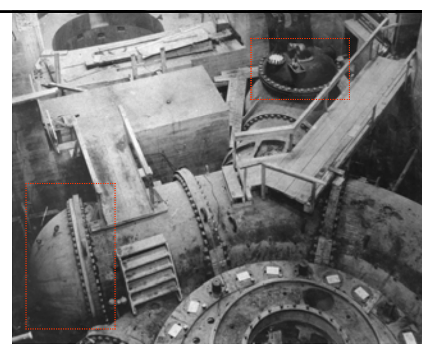
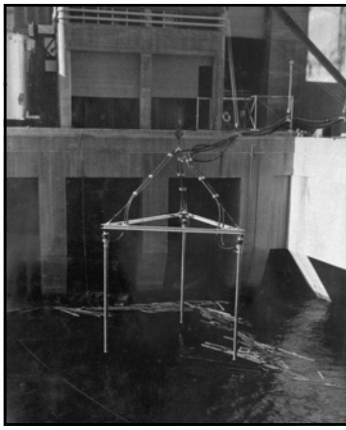


Testing bulkhead for scroll case of 115K-HP Turbine (power plant; November 1935) 203

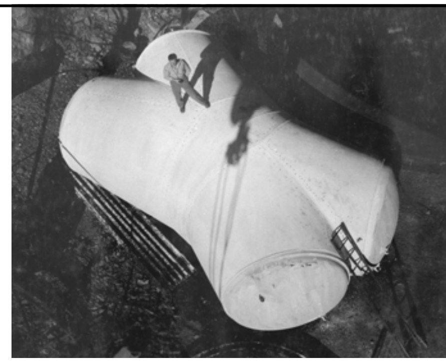


Partial view of scroll case showing relief valve (upper right) and testing bulkhead (lower left - power plant; November 1935) 204



Water Rheostat (for testing generators; October 1936)

205



Set-up for pressure testing of outlet manifold wyes (under 400psi of 1.5 operating pressure) Babcock and Wilcox Co. plant (April 1935)

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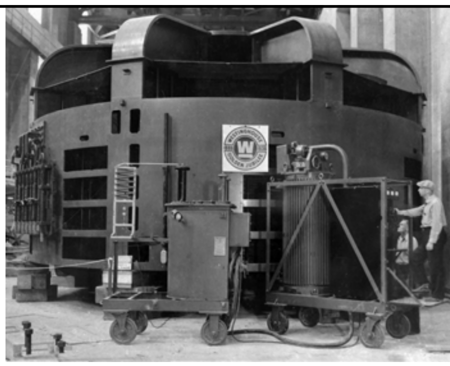

Westinghouse 82,500 kV-a stator shown with generator testing set (used to put artificial load on coils; June 1936)

207

"…Such a system should build a good dam. It should, human nature being human nature, breed as well some friction. No motorist likes to be asked by a detaining cop if he's going to a fire, particularly if he is going to a fire. But the friction factor at Boulder is not high. 'Of course,' says Frank Crowe (General Superintendent, Six Companies), speaking of Walker Young (U.S. Construction Engineer in charge), 'we like to cry at each other and raise hell. He says my foremen are no good, but he don't mean anything.' 'Yes,' agrees Young, with such circumspection as befits a great government engineer, 'sometimes we fight with each other for the fun of it…'"
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Walker R. Young - Construction Engineer, Bureau of Reclamation

209

Frank T. Crowe, General Superintendent – Six Companies, Inc.

210

I'd Go to Hell For Him

211

"…There are two reasons why Young and Crowe are not bitter enemies. One is that the job is too big for petty human friction. Young's inspectors and Crowe's foremen know this as well as their bosses. They know that friction which slows work quietly rubs somebody out of a job. The second reason is the mutual respect of Young and Crowe. Crowe spent years in the U.S. Reclamation Service, which Young now represents. He knows Young's duties and responsibility as well as Young does. 'I'd go to hell for him,' says Crowe. Frank Crowe, according to close guessers at the dam, gets $25,000 a year plus bonuses. Young gets $6,375. And this government work rates no bonus, there being no American Legion of the Reclamation Service. But regardless of salary, Walker Rollo Young is the boss at Boulder Dam. The U.S. hired the Six Companies, who hired Crowe. The U.S. flag flies just outside Young's office window…"

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Inspection party in front of the outlet portal of a diversion tunnel. City Manager *Sims Ely*, Construction Engineer *Walker Young*, Six Companies Director *H.J. Kaiser*, Interior Secretary *Ray Wilbur*, Six Companies President *W.A. Bechtel*, MWD Engineering Chairman *W.L. Honnald*, Six Companies Director *S.D. Bechtel*, MWD President *W.P. Whitsett*, Six Co. Superintendent *Frank Crowe* (September 1932).

213

Brig

214

"…The engineering career of this quiet, sharp-eyed man who at forty-eight is commander of the government guard at Boulder Dam began at the University of Idaho. He studied mining, in addition to working most of his way through, captaining the basketball team, and presiding over the student body. He prospected for a while after college and finally took a government job as a designer on the construction of Idaho's Arrowrock Dam, the Boulder Dam of its time. On this job he met Frank Crowe, bossing a shift for the head engineer. From that day to this he has worked in the Reclamation Service as field investigator, designer, administrator. He has figured hydraulics on more dams than he can remember, twenty five of them on the Colorado alone - ghost dams which never rose from mounds of paper. He contributed materially to the first and basic designs for Boulder Dam. He wears glasses, and hasn't smoked for months. He plays the violin, and played the cornet in the days before cornets wore derbies. He likes American history and when he has a vacation, heads for the ocean. He regards engineering as an art; 'The Art of Economical Construction.' Combined with his great talents both as a designer and administrator is his ability to make big decisions and small ones with equal speed. When the fearful heat of the first summer at Boulder and the lack of proper accommodations combined to brew a riot, he met it by ordering everybody off the U. S. Reservation. Then he invited every man who wanted to work to come back, assuring him of the best possible living conditions in the shortest possible time. The men came back. Houses were built. Today Boulder City is incomparably the finest construction camp in engineering annals. Mr. Young is known as 'Brig.' 'Why, I don't know,' he says. 'I have only one wife.' With that one wife he plays a lot of contract bridge evenings, when he is not reading blueprints or engineering journals or perhaps writing a letter to his daughter Jane at Scripps College…"

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"Hurry Up" Crowe

216

"…Walker Young helped design the dam and is on hand to see that it rises exactly according to specifications. But the man who is actually building it, probably the best man for the job in the world, is Frank T. Crowe. He has been called the Colonel Goethals of Boulder Dam..."
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"…Frank Crowe's last vacation was his honeymoon twenty years ago. He avoids cities except for required directors' meetings and an occasional football game. He plays the stock market a bit, buys Buicks exclusively for work on the job, and can be seen matching quarters with $4-a-day 'muckers' while waiting for a big dynamite explosion. He twists around in a chair a lot while he talks, preferring the outdoors, and makes an absolute rule that no letter shall go out of his office over one page long. He believes any idea can be expressed in that space and that anything longer is a waste of words. He had one dominant desire in life - to work on dams - and has gratified that desire almost steadily since Arrowrock…"
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To Hell With Excuses

219

"…He was U.S. Construction Engineer on the Tieton Dam in Washington and General Superintendent of the Jackson Lake Dam in Wyoming. For private contractors he built the Guernsey Dam on North Platte and Combre Dam on Bear River, California. His last job was the Deadwood Dam in Idaho, which began by walking with his construction gang through seventy miles of snow. He has one hobby - the development of men; specifically, the men who follow him by hundreds to work on his dams. His principal exhibit is Bernard (Woody) Williams, who first worked for him at thirteen, and now, at thirty, is in complete charge when Crowe leaves Black Canyon for Boulder City. For Williams and his foremen he has only one working rule: 'To hell with excuses - get results!' He is tall, talks loudly, and laughs hard. He is noted for his humor. It was Hoover's Secretary of the Interior Wilbur who asked him how smooth the tunnels had to be to conform to specifications. 'As smooth as a schoolmarm's leg, Mr. Wilbur, and if I remember my geography that's pretty smooth.' He knows thousands of construction laborers by their first names and 'generally how many kids they got.' He went to the University of Maine, as did the rather less rugged Mr. Rudy Vallee. He is down in Black Canyon most of the day and often part of the night. As a boy he swallowed a cigar and still cannot tolerate the taste of tobacco. He conveys an irresistible impression of drive, and translates it into almost magical results. The men dislike to work that hard, but they like Crowe. They work that hard. Once he had an incipient strike on his hands. The labor committee entered to present their demands. He got up before the leader could open his mouth. 'Gentlemen,' he said, 'the answer is NO.' There was no strike…"
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Walker R. Young (left) and Francis ("Frank") T. Crowe (right)

221

"…The gang on the job varies with the various steps in the dam's progress. The maximum estimated, but never reached, was 4,000. Less than 3,000 are at work this summer (1933). This horny-handed army enjoys a tidy comfort that seems luxury compared to army camps of 1918. They eat and sleep in Boulder City, built on a U.S. reservation. Nobody can build houses or sell so much as a radish without a U.S. permit. And 80 percent of the workers must live on the reservation…"
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Typical dormitory housing employees of Six Companies. Each dormitory of this type (of which there were eight) housed 172 men in separate rooms, all of which were equipped with an air cooling system (October 1933). 223

"…A community of some 5,000 is the result, with 1,050 houses on as parched and barren a patch of wind-swept rocky desert as could be found if one were seeking an ideal spot in which not to live. But the married men have trim cabins; bachelors live in huge refrigerated dormitories, each man with a seven-by-ten room for himself. Bachelors eat in a mess hall with excellent food, including iced tea and ice cream. The food is cooked and served on contract by Anderson Brothers, caterers who feed thousands of western laborers a day, including some workers in the rich vineyards of the movie locations. The quality of the food is guaranteed by a twenty-four-hour cancellation clause in Anderson Brothers' contract. The quality of the housing was dictated by the discovery that the better the workers' conditions, the faster they dug the dam. For their first-rate food and private rooms, plus transportation eight miles to the job, the construction stiffs pay $1.60 per day…"

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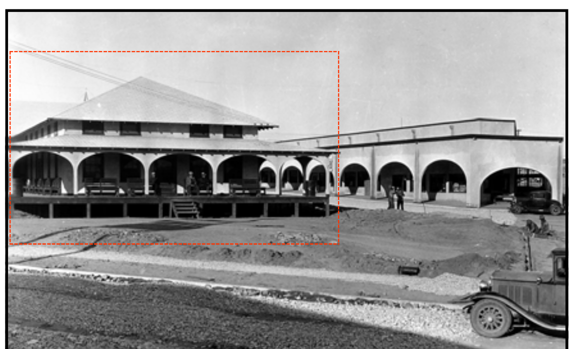
Married couple housing, Boulder City (September 1931) 225

Three room house (on *California Street*) built by the Six Companies (July 1937) 226

Six Companies office building (left) and dormitory (right; June 1931) 227



Left: *Anderson Mess Hall* / Right: *Six Companies Office Club* 228

Anderson Mess Hall, Boulder City - North Wing Dining Room (seating capacity was five-hundred in each wing; September 1931) 229

"…In Boulder City beer is for sale - but no hard liquor. Today no chickens, hogs, or horses are in evidence - due partly to the lack of feed. But the city has wide, paved streets, green grass, gas stations, a sumptuous movie house, excellent cement tennis courts (lighted for night play), a baked mud-pie golf course, an American Legion Hall, a hospital, and four churches - Catholic, Community (Protestant), Episcopal, and Mormon. The upper-crust employees of the government and the Six Companies live with their wives and young in tidy bungalows. Four tables of bridge of an evening strains the capacity of the largest. At the American Legion Hall dances remarkable democracy prevails, with the slippers of boss engineers' daughters tripping around to be stepped on by the best number nines of a $5-a-day laborer. The latter, however, is particular to come bathed, shaved, and with a clean white shirt…"

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Moving picture theatre (operated under permit in Boulder City; July 1932) 231

Six Companies' Hospital (left). The home of the Chief Surgeon is in the foreground (nurses residence beyond; May 1932) 232

Community (Protestant) Church, Boulder City

233

"…Perhaps the laborer's constantly clean shirt is the most astonishing phenomenon of life in Boulder City. It is to be expected that the 200-odd white-collared upper-crust will behave themselves, play bridge and gossip and live the normal restricted small town American existence. It is not at all to be expected that a great shifting labor community of various nationalities shall persistently maintain the peace. But Boulder City police records list one major crime - a holdup. Drunkenness is virtually unknown; street fighting, ruction, and personal explosion ditto. At evening mess scarcely any can be seen whose streaked and sweaty exterior suggests the conventional labor gang. All look respectable and self-respecting. Perhaps this calm is caused by the sense of money in the pocket - the unemployed are not allowed to hang about the reservation. But there are two better reasons. One is an odd, perhaps slightly sheep-like consciousness of living in a clean shirt community. The other is Las Vegas…" 234

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Lost Wages, Nevada

236

"…Las Vegas is a Nevada town twenty-three miles away, where drinking, gambling, and all the grosser forms of self-expression flourish. It has bars with fair whisky at twenty-five cents a shot, as well as more intricate and dearer drinks. It has gambling halls where crap, roulette, bird cage, blackjack, and good stud-poker games continue all night long. It has its famous if slightly sinister Block Sixteen, where life holds out smearily powdered and licensed human arms to comfort labor's loneliness. Every two weeks or once a month a man can visit Las Vegas - roar, lose money, fight, make love, even get knifed or shot if he goes berserk. Normally, however, he pilots his sagging frame back to Boulder City, where a federal ranger halts him at the reservation gate. If he is still stupid drunk he is placed in a stockade outside the gate to sleep it off. The next day he returns to work, purged, penitent, and pleased with his clean shirt…"

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Postcard (above) showing a visualized Las Vegas after completion of Hoover Dam (ca. 1930). The city of Las Vegas had lobbied hard to be the headquarters for the construction of Hoover Dam, going so far as to close its many *Speakeasy's* when Secretary of the Interior *Ray Wilbur* (the decision-maker) came to town. To the dismay of Las Vegans, Wilbur announced (in early 1930) that a model city was to be built in the desert near the dam site. This town became known as Boulder City, Nevada. Construction of a rail line joining Las Vegas to the dam site began in September 1930.

238

Aerial view of downtown Las Vegas (looking west; January 1947)

239

Union Pacific Station at Las Vegas; "Gateway to Hoover Dam" (ca. 1932)

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Freemont Street, Las Vegas (ca. 1933)

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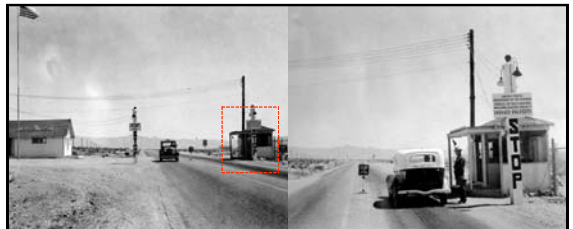

Federal Ranger on-duty at the *Sentry Station*; entrance to *Boulder Canyon Project Federal Reservation* (April 1935)

242

"This will be a job of machines"

Frank Crowe – General Superintendent, Six Companies, Inc.

243

"…It is in these matters of personnel, organization, and efficiency rather than in miracles of machinery that Boulder Dam is unique in engineering history. No problems have arisen which have not been solved before on other dams. The machines differ from previous ones principally in their gigantic size. The biggest trucks in the world had to be designed and built by Mack. Powered with 250-horsepower motors and equipped with special duralumin bodies, they are capable of waddling away with sixteen cubic yards of earth– just twice the capacity of the biggest truck hitherto…"

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An International truck with capacity of seven cubic yards (shown on the left), with approved type of "bath-tub" body. Two International trucks in the background have older type of bodies. White truck with seven cubic yard body is shown on right (January 1932).

245

One of the Six Companies' Mack trucks (in front of the upper portal of Diversion Tunnel No. 2). This truck has nine cubic yards capacity (note the steel canopies over the drivers' heads on all the trucks; January 1932).

246

A ten cubic yard Moreland truck dumping directly in the side-dump railroad cars at the dump hopper (in front of the low level mixing plant). Truck was carrying muck from upper portals of the Diversion Tunnels (January 1932).

247

A Moreland truck of twelve cubic yards capacity, used in hauling muck from upper portals of the Diversion Tunnels. This truck has dual rear axle. (note the wire mesh protection over the hood and the protected headlights; January 1932).

248

Mack truck; fourteen cubic yards capacity (February 1932). This was the largest truck ever built on two axles and weighed 65K-pounds when fully loaded. Mack's popular "AC" models evolved through the 1920s and, in response to a demand for trucks with larger capacities and higher speeds, Mack introduced the "B" series in 1927. Pneumatic truck tires were introduced by both Goodyear and Dunlop in 1919.

249

Mack truck with fourteen cubic yard body being loaded at the Nevada Spillway cut. Five similar trucks were being used on this operation (March 1932).

250

Caterpillar tractor at work (March 1932). Caterpillar introduced its first diesel powered tractor; the "Diesel Sixty," in 1931 (shown above). It was used extensively on-site at the BCP.

251

Two hundred-ton capacity (two-way) *La Crosse* trailer (for transporting sections of thirty-foot penstock pipe; July 1934)

252

Testing La Crosse 200-ton trailer under a dead load of 185-tons (December 1933)

253

"…Babcock & Wilcox of Barberton, Ohio, is building $10,908,000 worth of piping at a special plant erected one mile from the dam site. A General Electric unit will X-ray every inch of welding in the two and eight-tenths miles of penstocks (giant pipes carrying water from dam to power house). This world's record X-ray job involves 159,000 separate pictures and 24,000,000 square inches of film - a prodigious guaranty of welding quality…"
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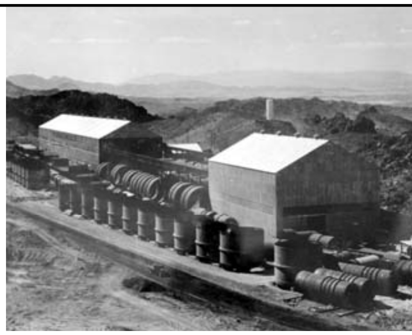
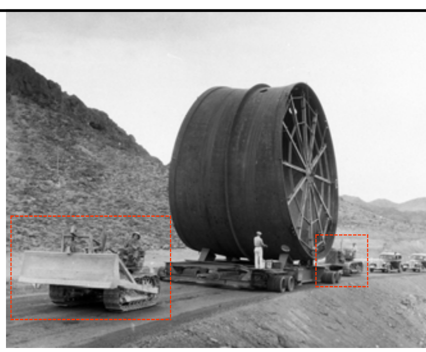


Plant of the Babcock and Wilcox Co. with view showing thirty-foot diameter penstock pipe awaiting transportation to the dam (July 1934)

255

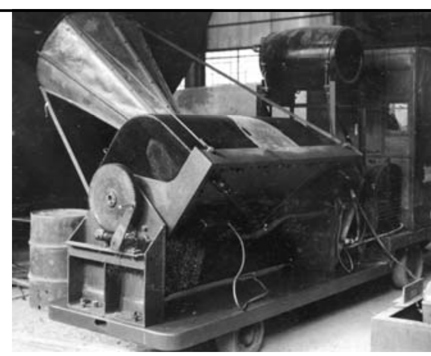
The 200-ton capacity La Crosse trailer used in transporting pipe sections from plant to dam slips on super-elevated roadbed between Boulder City and the Babcock and Wilcox Company plant (July 1934)

256



The first thirty-foot diameter penstock pipe section is transported from Babcock and Wilcox Company Plant to the dam on La Crosse trailer powered by Caterpillar tractors (July 1934)

257



X-ray machine (for exploring welded seams in pipe), Babcock and Wilcox Company plant (October 1933)

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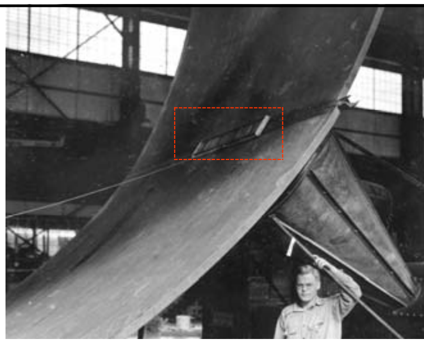

X-ray machine set up on thirty-foot diameter pipe section for exploration of longitudinal welded seam (note film holder supported inside pipe; October 1933)

259

"…The government cableway which spans the abyss has five times the capacity of any earlier cableway. Built by Ledgerwood Manufacturing Co. of Elizabeth, New Jersey, it has six steel ropes bigger than the average man's wrist (three and one-half inches diameter) and can lower 150 tons of concrete or steel hundreds of feet from the upper workings to the pit. Engineers say it could take 200 tons or more. The roller cradle which runs along the cable dangling these crushing weights is as big as a box car. The turbines and generators for the power plant are also the largest to date: four of the turbines, contracted for by Allis-Chalmers, will turn up 115,000 horsepower apiece…"

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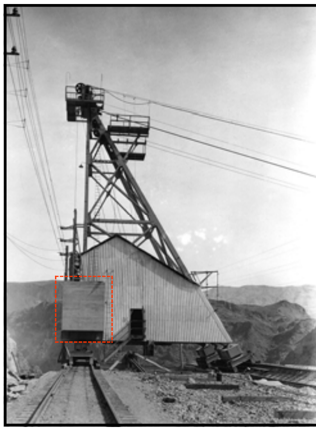

Movable cableway tower operating over Hoover Dam site. This photograph shows a typical installation. Note thrust rail and canal arrangement to provide lateral movement. Concrete counterweight seen at left (February 1933).

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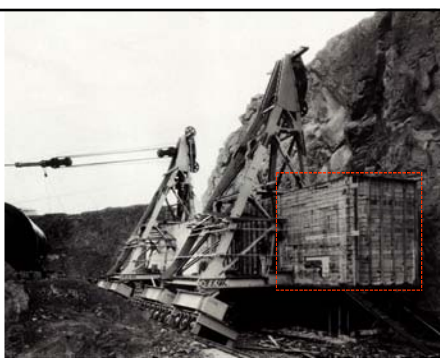

Head Tower for No. 8 Cableway showing counterweight, hoist resistor assembly and travel track arrangement (November 1932)

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Head-tower of permanent 150-ton cableway (June 1933)

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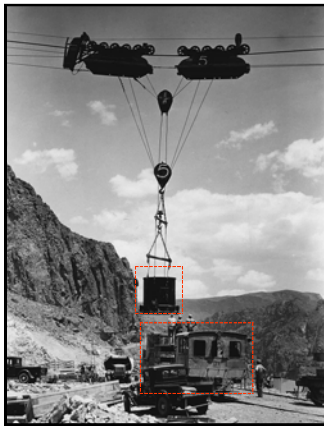
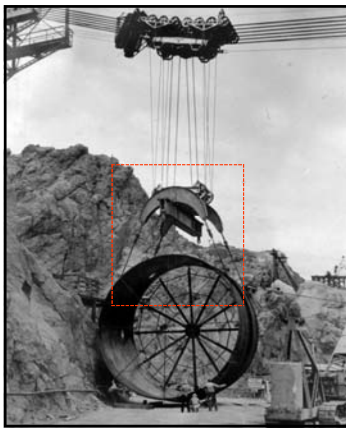


Handling eight cubic yard concrete bucket by overhead cableway for transport across canyon. Concrete being hauled into position by gasoline locomotive and being placed in Arizona spillway weir crest (May 1933).

265

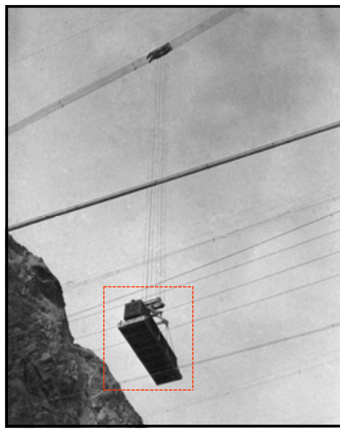
The 150-ton cableway transporting Penstock header tunnel lining forms into canyon (September 1933)

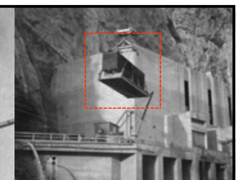
266



First section of thirty-foot diameter Penstock pipe being handled by cableway. View shows rig and tackle and manner of lifting pipe sections (July 1934).

267





Loaded freight car on platform being lowered over 150-ton cableway into position at Nevada wing of power plant (November 1935)

268

Railroad car (gondola), containing lower bearing support bracket for N8 generator, being transported by the 150-ton cableway preparatory to lowering to power plant (January 1961)

269

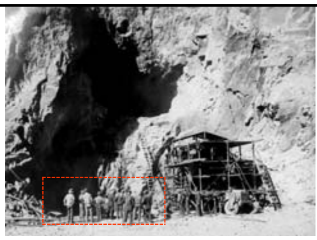
"…The fifty-foot diversion tunnels dwarf New York's subway tubes. Fantastic machines called Jumbos run on rails into these tunnels. One has thirty-two air drills to perforate the rock; another has seven platforms, like the carriages on a Ferris Wheel, and carries the men who trim the walls after the rock has been blasted out; another lines the walls with. Concrete - an eighty-foot section at a stop…"
Fortune **magazine, September 1933**

270

Drilling Jumbo

271

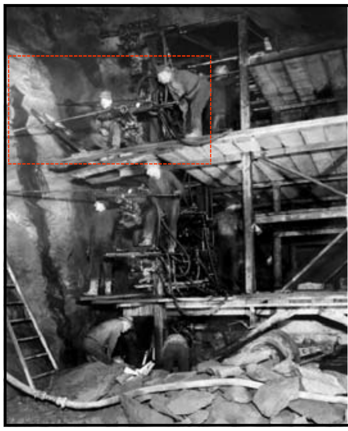
The greatest challenge faced by General Superintendent Frank Crowe and his staff was completion of the four diversion tunnels by May 1st 1934 (before the spring run-off swelled the river). Crowe was a master of construction scheduling using the *Critical Path Method* (CPM) very effectively. Even so, with each tunnel averaging 4K-feet in length and with a bore (diameter) of 56-feet, it would be a Herculean task to complete what were the largest diversion tunnels (up to that time) on schedule. To do the job, the world's first-ever "Jumbo" drill rig was created. Ten-ton trucks were modified to support platforms with thirty drills (fed by water and compressed air lines). A pilot bore at the crown of the tunnel was the first to be excavated, then the arch section was removed, then the side-wall/central section and last to be excavated was the invert (base) section of the tunnel. The tunnels were then finished with three-feet of concrete lining via the use of steel slip forms (accommodating each tunnel section). 272



Drilling the first round in enlarging upper portal of Diversion Tunnel No. 2. The welded steel "Jumbo" mounted on the truck has twenty five air drills on it (the swing shift crew is waiting to go to work in the lower left of the photo; November 1931). Holes for explosives were bored into the rock using pneumatic drills. Five hundred pneumatic drills, hoses and compressors were purchased from *Ingersoll Rand* for the BCP. Compressor plants were installed just below the outlet portals and upstream near the inlet portals. Compressed air was taken to the work sites through a network of pipes two to six inches in diameter. 273

View of drilling Jumbo taken outside the Diversion Tunnels. It was welded steel construction, mounted on a truck chassis (December 1931). 274

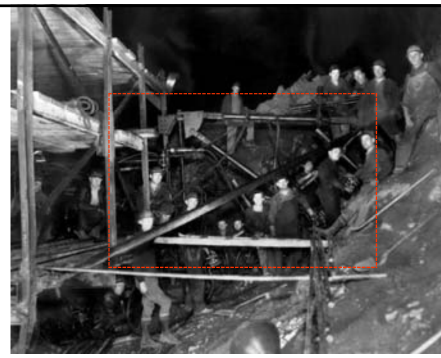
View of a drilling Jumbo tacked up to the tunnel-face (showing the method of construction and mounting; December 1931). The jumbo was backed up to the working face and 24 to 30 drills went to work, drilling powder holes into the rock. A drilling jumbo allowed half of the tunnel face to be worked on (with all the holes being drilled simultaneously). When the holes in that section were finished, the jumbo moved to the other side of the rock-face and began drilling, while the finished holes were packed with powder and wired. When both sides were drilled, the jumbo was removed. Eight of these jumbos were constructed enabling the drilling and blasting to be accomplished in record time. 275



Drilling Jumbo in operation (on the right-side face of one of the Diversion Tunnels. When the drilling was complete, the holes were filled with dynamite, and the rock broken up by the explosions and removed. One-ton of dynamite was used for every fourteen-feet of tunnel dug (December 1931).

276

On of the Drilling Jumbos ready for action. This view was posed outside the tunnel, just as the swing shift was ready to go to work on the upper portal of Diversion Tunnel No. 1 (January 1932). 277

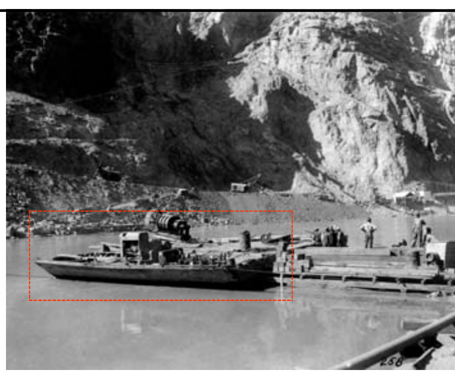


"Wings" extended for drilling fold-back (against the sides of the Drilling Jumbo; March 1932) 278

Adits

279

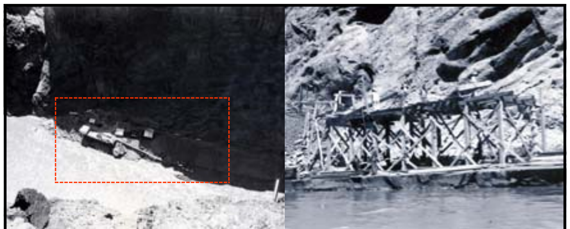
Crowe devised a tunneling plan that would open up as many "headings" as possible. This called for mining cross "Adits" perpendicular to the canyon walls intersecting with the diversion tunnel/s (near the center of the dam). Begun in the spring of 1931, there was no land access to the dam site in Black Canyon so Crowe improvised. He developed an amphibious means to gain access to the early Adit tunneling work whereby barges (assembled upstream of *Cape Horn*) were navigated downstream laden with hoses, drifter drills, Jackhammers, air compressors etc. The barges established their beachhead on a relatively level area of loose rock near the core of the dam. On May 12th 1931, the first blasting holes were drilled for the Arizona cross-Adit; just two months after the opening of bids. With the Arizona adit underway, the focus moved to the Nevada cross-Adit which would be a greater challenge. A sheer rock face dropped-off into the river at the location of the Nevada Adit. To gain access, a suspension bridge was built from the Arizona side to the Nevada side at the location of the Nevada cross-Adit. Until enough tunnel muck could be removed to gain a foothold, crews worked directly off of barges. Once the adits reached the diversion tunnels, 12'x12' "top headings" were begun in both the upstream and downstream directions. Thus, eight (additional) headings were created allowing the tunneling work to be expedited. Top headings allowed for access, ventilation and future tunnel enlargement. As well, before the main tunnel heading was advanced, the top heading/s allowed engineers and geologists to investigate the "in-situ" quality of the rock. Top headings were also established at the Diversion Tunnel/s portal opening/s, allowing (in theory) for as many as sixteen tunnel headings, but twelve simultaneous headings at once was the most ever achieved. 280



Six Companies freight barge (September 1931) 281

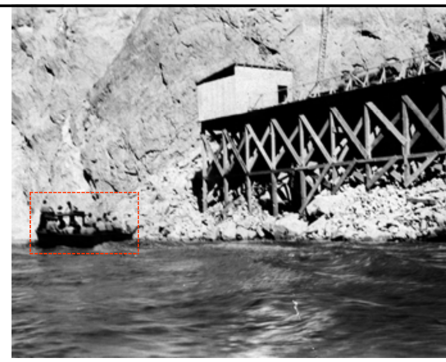
Arizona Adits

282



Boat landing (Arizona Adits under construction). Prior to the establishment of permanent electric power in Black Canyon, Six Companies used gas and diesel generators to supply electricity for the tunneling operations (July 1931).

283

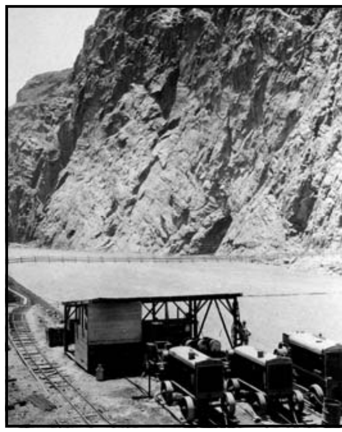


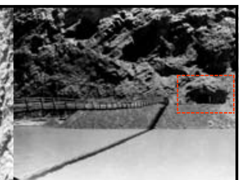
Boat carrying *Dr. Elwood Mead* - USBR Commissioner, leaving landing where Arizona Adit is under construction (July 1931)

284

Leveling bar at Arizona abutment (for compressor plant) to drill Adits to Diversion Tunnel/s (April 1931)

285





<u>Left</u>: Arizona Diversion Tunnel Adits compressor station (June 1931)
<u>Above</u>: Arizona tunnel Adit and cable footbridge (June 1931)

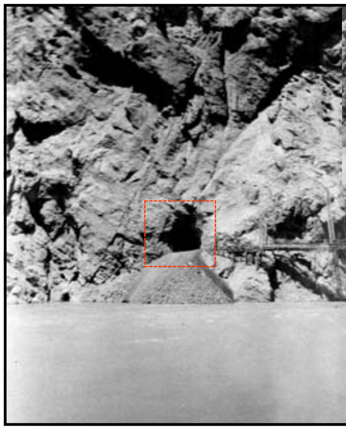
286

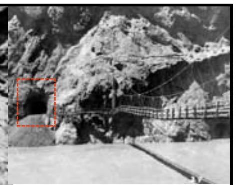
Arizona tunnel Adit (June 1931)

287

Nevada Adits

288



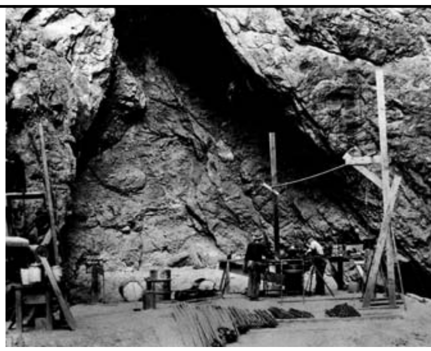


Left: Nevada tunnel Adit (June 1931)
Above: Nevada Adit and middle suspension bridge (June 1931)

289

Interior of Nevada Construction Adit (showing Drilling Jumbo at completion of drilling for blast; December 1932). Once a shot had been fired, expert miners inspected the tunnel for safety, then crews moved in and mucked out the broken rock with power shovels and hand tools. Several conveyor belt type mucking machines were used to speed the work. The broken rock was loaded into dump trucks and hauled down-river where it was dumped into great spoil dumps in the side canyons. To eliminate the need to turn trucks around (in the limited space available), the trucks were backed into the canyon. Ultimately, more than 1.5 million cubic yards of spoil were removed from the tunnels.

290

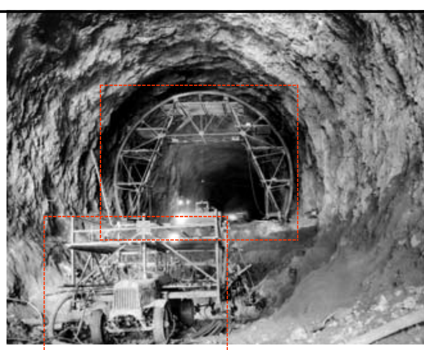


Halfway between the upper end of the diversion tunnels and the dam site, Six Companies operated a drill sharpening shop (on the Arizona side) in a large cave which afforded a cool spot for such work (May 1931)

291

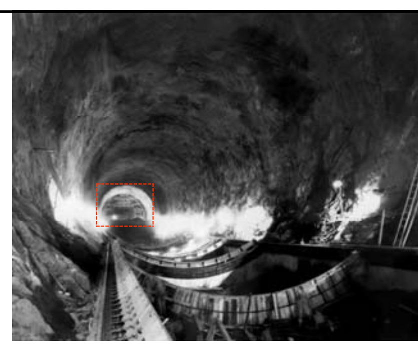
Trimming Jumbo

292



Diversion Tunnel No. 4; Drilling Jumbo for removing invert in foreground. Trimming Jumbo for removing project rock in background (February 1932).

293



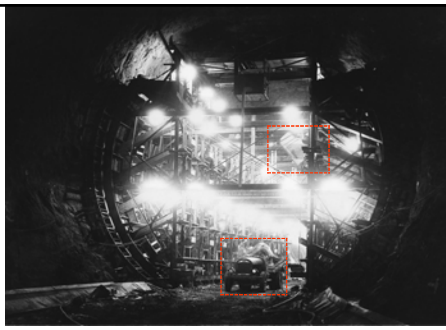
Invert forms in upper Diversion Tunnel No. 3 (showing method of pouring slabs). Trimming Jumbo (for aligning gauge of tunnels) in background (March 1932).

294

Close-up showing details of Trimming Jumbo used in scaling walls of diversion tunnels and removing projecting rock (April 1932) 295

Side-Wall Jumbo

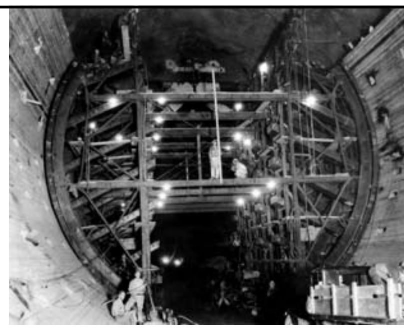
296



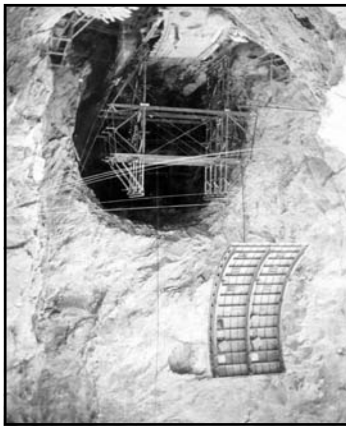
Diversion Tunnel No. 2 with side-wall forms in place. View is from "raw" or non-concreted end of the Jumbo. A truck is seen in position under the forms while the overhead crane is dumping a bucket into a chute at the right mid-section (May 1932). 297

Showing the method of construction and operations of the Side-Wall Jumbo for placing the lining in the Diversion Tunnels (June 1932) 298

Fabricated steel forms for placing the three-foot thick lining in the side-wall section of the Diversion Tunnels being erected outside the upper portal of Diversion Tunnel No. 1 (July 1932) 299



The Diversion Tunnels were lined with concrete and made to conform to an exact fifty-foot circular section by means of temporary wooden panel forms (July 1932) 300

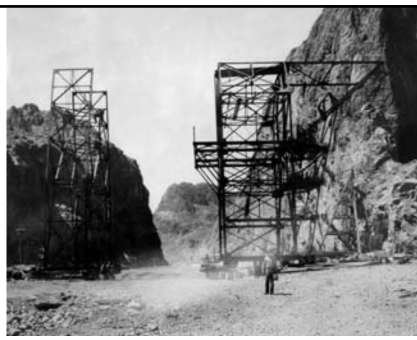



Erecting Side-Wall Jumbo at upper portal of Diversion Tunnel No. 1 (September 1932)

301

Arch Jumbo

302



Traveling section of the Arch Jumbo being erected. Concrete guns are to be mounted on the platform discharging into eight inch pipes (May 1932).

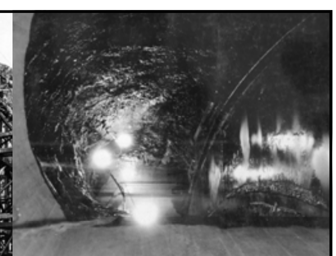
303

Interior of Diversion Tunnel No. 4 (near the upper portal) showing the Arch Jumbo in place. The arch section has been coated with a bituminous surface for curing the concrete (June 1932).

304

Pressure Grouting Jumbo

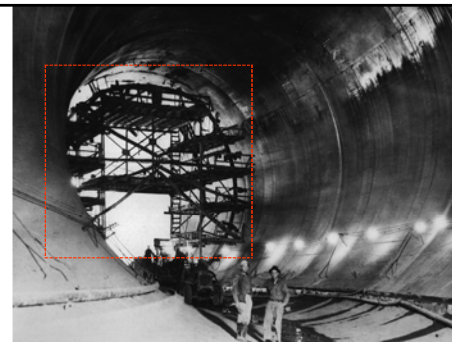
305

Left: Pressure Grouting Jumbo Frame
Above: access Adit to Diversion Tunnel Number One (upstream tunnel plug demonstrating leakage prior to grouting; April 1935)

306

Left: workmen inside a tunnel with Pressure Grouting Jumbo
Above: apparatus devised for drilling grout holes through the concrete lining of the diversion tunnels. Air drills were mounted on bars. The Pressure Grouting Jumbo traveled on rails laid on invert floors (July 1932). 307



Completed tunnel lining at intake portal of Diversion Tunnel No. 4; view looking toward entrance (Pressure Grouting Jumbo seen in operation; October 1932) 308

Penstock Jumbo

309

Left: steel Jumbo form for placing concrete lining in Penstock header tunnel. Conveyor used for sides and bottom, top arch concrete placed by pressure gun (October 1933).
Above: Jumbo used in placing concrete lining between Diversion Tunnel No. 3 and Penstock tunnel (June 1934) 310

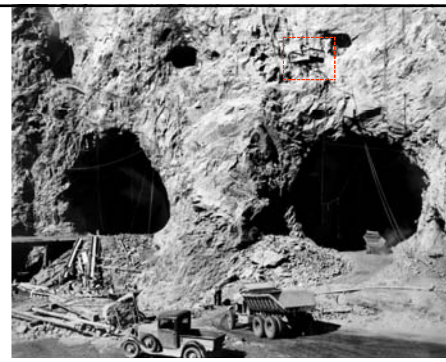
Miscellaneous Jumbos

311

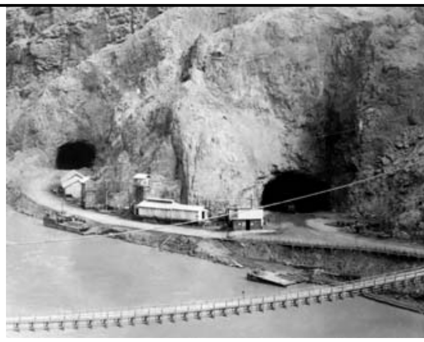
Left: looking down into intake of inclined tunnel (from transition at Nevada spillway). View shows transition forms and Materials Handling Jumbo (July 1934).
Above: looking into the Arizona Spillway Raise. The Jumbo is being used for grouting (back of the concrete lining; September 1935) 312

"…Many of the tools in Black Canyon are on a similar scale, too big and too complicated for the layman to grasp without extensive comparative pictures and diagrams. But the engineers are modestly positive on one point: among the dam's legacies to the world will be numbered no new machine device. No puzzles of construction or design have faced them that have not been solved before. The major problem has been the job's brutal size. Having solved this, their first and most vital task was to divert the unruly river from its bed. Once they had it dammed and turned into the diversion tunnels, the risk of sudden flood sweeping their work away was passed. From that point on the bosses - and particularly the directors of the Six Companies - breathed easily. Nothing short of earthquake could stop them. Their present sense of security and most pardonable pride is one of the sharpest impressions one gets at Boulder Dam. They are not relaxing, but they know they have won. All they have to do now to rear their monument is to keep at it…" 313

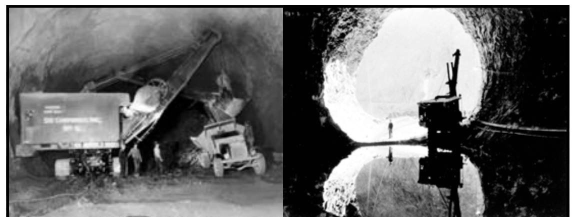
Fortune **magazine, September 1933**



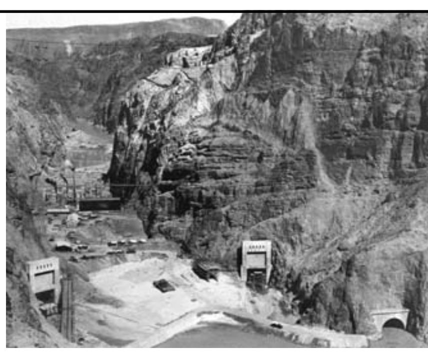
The upper portals of Diversion Tunnels No. 1 and No. 2. (note workmen scaling above portal of Diversion Tunnel No. 1; March 1932) 314



The downstream portals of Diversion Tunnels 3 and 4 on the Arizona side (the bridge in the foreground - in addition to being a foot-walk, carried a six inch compressed air-line; November 1932) 315



A 100-ton Marion Electric Shovel excavating blasted rock from one of the diversion tunnels (a three and a half cubic yard dipper was used on these shovels; December 1932). Shovel capacity and mobility were important factors for excavating equipment on the BCP in terms of efficient excavation operations. Around 1920, the first full rotation (slew) crawler-mounted crane shovels were being introduced. Through the 1920s, steam, gasoline and diesel power options for cranes were introduced and electrically powered shovel cranes made their appearance. Tunnel mucking (excavation) machines (as pictured above) were also evolving rapidly in the 1920s/early 1930s. 316



Looking upstream through Black Canyon (from permanent camera station). View shows dam structure and outlet portals of diversion tunnels Nos. 2, 3 and 4 (September 1933). 317

"…Accustomed to thinking in giant terms they are not particularly moved because the dam has been given a new label by the Roosevelt Administration. The reversion of the name from Hoover Dam to Boulder Dam is considered around Black Canyon as politics. It is unofficially estimated that the shift may cost the U.S. some $200,000 in printing bills to change the staggering mass of documentary record that a dam entails. But that is no concern of the builders. Their world is bounded by the desert mountains and their lives are for the current years dedicated to a job. It merely occurs to them to wonder, in smoky discussions after sundown in Boulder City why Washington, if it was bent on changing names, did not at least consider Davis Dam…"

Fortune **magazine, September 1933**

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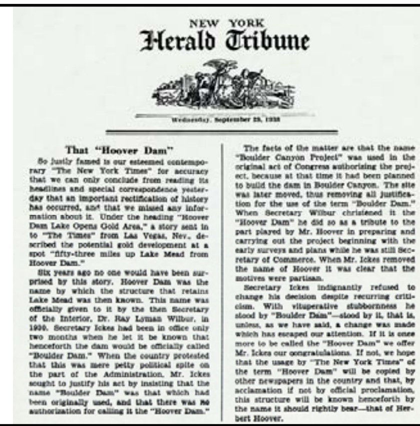
Construction on the Boulder Canyon Project in Black Canyon commenced with President Hoover's signature on the Appropriation Bill of July 7th 1930. Secretary of the Interior *Ray Lyman Wilbur* named it "Hoover Dam" at the commencement of construction (September 17th 1930). Secretary of the Interior during the Roosevelt administration; *Harold L. Ickes*, changed the name in a "Memorandum for Commissioner of the Bureau of Reclamation" to "Boulder Dam" (on May 8th 1931). Then commenced the debate on what to call the dam with many people expressing their opinions. Some still refer to it as "Boulder Dam." President Truman signed a bill officially naming the edifice "Hoover Dam" in 1947.

Left: reprint of editorial cartoon from Los Angeles Times; May 18th 1933

319



NEW YORK
Herald Tribune

Wednesday, September 28, 1938

That "Hoover Dam"

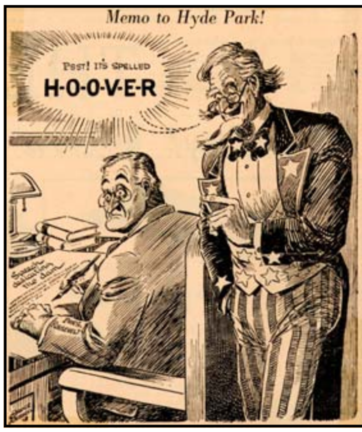
So justly famed is our esteemed contemporary "The New York Times" for accuracy that we can only conclude from reading its headlines and special correspondence yesterday that an important rectification of history has occurred, and that we missed any information about it. Under the heading "Hoover Dam Lake Opens Gold Area," a story sent in to "The Times" from Las Vegas, Nev., described the potential gold development at a spot "fifty-three miles up Lake Mead from Hoover Dam."

Six years ago no one would have been surprised by this story. Hoover Dam was the name by which the structure that retains Lake Mead was then known. This name was officially given to it by the then Secretary of the Interior, Dr. Ray Lyman Wilbur, in 1930. Secretary Ickes had been in office only two months when he let it be known that henceforth the dam would be officially called "Boulder Dam." When the country protested that this was mere petty political spite on the part of the Administration, Mr. Ickes sought to justify his act by insisting that the name "Boulder Dam" was that which had been originally used, and that there was no authorization for calling it the "Hoover Dam."

The facts of the matter are that the name "Boulder Canyon Project" was used in the original act of Congress authorizing the project, because at that time it had been planned to build the dam in Boulder Canyon. The site was later moved, thus removing all justification for the use of the term "Boulder Dam." When Secretary Wilbur christened it the "Hoover Dam" he did so as a tribute to the part played by Mr. Hoover in preparing and carrying out the project beginning with the early surveys and plans while he was still Secretary of Commerce. When Mr. Ickes removed the name of Hoover it was clear that the motives were partisan.

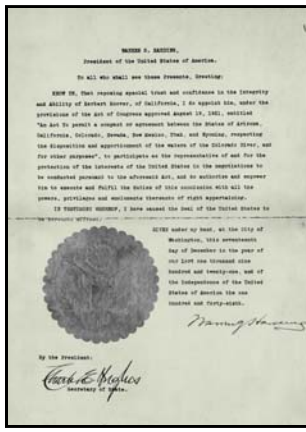
Secretary Ickes indignantly refused to change his decision despite recurring criticism. With vituperative stubbornness he stood by "Boulder Dam"—stood by it, that is, unless, as we have said, a change was made which has escaped our attention. If it is once more to be called the "Hoover Dam" we offer Mr. Ickes our congratulations. If not, we hope that the usage by "The New York Times" of the term "Hoover Dam" will be copied by other newspapers in the country and that, by acclamation if not by official proclamation, this structure will be known henceforth by the name it should rightly bear—that of Herbert Hoover.

320



Los Angeles Times cartoon entitled: "Memo to Hyde Park" (September 22nd 1935)

321



President of the United States of America.

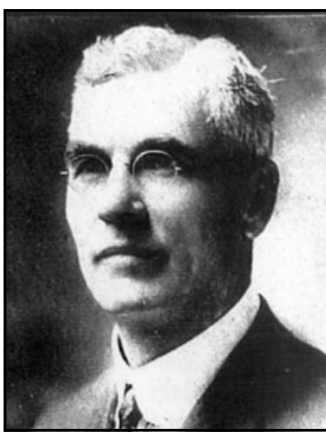
To all who shall see these Presents, Greeting:

By the President:

Secretary of State.

Herbert Hoover's presidential letter of appointment as Chairman of the *Colorado River Commission* (December 17th 1921)

322



"…Arthur P. Davis is the man who in 1902 conceived of Boulder, watched his idea become merely a political springboard and then, at seventy-two returned to help materialize his vision. Just one month later he died."

Fortune **magazine, Sept. 1933**

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Part 3

In the Beginning

324

Under the Ditch

325

In 1900, the ***Colorado Development Company*** began diverting water from the Colorado River to irrigate the ***Imperial Valley*** of Southern California – a large area of desert north of the Mexican border. Thousands of acres were "under the ditch" via a canal that connected the newly fertile land to the Colorado. There was one problem however; the canal kept getting clogged with silt, particularly at its Headgates (closest to the river). Seeking to move the Headgates of the canal beyond U.S. jurisdiction in order to irrigate Mexican fields, in 1904 the company excavated a more direct canal a few miles south of the border. In June 1905, heavy flooding washed away the new canal Headgates and flooded the Imperial Valley and the ***Salton Sink*** (forming the ***Salton Sea***). The flood was brought under control by the ***Southern Pacific Railroad*** (SPRR), but it took nearly two years to close the breach. By 1909, the SPRR had taken control of the assets of the Colorado Development Company and by 1916, the ***Imperial Irrigation District*** had purchased the water supply system from the SPRR. With the floodwaters receded and the breach sealed, irrigation and cultivation resumed albeit with a well-founded fear of a repeat of the events of June 1905. With residents concerned about their livelihood (and safety) and investors eager to protect their investments, the time was ripe for soliciting federally-funded/supported flood protection.

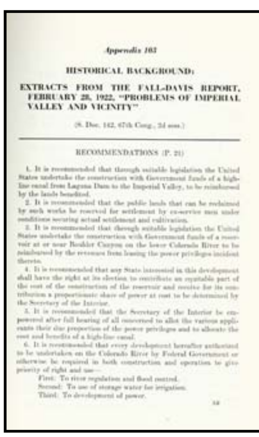
326

View of the floodwaters in the Imperial Valley (ca. 1905)

327

Though the federal government was not involved with fighting the floods of 1905-07, it did draw the attention of the USRS. In 1902, Arthur Powell Davis was Assistant Chief Engineer of the USRS and he envisioned then development of the lower Colorado basin via a high dam in a deep valley of the Colorado River. Other reclamation projects and America's involvement in WWI sidelined Davis' bold idea, but his appointment (in 1915) to the Directorship of the USRS and the service's willingness to put their dam-building skills to the ultimate test; building the largest dam in the world, came together in the post-WWI years. With the Imperial Irrigation District petitioning the federal government to do something meaningful, in May 1920 Congress authorized the USRS to develop preliminary plans for a storage dam on the Lower Colorado River. In 1922, the *Falls/Davis Report* (sponsored by Secretary of the Interior *Albert Falls* and USRS Director Davis) provided a detailed study of a proposed hydroelectric dam that would be over five-hundred feet high and capable of impounding over twenty million acre-feet of water to produce abundant amounts of electricity thus paying for the dam's construction and operation in perpetuity. The problem with this plan was the hostility to it from the privately owned companies controlling America's electrical grid in the 1920s. Cheap, clean and plentiful power supplied by the federal government to the developing Southwest was deemed (by them) not to be in their best interests.

328



Appendix 103

HISTORICAL BACKGROUND:

EXTRACTS FROM THE FALL-DAVIS REPORT, FEBRUARY 28, 1922, "PROBLEMS OF IMPERIAL VALLEY AND VICINITY"

(S. Doc. 142, 67th Cong., 2d sess.)

RECOMMENDATIONS (P. 21)

1. It is recommended that through suitable legislation the United States undertake the construction with Government funds of a high-line canal from Laguna Dam to the Imperial Valley, to be reimbursed by the lands benefited.

2. It is recommended that the public lands that can be reclaimed by such works be reserved for settlement by ex-service men under conditions securing actual settlement and cultivation.

3. It is recommended that through suitable legislation the United States undertake the construction with Government funds of a reservoir at or near Boulder Canyon on the lower Colorado River to be reimbursed by the revenues from leasing the power privileges incident thereto.

4. It is recommended that any State interested in this development shall have the right at its election to contribute an equitable part of the cost of the construction of the reservoir and receive for its contribution a proportionate share of power at cost to be determined by the Secretary of the Interior.

5. It is recommended that the Secretary of the Interior be empowered after full hearing of all concerned to allot the various applicants their due proportion of the power privileges and to allocate the cost and benefits of a high-line canal.

6. It is recommended that every development hereafter authorized to be undertaken on the Colorado River by Federal Government or otherwise be required in both construction and operation to give priority of right and use—

First: To river regulation and flood control.
Second: To use of storage water for irrigation.
Third: To development of power.

13

"The controversy over the power aspects of the Boulder Canyon Project involved a clamorous argument that took on the aspects of a nation-wide debate, chiefly because it involved the whole question of whether or not the federal government should enter large-scale power production activities..."

Paul Kleinsorge, Historian

329

Despite the private power industry's vehement opposition, the Falls/Davis Report advocated construction of a high dam in the vicinity of Boulder Canyon. Initial investigations had focused on Boulder Canyon, but by 1924 USRS engineers and geologists recognized that Black Canyon – lying twenty miles downstream, was the better choice. Both were steep, narrow gorges with granite walls several hundred feet high, but Black Canyon held the advantage from a geological, geographic and logistical standpoint. Though Boulder Canyon was out of the picture, the name "Boulder Canyon Project" stuck (despite the change of venue).

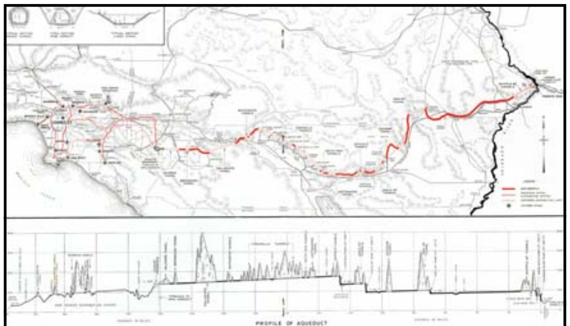
330

The MWD

331

Aside from the Imperial Irrigation District, the main proponent of the Boulder Canyon Project was the *City of Los Angeles* (along with other Southern California communities). In fact, in July 1921 Los Angeles proposed assistance in building the dam in return for control of its hydroelectric power plant. In 1910, the U.S. census had revealed that Los Angeles was now California's most populous city (to the dismay of San Franciscans). This population growth created not only a need for power but water resources as well. Thus, in 1924 LA expanded their interest in Boulder Dam to a formal claim (filed on behalf of the city) for "1,500 cubic feet per second" of Colorado River flow. In this claim lay the future All-American Canal (a.k.a. *Colorado River Aqueduct*) and the creation of the *Metropolitan Water District* (MWD) of Southern California. Most importantly (as far as Congressional approval was concerned), the MWD represented a potential major customer for the power the dam would ultimately produce.

332



Colorado River Aqueduct Map (above) / Profile (below)

333

Mulholland

334

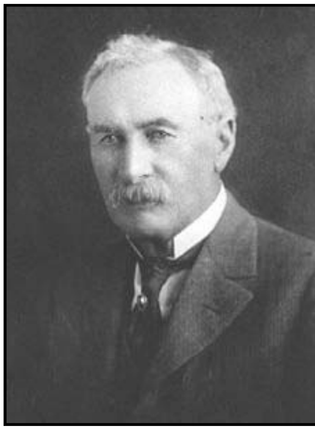
"It was early recognized that to secure favorable consideration, the Boulder Canyon Project must be self-supporting and that the power to be generated from any development must find a market which would eventually return all costs of the project to the Government. As additional engineering work for the Colorado River Aqueduct was done it became evident that any practical diversion of the river must involve pumping. Such pumping was only practical if a large amount of power could be obtained at a low price. This created, at once, a potential market for a substantial part of the power from any major Colorado River development. When these facts were laid before Congress support for the Swing-Johnson measure became easier to obtain"

RE: excerpt from the MWD's first annual report. California Congressman *Phil Swing* and California Senator *Hiram Johnson* were the primary champions and supporters of the *Boulder Canyon Project Act* (BCPA) of 1928. Power required to pump water through the Colorado Aqueduct would guarantee to Congress (weary of generating unmarketable power, as power industry lobbyists suggested) customers for the electricity the BCP would generate. Since the MWD possessed the right to tax land within its service area and could/would sign contracts with the federal government guaranteeing power sales, Washington's fear of generating huge quantities of unmarketable power were alleviated. Thus, it would be the City of Los Angeles that would guarantee the long-term viability of the BCP to absorb its unprecedented cost.

335

As Chief Engineer of the City of Los Angeles' *Bureau of Water Works and Supply* (BWWS) in the 1920s – in charge of dam design/construction and development of new water supply sources, *William Mulholland* was the master of all he surveyed where it concerned LA's water supply development and/or operations. As such, he would be intimately involved with the design/construction of the 200-mile long aqueduct which would carry Colorado River water across the *Mojave Desert* to the growing, thirsty City of Los Angeles and its satellites. Naturally, he would also serve as a major proponent of the BCPA without which the aqueduct could/would not be built. In November 1923, he took a well publicized journey down the Colorado River after which he confirmed Boulder Canyon as an ideal location for a high dam and the plan to channel water via an aqueduct completely viable. Early in 1924, he testified before Congress in support of the *Swing/Johnson Act* (BCPA) and consulted with the *Department of the Interior* concerning the dam/aqueduct. In 1925, he petitioned for the creation of the MWD and gave more testimony and made another inspection trip down the river by year's end. By the beginning of 1928, the momentum was building for BCPA approval and Mulholland submitted a report to Congress arguing LA's need for the BCP. His public advocacy of the BCPA would soon come back to haunt him as the year 1928 unfolded.

336



William Mulholland (1855-1935)

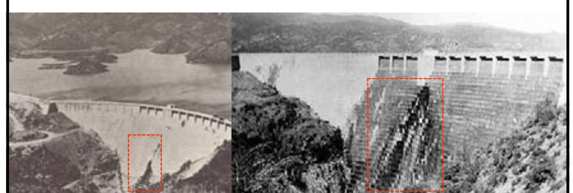
337

Murphy's Law

338

Just before midnight on March 12th 1928, the 205-foot high *St. Francis Dam* (in northwest *Los Angeles County*; about five miles northeast of what is now *Santa Clarista*) burst releasing 38K acre-feet of water from its reservoir. The thundering waters carrying mud, boulders, houses, trees, debris and bodies rushed through the *San Francisquito Canyon* destroying everything in its path (including ten bridges), devastating the *Santa Clara Valley* on it way to the *Pacific Ocean* (forty-five miles distant). Over four-hundred people were dead and/or missing and the event is still considered one of the greatest civil engineering disasters in U.S. history. The dam was a *Gravity-Arch* – very similar in design to the planned Boulder Canyon Dam, raising questions in the public mind as to the safety of such a design. For advocates of the BCPA, the disaster could not have happened at a worse time.

339



St. Francis Dam. First warning signs of imminent failure were expanding leaks evident on the face of the dam.

340

Los Angeles Examiner

SECOND EXTRA

100 BELIEVED DEAD IN AQUEDUCT DAM BREAK

Today

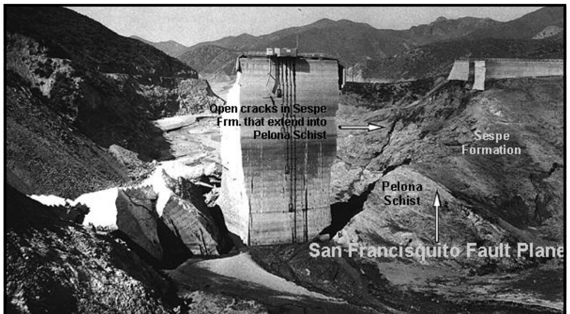
Cause of the Disaster

50-FOOT WAVE HITS VALLEY

Survivor Tells Vivid

341

342



The remains of St. Francis Dam

343

Municipal Exemption

344

To add fuel to the critic's of the BCP fire, as Chief Engineer of the BWWS, William Mulholland was intimately involved with the design and construction of the failed dam. Mulholland was never personally involved with the design of Hoover Dam, but in the eyes of officialdom and in the court of public opinion, the person and the project were inseparable. St. Francis dam was wholly a BWWS project including design and construction – no private contractors were involved thus the focus of blame was entirely on self-taught engineer Mulholland and his BWWS. California Governor *C.C. Young* authorized an engineering investigation into the dam's failure. By the 1920s, large public works projects typically included a design review by a group/board of consulting engineers/geologists. Mulholland kept the project entirely "in-house" and there was no such oversight by consulting engineers on the St. Francis Dam project. California state law also required the State Engineer to review/approve all dams over ten-feet high unless they were built by a corporation under the jurisdiction of the state railroad commission or built by a municipality with an engineering department. The latter "municipal exemption" would be used by Mulholland/BWWS to prevent any outside review of the dam's design.

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Empty reservoir after St. Francis Dam failure

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"…learning just what caused the failure of the St. Francis Dam…the prosperity of California is largely tied up with the storage of its flood waters. We must have reservoirs in which to store these waters if the state is to grow. We cannot have reservoirs without dams"

RE: California Governor C.C. Young's charge to the *St. Francis Dam Investigating Commission*. Young had been elected Governor of California (in 1926) on a platform strongly in favor of the BCPA. In fact, his strong support of the BCPA featured prominently in his inaugural address.

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Until the St. Francis disaster, Mulholland was a local hero having been the man who built the *Los Angeles Aqueduct* (1907-1913) which brought fresh water 230-miles distant from the *Owens River Valley* to the *San Fernando Valley.* The work was difficult and included the five-mile long *Elizabeth Tunnel*. No longer dependent on the meager water resources of the Los Angeles River, by 1913 Los Angeles was poised to grow exponentially thanks to the BWWS and engineer Mulholland. Being self-taught, Mulholland was unaware of advances in Gravity-Arch dam design/s by the 1920s and his aversion to criticism led him to keep his bureau's design work out of the public domain. The geology of the dam site was suitable for water storage but poor for the dam itself and there were vocal complaints about the quality of the concrete during construction. A fault line ran through the dam site and insufficient consideration in the design of the dam was made for "uplift" (the tendency for a gravity dam to be lifted upward thus reducing its effective weight resulting in a lessened ability to resist horizontal water pressure). The carefully studied failure of a concrete gravity dam in *Austin, PA* (on September 30th 1911) had highlighted apprehensions concerning uplift pressures on gravity dams.

350

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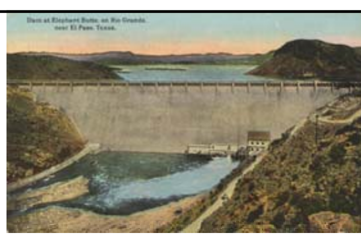
"I have been careful to say nothing regarding the Los Angeles dam which could come back to hurt Mulholland…he does not appreciate the benefit of calling in men from outside to get their better perspective and independent point of view…This St. Francis Dam site plainly required many precautions which were ignored, and while I have the highest personal regard for my good old friend William Mulholland, I can but feel that he trusted too much to his own individual knowledge, particularly for a man who had no scientific education."

John R. Freeman, Civil Engineer

352



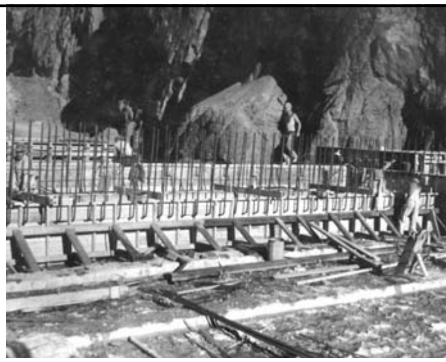
One of the engineers who investigated the Austin, PA dam failure was Arthur Powell Davis. He visited the site and became concerned about uplift on a 200-foot high dam then being designed by the USRS: The *Elephant Butte Dam* in southern New Mexico (on the *Rio Grande* river). To counter the effects of uplift, extensive foundation grouting, a drainage system (along the length of the dam) and a deep cut-off trench were added to the dam's design.

353

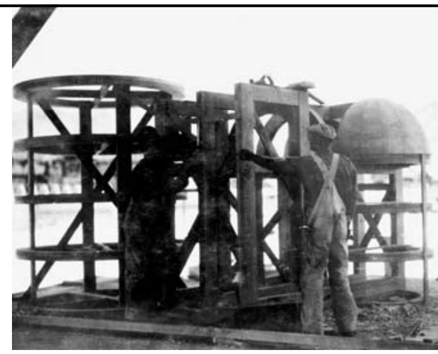
"…the ultimate failure of this dam was inevitable, unless water could have been kept from reaching the foundation. Inspection galleries, pressure grouting, drainage wells and deep cut-off walls are commonly used to prevent or remove percolation, but it is improbable that any or all of these devices would have been adequately effective, though they would have ameliorated the conditions and postponed the final failure."

RE: excerpt (from the conclusion) of the California *Governor's Commission* investigation into the failure of the St. Francis Dam

354



Form work and reinforcement for *Inspection Gallery* (at Elevation 674) across the mid-section of Hoover Dam (October 1933) 355



Carpenters working on Inspection Gallery forms at the Six Companies' shop (March 1934) 356

"In order to prevent leakage in the foundation of the dam, a line of holes was drilled into the foundation just below the upstream face of the dam to depths of thirty to forty feet. They were grouted under pressure…another line of holes was drilled to serve as drainage holes to relieve any leakage under the dam. These were continued upward into the masonry and emerged into a large tunnel running the entire length of the dam"

Arthur Powell Davis, USRS Director

RE: *Arrow Rock Dam* – a 354-foot high gravity dam built by the USRS between 1913 and 1915 (near Boise, Idaho). There are several ways of countering uplift in a gravity dam including;

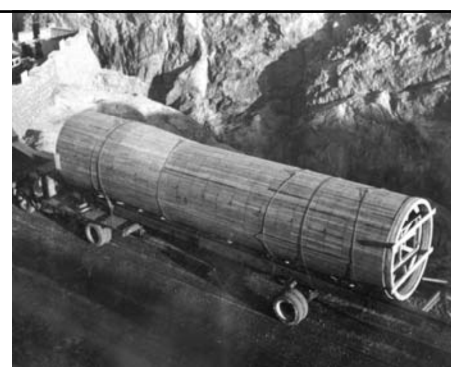
- **Excavating foundation "cut-off" trenches;**
- **Grouting the foundation;**
- **Draining the foundation through the use of relief wells;**
- **Draining the interior of the dam through the use of porous pipes and tunnels;**
- **Increasing the dam's thickness (cross-sectional profile) to counter the destabilizing effect of upward water pressure**

357

358

Unlike William Mulholland's design for the St. Francis Dam, the Bureau of Reclamation's design for Hoover Dam would pay close attention to uplift, learning the lessons applied to mitigate the problem at Elephant Butte, Arrow Rock and Black Canyon Dam/s (the latter in Southern Idaho, not on the Colorado – completed in 1924). Hoover Dam's design included in-depth foundation excavation, extensive pressurized grouting of the entire foundation and elaborate drainage systems for both the interior of the dam and the foundation.

359



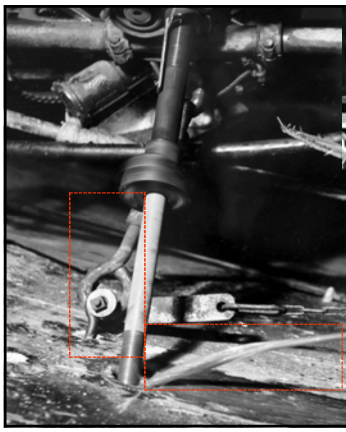
Form for radial Inspection Gallery en-route to Hoover Dam (December 1933) 360

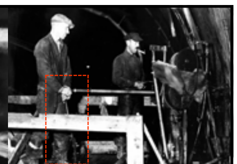
Seepage on the Nevada canyon wall (above roof of the central section of the Powerhouse; July 1938)

361

Seepage on the Arizona canyon wall (above the central section of the Powerhouse (at Elevation 790; July 1939)

362

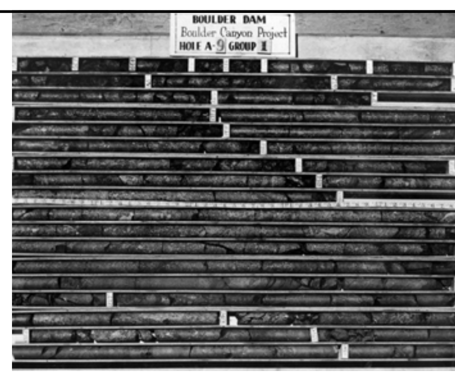




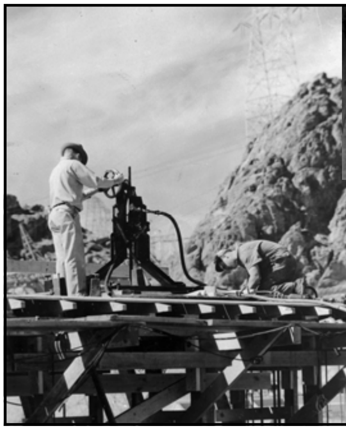
Left: Diamond drilling in Nevada (No. 2) tunnel. Notice that the drill is anchored to hold the drilling equipment close to the wall. The water flow was used to wash the cuttings away from the core bit (December 1940).
Above: Diamond drillers in Nevada (No. 2) tunnel. The drillers' helper is holding the water swivel which feeds water through the rod to the bit to keep it free (Dec. 1940). 363

Driller tightening the chuck after pulling the chuck back in order to drill another three-feet (December 1940). 364

Cores (from A-4 and other holes) were preserved in boxes similar to the one above (they were made out of plywood; June 1939) 365



Diamond drill cores (from hole A-9; July 1939) 366

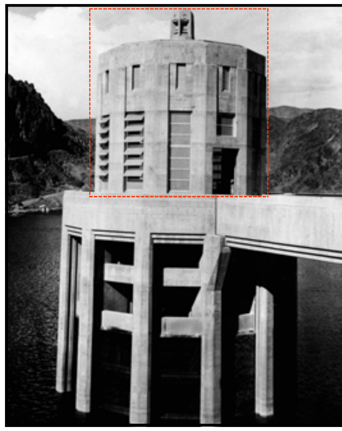


Left: Grouting and Diamond Drilling. Outdoor drilling was faster since the drillers could use longer rods, thus drilling to a great depth before changing drill bits. In this view, the drillers are working on the new canopy between the elevator towers of Boulder Dam (October 1940).
Above: Portable *Tiltmeter* used to detect heaving of the dam during grouting operations. This instrument could detect any movements up to one-millionth of an inch (October 1940). 367

Core drilling on the Arizona side of Black Canyon (at Spillways; May 1931) 368

Diamonds Are Forever

369



Because of the constant use of diamond drilling operations at Hoover Dam, a work shop was set up in one of the Nevada Intake Towers' superstructure to install and reclaim diamonds used in the drill bits (October 1940)

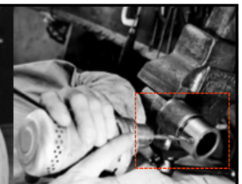
370

Diamond drill bits ranged in size from one to six inches. The two drills on the right are known as "Stoodite" drills. They were made of hard steel and did not contain diamonds. Stoodite drills were used in soft drilling such as freshly set grout (July 1940). 371

A pattern of new diamond drill core and plug bits (before diamonds have been set) 372

<u>Left</u>: with a compass, the larger core bit blanks were marked out preparatory to the setting of large black diamonds
<u>Above</u>: In the first operation (in preparing a bit for drilling), holes were drilled in a blank core bit preparatory to setting the diamonds (diamonds are in the small containers on the left)

373



<u>Left</u>: drilling holes in blanks
<u>Above</u>: The diamond drill bit blank being drilled for the insertion of the diamond/s. Mild steel was used in the bit blank for its ease of handling. The steel had to be mild enough to permit drilling and tamping and tough enough to retain the diamonds in place.

374

<u>Left</u>: *Diamond Setter* placing diamonds in the previously drilled blank core bit (using Jeweler's tweezers)
<u>Above</u>: Jeweler's scales for weighing diamonds. The diamonds were weighed before being placed in the bit blanks (and after they were removed from the bits to determine the loss). Dome-shaped bits were called "plug bits"; cylindrical bits were called "core bits."

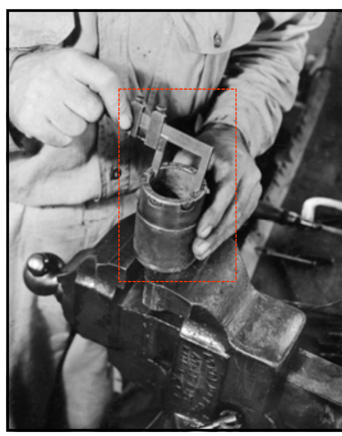
375

Setting *Bortz* diamonds in the core bit blank

376

Temping the mild steel metal around the diamonds in the core bit blank. The Diamond Setter stands in a catch pan in case a diamond should be dropped.

377



Finished bits were "Miked" to check on necessary clearance. The outer black diamonds prevented the bits from sticking in the drill holes

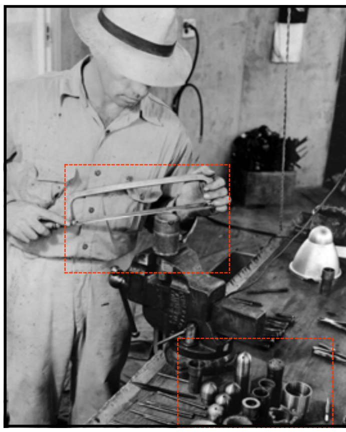
378

View showing a completed bit being removed from its temporary support (vise)

379

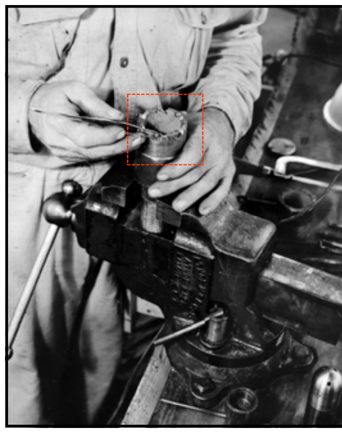
Drill bits were inspected with a magnifying glass before and after use (to check on alignment and/or fractures)

380



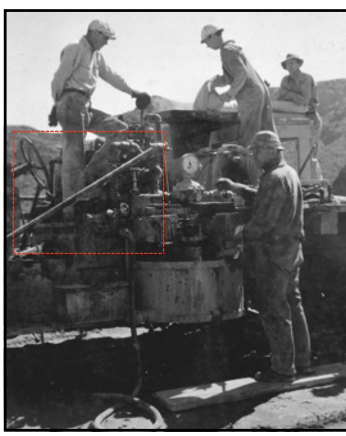
When drill bits became dull, the diamonds were removed by sawing out the metal around the diamond. The final removing of the diamond from the metal was done by the use of acid (note the many types of drill bits on the table).

381



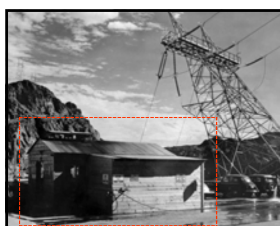
Removing the diamonds from the sawed bit. Diamonds were used over and over until they were too small to handle; they then were sold as diamond dust for grinding, etc. A black diamond would last through several thousand feet of rock drilling.

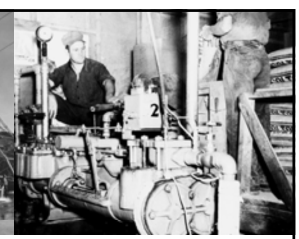
382



Left: Grout Rig. Grout is discharged through pipe at left (April 1935)
Above: Grout Rig operating on crest of dam (for grouting dam construction joints and middle slot; April 1935)

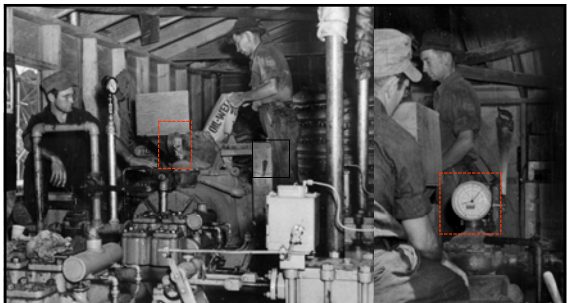
383





Left: the *Grout Shack* (housing the mixer and pump for operations on Hoover Dam) was located at the Nevada approach to the dam (October 1940)
Right: Grout pump (pressure used was up to 700psi; October 1940)

384



Water and cement being carefully proportioned. The gauge displayed pressure at the pump. The grout pressure was constantly monitored as it was pumped into the rock.

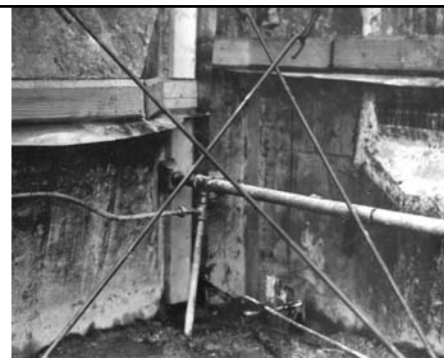
385

The grout was momentarily stored in this tub where it was mechanically stirred. Here it was picked up by the pump and forced into pipes under pressure.

386

The grout was pumped through pipes to its entrance into the rock (left). The pressure at the entrance to the hole was carefully monitored and constant communication with the pump operator was maintained by portable telephone sets (right).

387

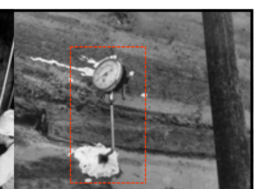


Grouting system installation showing and distributor pipes and copper strip stops (October 1933)

388

The grout was pumped through pipes through the Inspection Galleries deep into the dam (October 1940)

389



<u>Left</u>: placement of washed gravel (in eroded cavity) prior to grouting (May 1942)
<u>Above</u>: expansion gauge installed at joint during grouting operations

390

No Worries

391

"Report of the Investigating Committee St. Francis Dam just completed but not yet in the hands of Governor Young STOP Statement to you to the effect that there is absolutely no relation between the failure of the St. Francis Dam and the safety of the proposed Boulder Canyon Dam can be sent best advantage tomorrow morning after conference between Governor Young and A.J. Wiley Chairman of the investigating commission STOP Please wire advice if this is satisfactory or if statement absolutely necessary today"

RE: telegram sent by California State Engineer *Edward Hyatt* to Congressman Phil Swing (March 25th 1928)

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"I have positive assurance from A.J. Wiley, Chairman of Commission and of Dr. F.L. Ransome Professor of Economic Geology at California Technical Institute, who is also a member of the St. Francis investigating commission, both of whom have examined the Boulder and Black Canyon Dam sites that the bedrock there is sound, hard and durable and so very different from the very soft foundation of the St. Francis Dam, that the failure of St. Francis Dam need cause no apprehension whatever regarding the safety of the proposed Boulder Canyon Dam…The report of the investigating committee also states that there is nothing in the accepted theory of gravity dam design that is in error or that there is any question about the safety of concrete dams designed in accordance with that theory when built upon ordinarily sound bedrock but that on the contrary the action of the middle section of the St. Francis Dam that remained standing even under such adverse conditions is most convincing evidence of the stability of such structures when built upon such firm and durable bedrock as is present in Boulder Canyon."

RE: telegram (sent the following day; 03/26/28) by Governor Young to Congressman Swing

393

394

The Colorado River Compact

395

The timely completion of the Governor's Investigation Commission report helped allay fears and uncertainties concerning the safety of the BCP, but momentum for its passage had been lost. Six years had passed from its inception but just as it seemed ready to pass muster, tragedy struck. Influential publications such as the *Wall Street Journal* advised readers (and supporters of the BCPA) that: *"The St. Francis Dam break is an indictment of public ownership."* Adding to the apprehensions about dam safety, the State of Arizona vehemently opposed the BCP on the grounds that it served the interests of Southern California at the expense of Arizona. In November 1922, the seven Colorado River "basin states": *Arizona, California, Nevada, New Mexico, Utah, Colorado* and *Wyoming* had agreed to a water apportionment which came to be known as the *Colorado River Compact.*

396

COLORADO RIVER COMPACT

SIGNED AT

SANTA FE, NEW MEXICO

NOVEMBER 24, 1922

COLORADO RIVER COMPACT.

The States of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, having resolved to enter into a compact under the Act of the Congress of the United States of America approved August 19, 1921 (42 Statutes at Large, Page 171), and the Acts of the Legislatures of the said States, have through their Governors appointed as their Commissioners:

ARTICLE I.

The major purposes of this compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River System; to establish the relative importance of different beneficial uses of water; to promote interstate comity; to remove causes of present and future controversies; and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods. To these ends the Colorado River Basin is divided into two Basins, and an apportionment of the use of part of the water of the Colorado River System is made to each of them with the provision that further equitable apportionments may be made.

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Appendix 226

1925 LEGISLATION RATIFYING THE SIX-STATE COMPACT

WYOMING

(Act of February 25, 1925; Ch. 82, 18th Sess.; State Legislature; Session Laws of Wyoming, 1925, pp. 85-86)

CHAPTER 82

(Original Senate File No. 75)

RATIFICATION OF COLORADO RIVER COMPACT

An Act relating to the Colorado River Compact

Whereas the Legislatures of the States of California, Colorado, Nevada, New Mexico, Utah, and Wyoming, heretofore have approved the Colorado River Compact, signed by the Commissioners for said States and the state of Arizona, and approved by Herbert Hoover as a representative of the United States of America, at Santa Fe, New Mexico, November 24th, 1922 (Chapter 3 of the Session Laws of Wyoming, 1923), and notice of the approval by the Legislature of each of said approving states has been given by the Governor to the Governors of the other signatory states, and to the President of the United States, as required by Article XI of said Compact: Now, Therefore,

398

THIS is not the first time I have visited the site of this great dam. And it does give me extraordinary pleasure to see the great dream I have long held taking form in actual reality of stone and cement.

It is now ten years since I became chairman of the Colorado River Commission. That Commission solved in a unique way the legal conflicts as to water rights among six of the States which had long held up any possibility of the realization of these works. This was accomplished after three years of negotiation, finally closing with the Santa Fe compact. It was the first time that a provision in the Constitution of the United States for treaties among the several States was utilized on so great a scale. That compact was ratified by six of the States and is held open to the seventh to join at any time it may desire. It cleared out the legal underbrush in a way that enabled the next step to be taken. And I again had the satisfaction of presenting, both as an engineer and as head of the Commission, to President Coolidge and to the Congress, the great importance of these works. And I had a further part in the drafting of the final legislation which ultimately brought them into being.

Excerpt from Nov. 12th 1932 campaign speech by POTUS Herbert Hoover

399

POTUS Hoover at BCP site (1932)

400

Bronze inscription plaque (on base of flag pole erected by the *Elks Lodges* of the seven states of the Colorado River Pact; February 22nd 1932)

401

The Colorado River Board

402

In late May 1928, a compromise was reached whereby a Senate vote on the Swing/Johnson Bill would be delayed until Congress reconvened in December. In the meantime, a board of engineers and geologists chaired by Major General *William Sibert*; collectively known as "The Colorado River Board," would submit a report evaluating the proposed BCP (inclusive of the dam's gravity arch design) within six months. The creation of such a board would most likely never occurred had it not been for the St. Francis Dam failure, but with the disaster fresh in the minds of the public and politicians, caution was the watchword of the day. By the end of November – with the calamity a fading memory, the board endorsed the basic design of the dam with one important change: a reduction in the allowable stresses in the structure of the dam from forty to thirty tons per square foot. This change would add significantly to the bulk of he dam thus increasing costs. Using the "Trial-Load Method," the USBR determined that the proposed design included a maximum allowable stress of thirty-four tons per square foot, sufficient to meet the new thirty-ton requirement. Ultimately, the Board's recommendation had no significant impact since the USBR asserted that their design could meet the thirty-ton criteria without any substantial design change/s.

403

"It is not believed that the maximum stress as finally calculated will appreciably exceed the 30-ton limit. It is believed that the general plan of the dam can be agreed upon without serious difficulties"
Elwood Mead – USBR Commissioner

404

"Don't blame anyone else, you just fasten it on me. If there is an error in human judgment, I was the human"
William Mulholland
RE: excerpt from his testimony at the Los Angeles County Coroner's inquest into the St. Francis Dam disaster. Mullholland was widely praised by the engineering press for his "Big Man" posture and willingness to fall on his own sword. In reality, there was no one else to blame and his career came to an ignominious conclusion as a result. Mulholland resigned as *Chief Engineer and General Manager* of the BWWS on November 13th 1928 – a few weeks before the BCPA came back up for final congressional approval. In his retirement, Mulholland retained much high regard and appreciation from peers and the public he had served during his long career despite the disaster that ended it. However, the political fallout from the St. Francis Dam failure would take longer to ameliorate.

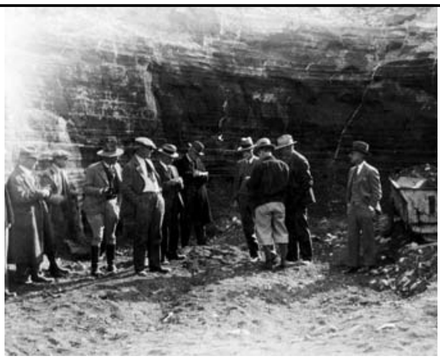
405

"I think that for any of the larger reservoirs the services of a Board of Consulting Engineers should be <u>mandatory</u>. Otherwise, picture one of our powerful municipalities proposing a great reservoir to be built from plans by an engineer of that municipality who has much prestige but who alone considered the plans and the location. His reputation might far outweigh that of the State Engineer and might therefore make a critical review by the latter appear foolish. With political pressure reaching even to the Governor, would not a perfunctory review by the State Engineer, his early approval and a permit from the Department, be almost certain to follow without reference to consultants. Thus we would have failed to provide that protection to the public which we are seeking to accomplish."
Walter L. Huber **– St. Francis Dam failure Investigation Committee member and Civil Engineer (he later served as President of the *ASCE*)**

406

"The failure of the St. Francis Dam has greatly disturbed public confidence in the safety of all dams, and for a time at least, proposals for the construction of new structures are going to face unmerited opposition no matter how carefully supervised by public authority. Even among competent engineers there will be a tendency toward undue conservatism…We in the California Department of Public Works are thoroughly in sympathy with the feeling that the public interest requires dams…to be made absolutely safe against failure and provided with adequate spillway capacity. At the same time, we feel that we must exercise great care to avoid insisting upon safeguards beyond the actual needs since many meritorious projects might be thereby rendered financially infeasible."
Edward Hyatt – California State Engineer, April 1928
RE: the Governor's Commission report had urged in its conclusion that all dams be: *"erected and maintained under the supervision and control of state authorities…with the police powers of the state…extended to cover all structures impounding any considerable quantities of water."* This public call for state supervision of dam projects was understandable in the wake of the St. Francis Dam calamity, but the fear was that too much legislation and/or unrealistic safety requirements could/would impede economic growth. Ultimately, California passed a "Dam Safety Law" (in 1929) that did not require the use of consultants, but did not preclude it.

407



BCP *Concrete Consulting Board* at black sand deposit (near Sloane, Nevada; January 1931)

408

So This Is Engineering

409

"Well, at the time we worked up the scheme – let's say the scheme, not the design – on the spillway, and put it in the specifications, that was the time that we were making model testing. So, when we issued the specification, Erdman Debler told us we should have a capacity of the spillway of 250K cubic feet per second. I can't remember exactly. Later on he had a change of heart, and we didn't dispute him ever, as far as hydrology was concerned…we designers didn't have a lot of information on foundations. Testing was done, always, but never in sufficient amounts. So we were really working on meager information. And so, after specifications were written, as construction developed, why then of course there always were changes in concept, changes in actual conditions as they were encountered in the field, and so on. So you have to have changes, you make modifications and changes based on conditions. So this is engineering, you see…"

Carl Hoffman, Civil Engineer
RE: recalling (in February 1995) his contribution to the design of Hoover Dam's Spillways

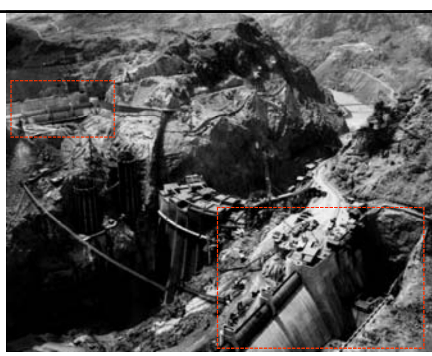
410

Yard for manufacturing porous drain tiles for the Spillways (January 1933)

411

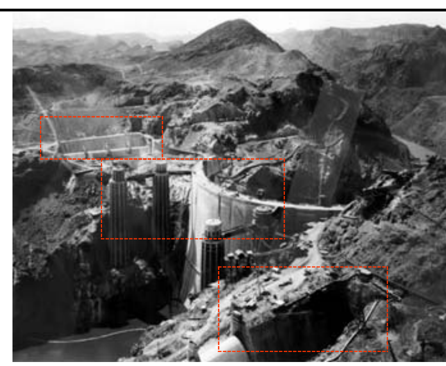
Nevada spillway (view from the construction trestle over the Nevada Intake Towers (November 1933). Each Spillway consisted of a concrete-lined open channel approximately 650-feet long, 150-feet wide, and 170-feet deep on each canyon wall. More than 600K cubic yards of rock were excavated for the Spillways. The Spillway walls were lined with eighteen-inches of concrete and the floors with twenty-four inches. A total of 127K cubic yards of concrete were placed for the Spillways.

412



Looking downstream from the Nevada side (toward the upstream face of Hoover Dam) showing the Arizona (left) and Nevada (right) Spillway/s (August 1934)

413



View looking downstream (showing Hoover Dam's four Intake Towers and two Spillways from the Nevada side of the river; April 1935)

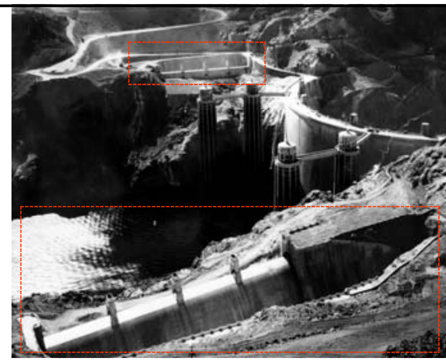
414

Okay, so this is a maximum release that could happen at Hoover Dam. But at Hoover Dam, one way or another, Debler changed his mind. Finally decided that we have to have a spillway capacity of 400K cubic feet per second. So we designed it, and this is a potential release that can happen from Hoover Dam."

Carl Hoffman, Civil Engineer

E.B. Debler, USBR (left) - Head of the USBR's *Water Resources and Project Investigations* section

415



Looking downstream from the Nevada side showing Hoover Dam Spillways and Intake Towers (September 1935)

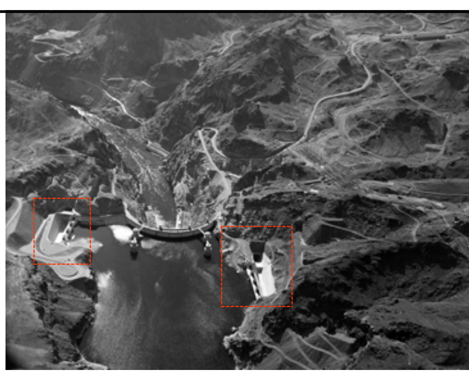
416

The purpose of the spillways was/is to prevent water from going over the top of the dam. If water ever did flow over the top of the dam, the Powerhouse (located at the foot of the dam) containing seventeen generators would be adversely affected (to say the least). The Spillways work just like the overflow hole in a home bathtub or sink. If the water ever gets up that high, it will go in the hole and down the drain, not over the top and onto the bathroom floor. The Spillways are located twenty-seven feet below the top of the dam (one on each side of the dam). Any water getting up that high will go into the Spillways then into fifty-foot diameter tunnels which are six-hundred feet long (inclined at a steep angle) connected to two of the original diversion tunnels. Each Spillway can handle 200K cubic feet per second of water. To put this in perspective, the flow at *Niagara Falls* is about 200Kcfs so the spillways could handle the equivalent flow of *two* Niagara Falls simultaneously. Maximum water velocity in the Spillway tunnels is +/-175 feet per second (120mph).

417

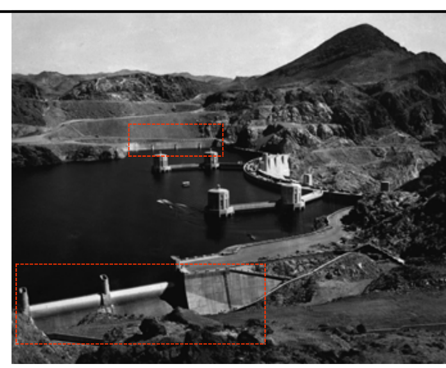
Open channel of the Arizona Spillway and the Highway Bridge (as seen from atop the arch of the inclined tunnel; September 1936). The Spillways each have a capacity of 200Kcfs totaling 400Kcfs. If the Spillways were operated at full capacity, the energy of the falling water would be about twenty-five million horsepower. The flow over each Spillway would be about the same as the flow over Niagara Falls, and the drop from the top of the raised Spillway gates to river level would be approximately three times as great as Niagara Falls.

418



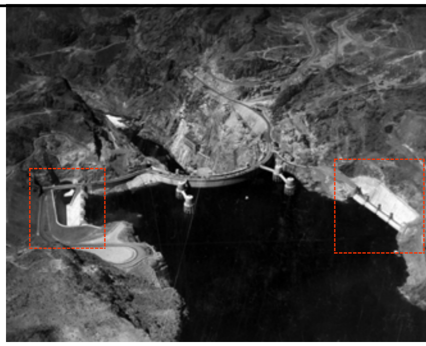
Aerial view of Hoover Dam showing Intake Towers, Spillways and roadways (October 1947)

419



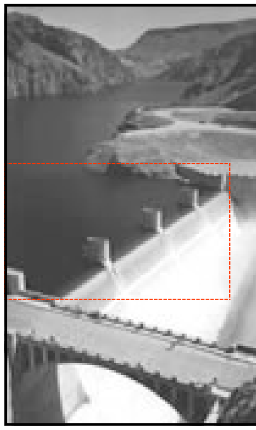
Hoover Dam Intake Towers and Spillways (from point above the Nevada spillway; August 1941)

420



Aerial view of Hoover Dam as the rising waters of Lake Mead neared the crest of the Nevada and Arizona Spillways (Lake Elevation, 1181.52; May 1941)

421

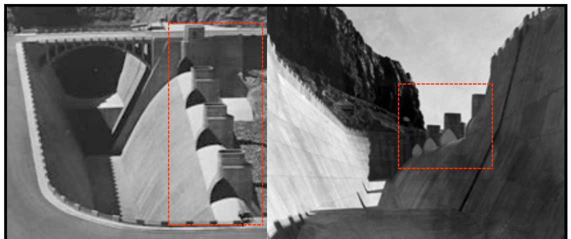


Each Spillway has four steel *Drum Gates*, each one-hundred feet long by sixteen-feet high. These gates cannot stop reservoir water from going into the Spillway, but they do allow an additional sixteen-feet of water to be stored in the reservoir. Each gate weighs approximately five-million pounds. Automatic control (with optional manual operation) is provided for raising and/or lowering the gates. When in the raised position, a gate may be held continuously in that position by the pressure of water against its bottom, until the water surface of the reservoir rises above a fixed point when, by action of a float, the gate is automatically lowered. As the flood peak decreases, the gate can be operated manually so as to gradually empty the flood control portion of the reservoir without creation of flood conditions downstream of the dam. The first time the Spillways were used was in 1941 (for a test of the system). The second time was for the real thing; a flood, in July 1983.

422

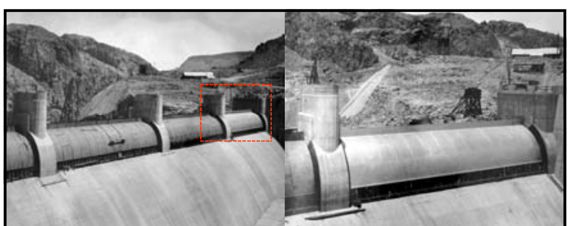
Left: looking upstream through the channel of the Arizona spillway (with view showing the nearly completed drum gates and piers). Trestle in foreground is false-work for the (concrete arch) Highway Bridge (June 1934).
Above: upstream face of Hoover Dam. Spillways and Intake Towers from point above the Nevada Spillway (four gates atop Spillway in view; May 1938)

423



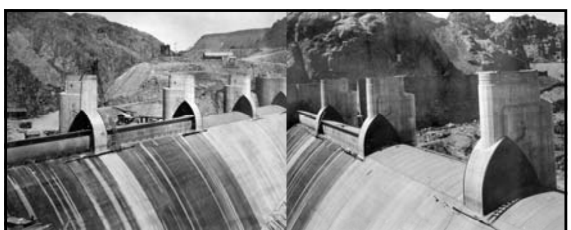
View/s of Spillway/Drum Gates taken from above (left) and through (right)

424



Left: view of Arizona Spillway (looking obliquely upstream and showing nearly completed Drum Gates and piers). Upstream gate (far right) has been aluminized (June 1934).
Right: nearly complete (aluminized) Drum Gate installation at upstream end of overflow weir in Arizona spillway (June 1934)

425



Left: looking diagonally across Arizona Spillway with view showing nearly completed installation of Drum Gates. Two upper gates at right in lowered position (October 1934).
Right: looking directly downstream along overflow weir in Arizona Spillway with view showing nearly completed installation of Drum Gates (gates at right in lowered position, other two partially lowered; October 1934).

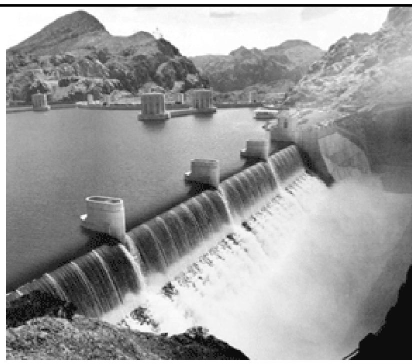
426

The Arizona Spillway was placed in operation on August 6th 1941, soon after the reservoir level had reached a maximum elevation of 1220.44. The Drum Gates were raised for several hours (on August 14th 1941) and a hurried inspection revealed that the tunnel lining was intact (the inclined portion showed little or no signs of erosion at that time). Operations were then continued without interruption until the reservoir level had been lowered to elevation 1205.60 (on December 1st 1942). The average discharge flow through the Arizona Spillway during this period was approximately 13,500cfs with a maximum flow of 38Kcfs (on October 28th 1941, when one of the drum gates dropped without warning). That much water falling down a steeply inclined tunnel caused erosion of the tunnel lining. The eroded area was approximately 115-feet long by 30-feet wide, with a maximum depth of approximately 45-feet. Repair work was started immediately, but because it was believed that ordinary concrete was not suitable, it was decided to utilize the ***Pre-Pack and Intrusion Process*** of concrete repair developed by the ***Durite Company*** of Chicago, Illinois. After repair, the tunnel was polished smooth to help prevent future erosion. During 1983, record flows into Lake Mead were recorded. The record surface elevation was recorded on July 24th, with more than two feet of water spilling over the raised spillway gates of Nevada and Arizona. The record flows through the Spillway tunnels again caused erosion in the concrete base requiring repair.

427

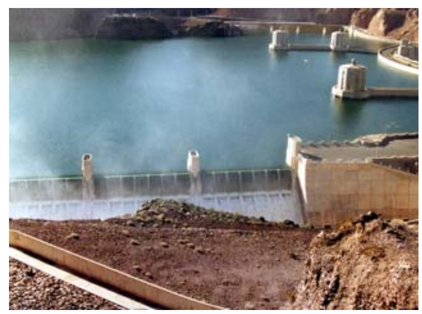
July 1983

428



Nevada Spillway

429



430

Westerly view of Arizona Spillway

431

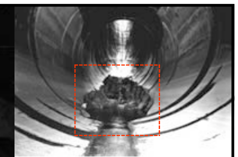
Left: northerly view of the Arizona spillway shows water spilling at 5,244cfs. Lake Mead water elevation was 1223.66 (at noon), which indicated that approximately 10,488cfs of water (total) was crossing both the Arizona and Nevada Spillways. Thus, water depth over the raised gate was two-feet, three-inches.

Above: water being discharged into the Colorado River from Spillways. A total of 11,128cfs of water was being discharged through each Spillway. Lake Mead water level was at elevation 1225.12 feet (at noon).

432

Inspections performed by engineers on the Spillway tunnels (after the Spillways were used in 1941 and 1983) revealed major damage to the concrete linings and underlying rock. The 1941 damage was attributed to a slight misalignment of the tunnel invert (base) which caused *Cavitation* (a phenomenon in fast-flowing liquids in which vapor bubbles collapse with explosive force). To remediate this finding, the tunnels were repaired with special heavy-duty concrete and the surface of the concrete was polished mirror-smooth. The spillways were modified in 1947 by adding "flip buckets" which both slow the water and decrease the Spillway's effective capacity. The 1983 damage (also due to Cavitation) led to the installation of *Aerators* in the spillways. Tests at *Grand Coulee Dam* demonstrated that the technique worked (in principle).

433



Left: cavity under the concrete lining (left side of the eroded area) in the Arizona Spillway tunnel (April 1942)
Above: eroded area at the base of the inclined section of the Arizona Spillway tunnel. The deep cavity has not yet been completely dewatered (April 1942).

434

Left: placement of gravel in eroded cavity prior to grouting (May 1942)
Above: cavity has been filled with gravel and is ready for grout (May 1942)

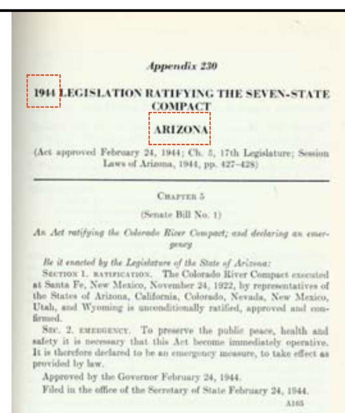
435

Done Deal

436

In 1927, floodwaters from the Mississippi River inundated many southern and mid-western states having the effect of making congressman and senators from those states affected by the flooding much more sympathetic to legislation concerning flood control measures, though many other states still saw the BCPA as extremely expensive and, primarily, for the benefit of California. With the Colorado River Board giving the BCP its blessing but recommending: *"…the proposed dam should be constructed on conservative if not ultra-conservative lines,"* the die was cast for the passing of the BCPA. On December 21st 1928, President *Calvin Coolidge* signed the bill authorizing the BCP to commence at a cost of $165 million. This appropriation included Hoover Dam and its appurtenances, the downstream Imperial Dam and the All-American Canal. It also allowed for a replacement (on the U.S. side of the border) of *Beatty's Canal*. The legislation allowed the Colorado River Compact to go into effect provided at least six of the seven states party to the Compact approved it. Utah's state legislature ratified the Compact on March 6th 1929 thus, the Colorado River Compact went into effect. Arizona - the last holdout of the seven states concerned, did not ratify the Compact until 1944.

437



Appendix 230

1944 LEGISLATION RATIFYING THE SEVEN-STATE COMPACT

ARIZONA

(Act approved February 24, 1944; Ch. 5, 17th Legislature; Session Laws of Arizona, 1944, pp. 427–428)

CHAPTER 5

(Senate Bill No. 1)

An Act ratifying the Colorado River Compact; and declaring an emergency

Be it enacted by the Legislature of the State of Arizona:

SECTION 1. RATIFICATION. The Colorado River Compact executed at Santa Fe, New Mexico, November 24, 1922, by representatives of the States of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming is unconditionally ratified, approved and confirmed.

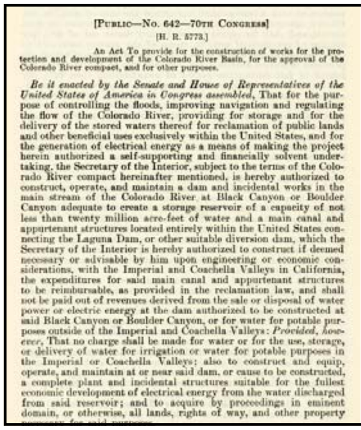
SEC. 2. EMERGENCY. To preserve the public peace, health and safety it is necessary that this Act become immediately operative. It is therefore declared to be an emergency measure, to take effect as provided by law.

Approved by the Governor February 24, 1944.

Filed in the office of the Secretary of State February 24, 1944.

A165

438



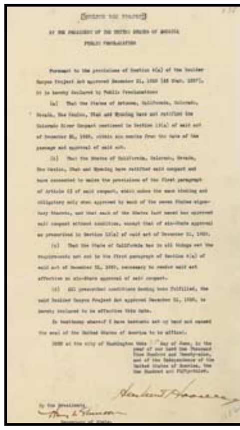
[Public—No. 642—70th Congress]
[H. R. 5773.]

An Act To provide for the construction of works for the protection and development of the Colorado River Basin, for the approval of the Colorado River compact, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That for the purpose of controlling the floods, improving navigation and regulating the flow of the Colorado River, providing for storage and for the delivery of the stored waters thereof for reclamation of public lands and other beneficial uses exclusively within the United States, and for the generation of electrical energy as a means of making the project herein authorized a self-supporting and financially solvent undertaking, the Secretary of the Interior, subject to the terms of the Colorado River compact hereinafter mentioned, is hereby authorized to construct, operate, and maintain a dam and incidental works in the main stream of the Colorado River at Black Canyon or Boulder Canyon adequate to create a storage reservoir of a capacity of not less than twenty million acre-feet of water and a main canal and appurtenant structures located entirely within the United States connecting the Laguna Dam, or other suitable diversion dam, which the Secretary of the Interior is hereby authorized to construct if deemed necessary or advisable by him upon engineering or economic considerations, with the Imperial and Coachella Valleys in California, the expenditures for said main canal and appurtenant structures to be reimbursable, as provided in the reclamation law, and shall not be paid out of revenues derived from the sale or disposal of water power or electric energy at the dam authorized to be constructed at said Black Canyon or Boulder Canyon, or for water for potable purposes outside of the Imperial and Coachella Valleys: *Provided, however*, That no charge shall be made for water or for the use, storage, or delivery of water for irrigation or water for potable purposes in the Imperial or Coachella Valleys; also to construct and equip, operate, and maintain at or near said dam, or cause to be constructed, a complete plant and incidental structures suitable for the fullest economic development of electrical energy from the water discharged from said reservoir; and to acquire by proceedings in eminent domain, or otherwise, all lands, rights of way, and other property

Congressional Act to build Hoover Dam; December 21st 1928

439



President Hoover's proclamation to start construction on Hoover Dam; June 25th 1929

440

441

Part 4

The Art of Economical Construction

442

A Great Natural Resource

443

"Work on Boulder Dam, world's highest (727-feet), was ready to start last week. Congress had appropriated $10,660,000 to get the $165,000,000 project under way. Secretary of the Interior Wilbur approved a construction order which was telegraphed to Las Vegas, Nevada. Where Walker R. Young, resident U.S. Engineer, received it. Said Secretary Wilbur: 'With dollars, men and engineering brains we will build a great natural resource…make new geography…start a new era…conquer the Great American Desert. To bring about this transformation requires a dam higher than any the engineer has hitherto conceived or attempted to build.' Secretary Wilbur warned against a rush of workmen to the barren dam site where their services are not yet needed."

Time **magazine, July 21st 1930**

444

Secretary of the Interior, ***Ray Lyman Wilbur*** **(at top of cliffs, Hoover Dam site; July 1931)**

445

John Lucian Savage **(1879-1967) was the USBR's chief design engineer and oversaw the design of the arch-gravity dam design chosen for Black Canyon. The thick base would taper to a thin top and the convex arch would face the impounded waters of the reservoir (Lake Mead) transmitting the force of the water pressure into the rock-wall abutments on either side of the canyon. Wedge-shaped, the dam would be 660-feet thick at bottom narrowing to 45-feet at the top of the arch thus allowing for a highway connecting Arizona and Nevada. Bid documents were issued on January 10th 1931 to interested bidders stipulating the government was to provide all materials, but it was the contractor's responsibility to prepare the site and provide the labor force to build the dam.**

446

Six Companies

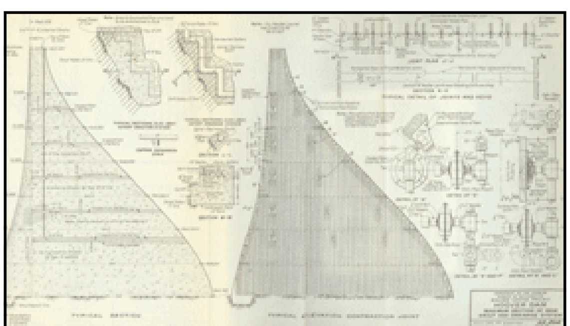
447

Seventy-six drawings and one-hundred pages of text described the dam's construction in detail. To formally submit a bid, a $2 million *Bid Bond* was required of each potential bidder and a $5 million *Performance Bond* and monetary penalties (*Liquidated Damages*) would ensure the completion of the dam in seven years time. Several contractors interested in bidding the project could not secure the bond/s required (i.e. *Utah Construction Company*). *Morrison-Knudsen* (a long time partner of Utah Construction Co.) and employer of Frank T. Crowe – the nation's leading dam builder, together could not afford the bonding requirements. Ultimately, a joint-venture of six construction companies was formed to bid the project;

- **Utah Construction Company - Ogden, Utah (20%)**
- **Morrison-Knudsen Company – Boise, Idaho (10%)**
- **Pacific Bridge Company – Portland, Oregon (10%)**
- **Henry J. Kaiser – Oakland, California (*Kaiser and Bechtel shared 30%)**
- **W.A. Bechtel – San Francisco, California (*)**
- **MacDonald & Kahn – Los Angeles, California (20%)**
- **J.F. Shea – Portland, Oregon (10%)**

For naming purposes (and share percentage), Kaiser and Bechtel were considered one company thus the conglomerate became *Six Companies, Inc.* Three qualified bids were received varying up to $5 million from the official USBR estimate. Six Companies' low bid came in within $24K of the government estimate at $48,890,955.00.

448



From "The Construction of Hoover Dam" (published by the *Department of the Interior*, 1933)

449

Government and Six Companies officials inspecting the Nevada Spillway. From left to right: *Norman S. Gallison*, *H.J. Lawler*, *Walker R. Young*, *Charles A. Shea*, *E.O. Wattis*, *Dr. Elwood Mead*, *Frank T. Crowe*, *R.F. Walter* and *W.A. Bechtel* (February 1932).

450

Hoover Dam was to be the first round-the-clock federal works project using three shifts per day, seven days a week (save for *Independence Day*, *Labor Day* and *Christmas Day*). As such, the federal government would provide the following;
• All materials (except concrete aggregate)
• Railroad spur and highway (to crest of gorge)
• Construction of Boulder City (a federal reservation)
• Assumption of flood damage liability (after Cofferdams were accepted
• Turbines and machinery for hydroelectric power plants
Ultimately, 4.4 million cubic yards of concrete (3.25 million for the dam alone), five-million barrels of cement (used for concrete production), 9K-tons of structural steel and 44K-tons of large diameter steel pipe would be consumed by the BCP. Given the remoteness of the dam site, transportation of materials and equipment to the site was imperative. As such, high priority was given to constructing a 34-mile long railroad spur from the Las Vegas rail-head to the dam site. 451

Boulder City, Nevada; Headquarters of the "Boulder Canyon Project" (December 1934) 452

Mobilization

453

The USBR contracted with the Union Pacific Railroad to build a twenty-two mile spur from Las Vegas to Boulder City prior to site mobilization. Additionally, *Lewis Construction Company* was contracted with by the USBR to build a ten mile long spur from Boulder City to the edge of the Nevada canyon wall. Ultimately, Six Companies would itself build twenty-miles of RR track to tie into the USBR tracks. In total, it was estimated that the rail lines carried 440 million ton-miles of live/dead loads (combined) and 63K trains traveled a distance of 700K miles. After sand and gravel were processed, three million tons were transported five miles to the low level concrete plant while five-million tons were transported ten miles to the high level mixing plant. Though most tunnel excavation "muck" (excavation spoil material) was moved by truck, an estimated three-million cubic yards was moved by special "muck trains." Railroads also delivered cement and other long-haul materials (i.e. generator equipment). Searching for any/all access points to get men and material in and out of Black Canyon, Crowe/Six Companies built a two-mile road connecting to the USBR road (on the Nevada side of Black Canyon, near the site of the Diversion Tunnel outlet/s). Just half-a-mile downstream from the dam, the work to create the road required extensive rock excavation. Six Companies also built an upstream access road. 454

Delivering the silver spike connecting with railroad Las Vegas and the BCP site; September 17th 1930. Left to right: Senator *Key Pitman* (NV), Governor *Balzar* (NV), *Carl Gray* (Union Pacific RR), Secretary of the Interior *Ray Lyman Wilbur*. The RR spur was the first construction for the BCP. 455

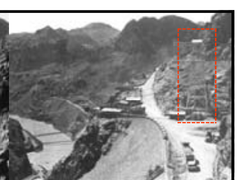
Six Companies warehouse and spur track (under construction; March 1931) 456

First train load of gravel arriving at screening plant (January 9th 1932)
457

Mixers being unloaded from railroad cars. These mixers were four cubic yards capacity and had a cycle of three-and-a-half minutes for loading, mixing, and discharging (January 1932).
458

The machine shop and warehouse group of buildings. These buildings were served by railroad spurs (March 1932).
459

Gravel train crossing a trestle on the way to BCP site (May 1932)
460



Left: rip-rapped fills on *Black Canyon Highway* (October 1932)
Above: Black Canyon Highway as it approached dam site along Nevada rim of Black Canyon. View looks downstream and shows Headtower of 150-ton permanent cableway (at right; Sept. 1933).
461

"We must have a place to eat and sleep before we can put men out there"
Frank Crowe – General Superintendent, Six Companies
RE: with Boulder City still on the drawing boards and a requirement for about five-hundred men to get the BCP started (without having to bus workers back and forth from Las Vegas), Crowe set-to-task *Charlie* "The Wizard with Wood" *Williams* to creating on-site housing for the initial work-force at a location known as *Cape Horn* (a.k.a. *River Camp*)
462

<u>Left</u>: Six Companies' bunkhouse at Cape Horn (June 1931)
<u>Above</u>: Cape Horn, the site chosen for housing the initial workforce of +/-500 men

463

Boulder City was to be built by the federal government (providing 80% of worker housing) before actual work on the dam began (scheduled for October 1931). President Hoover instead ordered work to begin in March 1931 (to help alleviate the problem of large numbers of unemployed men seeking work in the vicinity of the dam). Hastily built Dormitories housed 480 single men in bunkhouses (attached to the canyon wall) in what became known as "River Camp" while workers with families lived, primarily, in "Ragtown" (a.k.a. "Williamsville" – on the flats of the Colorado) until Boulder City was ready for habitation. Las Vegas was a city with a population of about 5K. When it was announced that a dam was to be built nearby, between 10K to 20K unemployed setup a squatter's camp known as "McKeeversville" (surrounding a government camp).

464

"We found in our investigation that the temperature was at least ten degrees lower than at the dam site. We also found that the air currents, particularly from the lake area, from around Hemenway Wash, created almost a continuous breeze, very slight on some occasions, very stiff and very severe in other instances. It wasn't a very attractive site for us, but better than anyplace else in that particular area"
Frank Crowe
RE: River Camp

465

"Ragtown" Family

466

Wobblies

467

By 1932, Six Companies had hired over three-thousand workers exclusive of "Mongolian" (Chinese) labor which was expressly forbidden by the construction contract (fewer than thirty African-Americans were employed as low-paid, segregated day laborers). Employment would peak in July 1934 with 5,251 officially on the Six Companies' payroll. The *Industrial Workers of the World* (IWW) – a.k.a. "Wobblies," sent eleven organizers in an attempt to unionize the Six Companies' workforce (several were arrested by the Las Vegas police). Labor unrest ensued, much relieved by improving living conditions and compromise/concessions on both sides. Early in the BCP, the work crews were not large and most of the jobs available were dirty, dangerous and low paying. Three daily shifts worked eight hours per shift. The highest wage was $1.25/hour, the lowest hourly wage was $0.50/hour. The average wage was $0.625/hour.

468

Job	Wage		Job	Wage
Steel Worker	$422.87		Coal Miner	$723.00
Hired Farm Hand	$216.00		Waitress	$520.00
Bus Driver	$1,373.00		Civil Service Employee	$1,284.00
Engineer	$2,520.00		Doctor	$3,382.00
Lawyer	$4,218.00		U.S. Congress-man	$8,663.00

At eight hours per day for a year, $0.50/hour (lowest wage) worked out to $1,460.00/year. The average ($0.625/hour) worked out to an annual income of $1,825.00. The highest wage ($1.25/hour), worked out to $3,650.00 per year. The above chart provides a comparison of what other tradesmen/professionals were earning (per annum) in the early '30s. 469

African-American Work Crew

470

To See A Brighter Day

471

Officials and other notables at unveiling of *Memorial Tablet* (left) placed in canyon wall at the Nevada end of the dam by the *Boulder City Central Labor Committee* on May 30th 1935. Officially, the BCP death toll was 96, unofficially it was 112. Tragically, the first and last men to die were related – they were *J.G. Tierney* (father) on 12/20/22 and *Patrick W. Tierney* (son) on 12/20/35 – they died on the same day exactly thirteen years apart. 472

Memorial Tablet inscription: *They Laboured That Millions Might See A Brighter Day*. The tablet is made of bronze and measures three by four feet 473

In the Dry

474

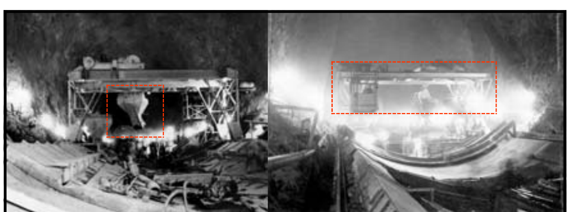
The first step in constructing the dam was diversion of the river itself so that work on the dam could be done “in the dry.” To accomplish this, four 50-foot diameter Diversion Tunnels (two on each side of the canyon) would have to be dug through solid rock. Combined, the length of the four tunnels was over three miles (nearly 16K feet). The construction contract required all four tunnels to be completed by October 1st 1933, if not, a penalty of $3K/day would ensue (the Colorado River was only low enough to safely divert in the late fall/winter). In May 1931, tunneling began at the lower portals of the Nevada tunnels (Nos. 1 & 2) and soon after similar work began on the Arizona tunnels (Nos. 3 & 4). By March 1932, work began lining the tunnels with three-feet of concrete. The base (a.k.a. “invert”) was poured first (using gantry cranes running the entire length of the tunnel/s to pour the concrete). Next, the sidewalls were poured using movable steel forms. The “arch” was formed using a form and pneumatic concrete guns. On November 14th 1932, using only one (No. 4) of the two Arizona tunnels (the Nevada tunnels were held in reserve for high-water) the Colorado River was diverted from its natural course around the dam site. To achieve diversion, a temporary wooden Cofferdam (protecting the Arizona tunnels) was dynamited while rubble from trucks diverted the river into the now exposed Arizona tunnel. 475

Interior of one of the Diversion Tunnels. The Drilling Jumbo is working at the tunnel face (the twelve-foot by twelve-foot top-heading can be plainly seen; January 1932). Each tunnel was dug to a diameter of fifty-six feet. With the addition of the three-foot thick concrete lining, the finish diameter of each tunnel was fifty-feet. 476

Left: “Muck Train” dumping along the railroad right-of-way, upstream from the river camp (showing western side-dump/drop-door type of cars; January 1932)
Right: trucks (hauling spoil from Diversion Tunnel inlet headings) dumping their loads into railroad cars at transfer dock operated by Six Companies (near low level concrete mixing plant in Black Canyon; February 1932)

477

Left: loading concrete into two cubic yard bottom dump buckets at Six Companies’ low level concrete mixing plant. Buckets were hauled (two to a truck) into Diversion Tunnels where they were handled by crane into position over invert forms (April 1932)
Above: truck loaded with concrete entering the upper portal of Diversion Tunnel No. 2 (through opening left in Cofferdam; April 1932) 478



Left: concrete lining in Diversion Tunnel No. 2. Two cubic yard buckets were suspended from the gantry crane (March 1932).
Right: dumping concrete from buckets suspended from gantry crane into invert forms in Diversion Tunnel No 2. Screed is seen below crane, finishing platform is seen in front of the screed (April 1932).

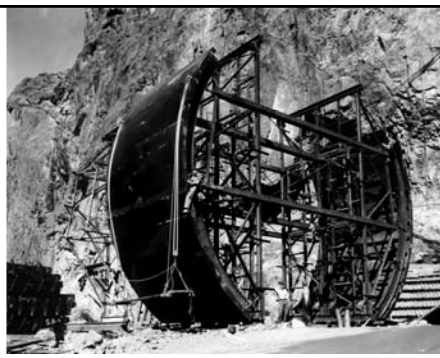
479

Left: first forty-foot slab of concrete poured in the lining of the Diversion Tunnel/s (March 1932)
Right: movable template used in forming forty-foot slabs of invert lining (April 1932)

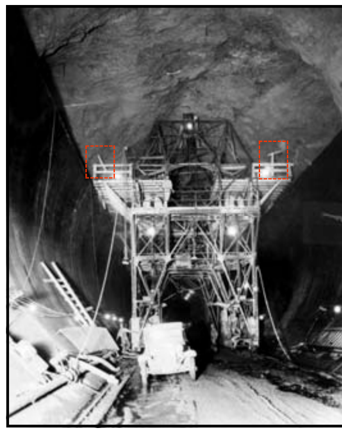
480

Detail picture of the Side-Wall Jumbo used in placing the three-foot thick lining in the Diversion Tunnels. The side winds were jacked into place, and concrete was poured through ports by means of a traveling crane and two cubic yard buckets (April 1932). 481

Placing steel form for the first pouring of concrete in the lining of the arch section of the Diversion Tunnels. View shows upper portal of Diversion Tunnel No. 4 (June 1932). 482



A close-up view of a section of the forms used in placing the side-wall sections of the concrete lining in the Diversion Tunnels (Aug. 1932) 483

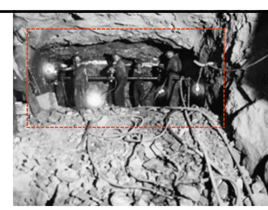


Moveable carriage, on which concrete guns are mounted (at lower right and left) and used in placing concrete lining in the arch section of the Diversion Tunnel/s (stationary arch form shown in the background; August 1932)

484

Drill & Shoot

485



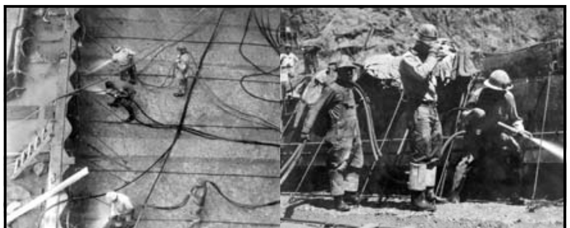
Drilling face of tunnel (at "Crown"; September 1931). If nothing else, the BCP was a large-scale "Drill & Shoot" project requiring the latest in compressed-air drilling technology. In 1912, *Chicago Pneumatic* introduced the "Simplate Valve" which replaced mechanical valves. Also in 1912, the revolutionary lightweight, hand-held "Jackhammer" sinker drill was invented. By the time of the BCP, a wide variety of portable and stationary air compressors were available in diesel, gasoline and electrically powered models. BCP required several air compressor plants producing (cumulatively) 16K cubic feet per minute (cfm) of compressed air. Several types of compressed-air tools were use on Hoover Dam including "air-tugger" winches and air-powered concrete vibrators. 486

<u>Left</u>: "Jackhammer"" drill crew at work in open cut at outlet of Nevada Spillway tunnel (December 1931)
<u>Above</u>: *Ingersol-Rand Air-Hammer* (a.k.a. "Jackhammer")

487

<u>Left</u>: Jackhammer men drilling near Lookout Point (July 1932)
<u>Above</u>: Jackhammer men working on the floor of the Arizona Spillway open cut excavation (workman in foreground is blowing dust from Jackhammer hole; July 1932)

488



Clean-up gang washing down surface concrete in one of the lower forms (near the upstream face of the dam). Water and compressed air are being used (June 1934).

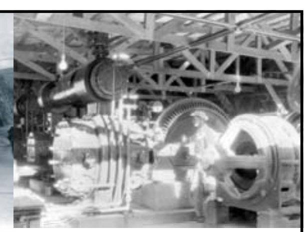
489

Compressed air vibrator being used in test pour (Column H-5, Elevation 635; August 1933)

490

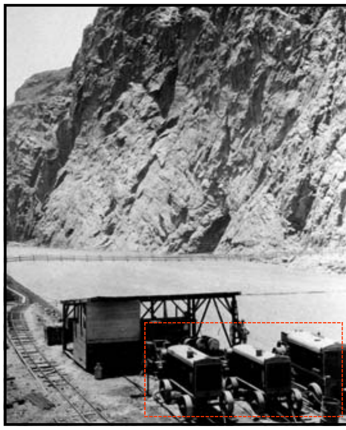
<u>Left</u>: crew distributing concrete in floor slab in the Arizona wing of power plant (note compressed-air vibrators in use; December 1934)
<u>Right</u>: workman using a compressed air vibrator for compacting concrete (January 1934)

491



<u>Left</u>: Six Companies *Compressor Station* (near outlets of Nevada Diversion Tunnels; August 1931)
<u>Right</u>: interior of compressor station

492



Six Companies Compressor Station (Arizona side; June 1931)

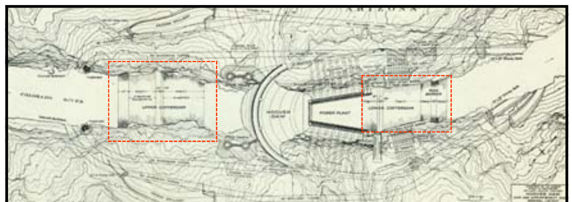
493

Frigidaire **drinking water and water cooling plant (at compressor No. 2, Arizona side; August 1931)**

494

Cofferdams

495



To facilitate the diversion of the river and protect the worksite, two *Cofferdams* were constructed. The specifications for their construction was as detailed as for the dam itself. After all, their purpose was to prevent the possibility of the site flooding while +2K men were at work. Once the *Upper* and *Lower* Cofferdams were established, the site was dewatered and excavation for the dam could begin. The Cofferdams, *Rock Barrier*, and Diversion Tunnels were all completed before the spring floods of 1933. The engineers watched with great anticipation to see if the Cofferdams would hold. They did, and the four mammoth Diversion Tunnels readily handled the flood waters. The work of actually building Hoover Dam could begin.

496

Upper (Upstream) Cofferdam

497

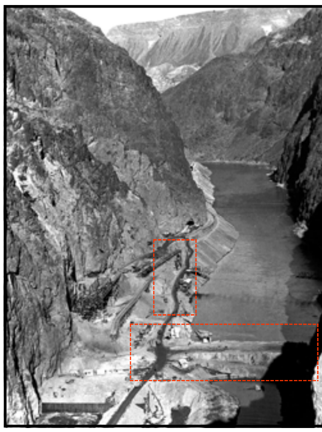
Work on the Upper Cofferdam began in September 1932. The Upper Cofferdam was located approximately six-hundred-feet down river from the inlet portals of the Diversion Tunnels. Before the cofferdam could be constructed, 250K cubic yards of river silt had to be removed to provide a firm foundation. When completed, the Upper Cofferdam stood ninety-eight feet high, and reached about thirty-feet above the top of the Diversion Tunnels. The Cofferdam was 450-feet long, 750-feet thick (at the base) and contained 516K cubic yards of earth and 157K cubic yards of rock. The upstream face was protected by a six-inch thick concrete paving laid over three-feet of rock blanket. The downstream face was covered by a thick rock fill. The Cofferdam was designed so that if the Diversion Tunnels were discharging water at 200Kcfs, the water would still be thirteen-feet below the crest of the cofferdam (200Kcfs was the greatest flow of water ever recorded through Black Canyon).

498

Looking downstream into the Upper Cofferdam excavation (dyke and restricted river channel are at left; October 1932) 499

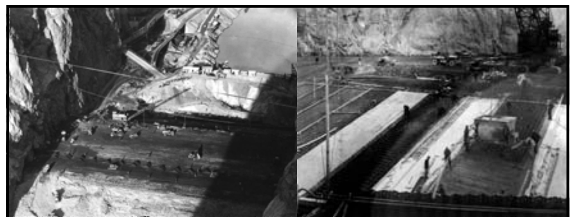
<u>Left</u>: Lower Portals of Diversion Tunnels Nos. 3 and 4 (after diversion of the Colorado River was completed; November 14th 1932)
<u>Right</u>: Upper Portals of Diversion Tunnels Nos. 3 and 4 and temporary dyke (after the diversion of the Colorado River was completed). The temporary horseshoe-shaped dyke protected the cofferdam on the Nevada side of the river (November 14th 1932).

500



Looking down into Upper Cofferdam area (from rim of Arizona side of Black Canyon). Temporary earth diversion dam is shown. Note the steel piling extending out from the Nevada abutment and marking upstream toe of cofferdam proper; November 18th 1932).

501

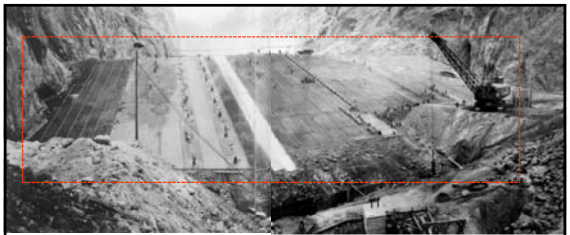


<u>Left</u>: looking down onto Upper Cofferdam operations from point on Arizona abutment (fill is approaching maximum Elevation 720; December 1932)
<u>Right</u>: placing concrete paving on the Upstream Cofferdam (December 1932)

502

Upstream Cofferdam (looking downstream; Dec. 1932) 503

Looking upstream through Black Canyon toward the dam site (showing condition after the diversion of the Colorado River). Lower levels of canyon choked with material blasted and scaled from the canyon walls. A downstream rock barrier can be seen in foreground (January 1933). 504



Upstream Cofferdam (panoramic view looking downstream; January 1933)

505

Cat-walk spanning canyon over Upstream Cofferdam (August 1933)

506

Upper portals of the Diversion Tunnels. The dyke being built is at Elevation 690 (which is the elevation of the top of the tunnels). The upstream dyke required 732K cubic yards of concrete and the downstream dyke required 500K cubic yards (November 1933).

507

Lower (Downstream) Cofferdam

508

Work on the Lower Cofferdam was delayed until the High-Scaling of the canyon walls (above the sites of the power plant and outlet works) was completed. The Lower Cofferdam was built of a compressed earth fill. It was 66-feet high, 350-feet long and 550-feet thick at its base. The Cofferdam contained approximately 230K cubic yards of earth, and another 63K cubic yards of rock. A thick rock fill covered the downstream side of the Cofferdam. Because the Lower Cofferdam was made of a soft earth fill, there was concern that during floods back washing from the outlet portals would damage the Cofferdam. To lessen the force of the water, approximately 350-feet down river from the Lower Cofferdam a rock barrier was built. This barrier was 54-feet high, 375-feet long and 200-feet thick at its base and contained approximately 98K cubic feet of rock.

509

Looking upstream in Black Canyon (from lower portals) showing Lower Cofferdam site and general conditions after diversion of the Colorado River (November 1932)

510

<u>Left</u>: Looking upstream (from the Nevada side). Excavation operations for Downstream Cofferdam shown in foreground (and above; January 1933).
<u>Above</u>: power shovel excavating Downstream Cofferdam (January 1933)
511

Lower Portals of the Diversion Tunnels and excavation in the river bottom (for Downstream Cofferdam and rock barrier; January 1933) 512

General view of Downstream Cofferdam and excavation in riverbed for Powerhouse (February 1933) 513

<u>Left</u>: looking downstream on the Lower Cofferdam, showing excavation and dykes (view taken from the Nevada side; September 1934)
<u>Above</u>: view downstream (from 150-ton cableway) of Downstream Cofferdam (August 1934) 514

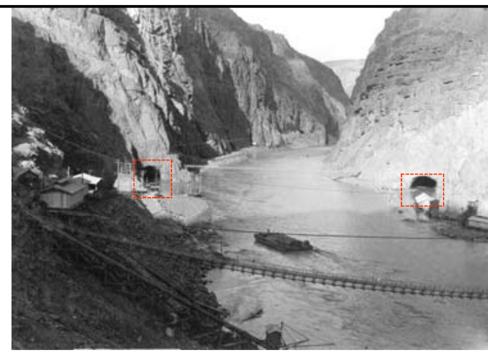
Power shovels and trucks removing Downstream Cofferdam (January 1935) 515

Trucks depositing material (from Lower Cofferdam removal) in dump (downstream from dam on the Arizona side of the river (March 1935) 516

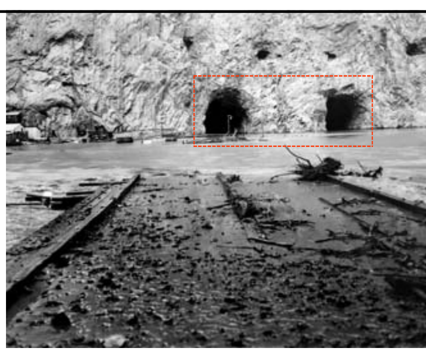
The excavation of the four Diversion Tunnels cost $13,285,000.00 (fully 27% of the BCP cost). The three-foot thick concrete lining coat cost an additional $3,432,000.00. After the concrete lining was complete, the invert section was filled with a gravel bed to provide temporary vehicular access. Two tunnels (one on each side of the dam) were assigned to carry floodwaters and are connected to the Spillway/s (on their respective sides of the dam). The other two tunnels (again, one on each side of the dam) were modified to hold a large "Penstock" pipe. Each Diversion Tunnel was designed to carry 50Kcfs for a total of 200Kcfs during construction. On February 10^{th} 1932 – before completion of any of the Diversion Tunnels, a flash flood inundated the construction site requiring a shut-down and clean-up lasting five days. The successful diversion of the river on November 14^{th} 1932 – a year and a half early, provided Six Companies much needed cash flow and practically guaranteed them a profit on the job. The greatest flow the Diversion Tunnels had to carry during construction occurred on June 16^{th} 1933 when 73Kcfs passed through the tunnels to the downstream river. The lowest flow occurred on August 26^{th} 1934 with 1kcfs passing downstream through the tunnels. In July 1931, fourteen men died working in the overheated and under-ventilated tunnels leading to a strike in August 1931. Medical care/facilities, better safety precautions and water carriers were the result. 517

Squatters camp residents. The summer of 1931 was particularly hot with daytime temperatures averaging highs of 119.9 degrees (F). Between June 25^{th} and July 26^{th}, fourteen workers and two riverbank residents died of heat prostration. 518

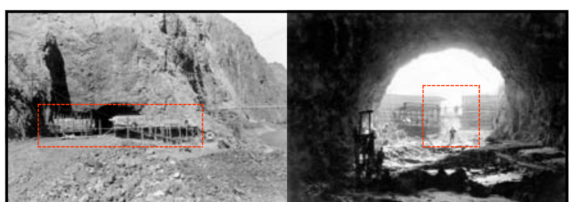
Workmen at isolated points away from drinking fountains were supplied by water bags. The photograph above shows a crew of water-boys at the Arizona Spillway (July 1932). 519



Looking upstream through Black Canyon during high water stage (view shows outlet portals of Diversion Tunnels; February 10^{th} 1932) 520

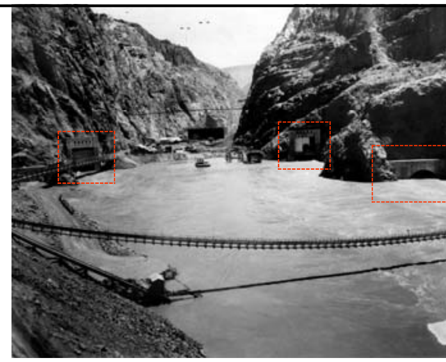


Looking across river (from the Arizona side) at the upper portals of Diversion Tunnels Nos. 1 and 2. The truck bridge in the foreground has been partially washed out due to flooding (February 10^{th} 1932). 521

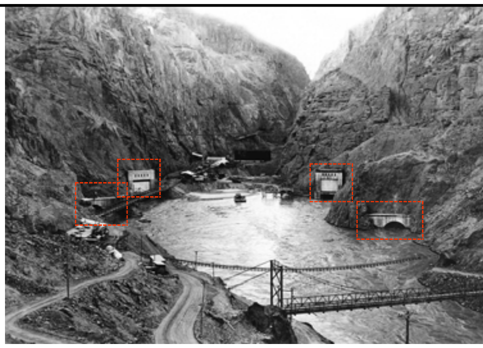


<u>Left</u>: Cofferdam being erected around outlet portal of Nevada Penstock Tunnel. Like structures were built to protect all eight of the Diversion Tunnel portals (February 28^{th} 1932)
<u>Right</u>: view from within outlet portal of Nevada Penstock tunnel showing form-work for Cofferdam being erected by Six Companies (February 28^{th} 1932). The opening through which trucks operated could be closed (by steel gates) in the event of high water (note deposit of silt left by high water on February 10^{th} 1932, which flooded the entire length of the tunnel). 522

Semi-circular (arch) concrete Cofferdams being erected around the portal of Diversion Tunnel (as protection against high water; April 1932) 523



Lower portals of Diversion Tunnels (discharging 73K cubic feet per second flow into the Colorado River; June 16th 1933) 524



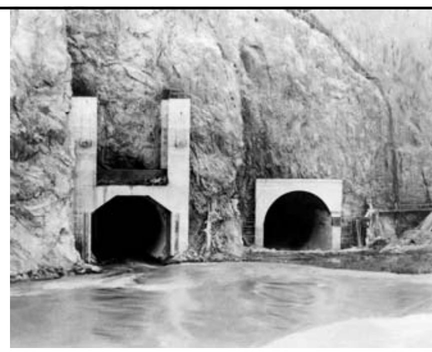
View looking upstream toward lower end of Black Canyon showing outlet portals of all four Diversion Tunnels. Flow of Colorado River was approximately 70Kcfs (June 20th 1933). 525

<u>Left</u>: the period of danger from high water having passed, protecting arch Cofferdam/s were blasted from the lower portals of the Diversion Tunnels, and muck fill was removed (July 1932)
<u>Right</u>: protecting arch Cofferdam has been blasted out, and muck fill removed at the upper portal of Diversion Tunnel No. 1 (pouring of lining in the floor of the tunnel commenced (July 1932)

526

In November 1932, the Diversion Tunnels were complete and a barrier across the inlets of the Arizona tunnels was breached with explosives. Earth and rock were dumped from a trestle bridge to block the river channel forcing the entire flow of water into the tunnels. For nearly two years, the Colorado River flowed unchecked through the Diversion Tunnels. In the fall of 1934, this all changed. Cofferdams were built at the entrances to "inner" tunnels Nos. 2 and 3 (those closest to the river). Concrete plugs 405-feet thick were dovetailed into the tunnels, closing the bores forever. As winter low-water approached, another Cofferdam closed off tunnel No. 1. When this tunnel was plugged, four six-foot diameter holes were left in the plug, each fitted with a gate valve.

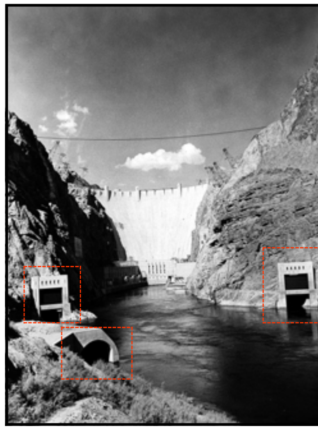
527



Close-up of upper portals of Diversion Tunnels Nos. 3 (inner) and 4 (outer) showing flow in Diversion Tunnel No. 4 (at left, shortly after blast; November 13th 1932) 528

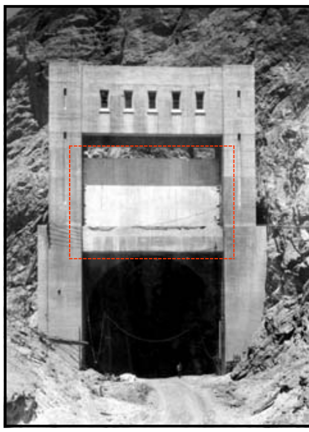
Dumping materials at temporary pile (trestle) bridge to complete diversion of the Colorado River (after blast; November 13th 1932)

529



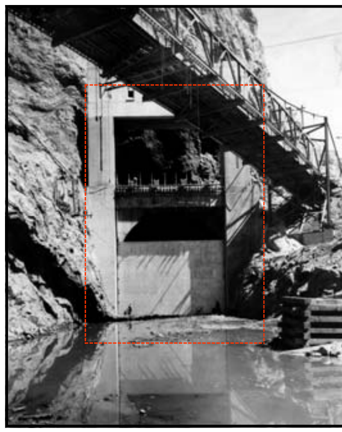
The inlets of the two outer tunnels were permanently closed with 50-foot by 50-foot bulkhead gates (fall of 1934). Each gate (with steel frame) weighs about three-million pounds and required forty-two railroad cars for shipment. At the outlets of the two inner tunnels, 50-foot by 35-foot *Stoney* gates were installed. These gates can be closed when the tunnels need to be emptied for inspections or repairs .

530



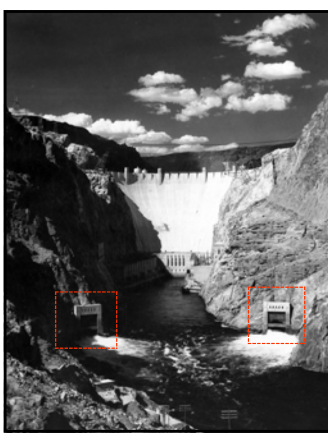
Fifty-foot by thirty-five foot Stoney gate structure at outlet to Diversion Tunnel No. 3 (gate in raised position; June 1934). There is one such gate each side of the river (on the inner Diversion Tunnel portal/s) on the downstream side of the dam (serving the pair of Spillways). On February 1st 1935, the steel gate (weighing more than 1K-tons) was permanently lowered over the entrance to Diversion Tunnel No. 4. By opening the valves (in plug No. 1), sufficient water to meet downstream needs was released (via the inner tunnels) while the waters of the Colorado River began to back up behind Hoover Dam (to form Lake Mead).

531



Final test of fifty-foot by thirty-five foot Stoney gate (at the lower portal of Diversion Tunnel No. 2; April 1933)

532

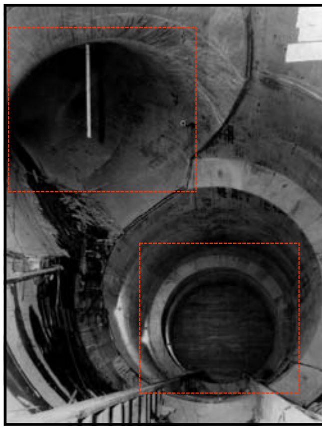


<u>Left</u>: upstream view of the dam and Stoney gates (January 1942)
<u>Above</u>: northwest (cross-canyon view) of the Stoney gate superstructure (on the Nevada side of the River; January 1981)

533

Plugs

534



The inner tunnels were plugged with concrete approximately one-third their length below the inlets, and the outer tunnels were plugged approximately halfway. The two inner tunnels contain thirty-foot diameter steel pipes which connect the Intake Towers in the reservoir with the Penstocks to the power plant and the canyon wall outlet works. The downstream halves of the two outer tunnels were/are used as spillway outlets.

Left: looking upstream toward the upper plug and inclined tunnel (a.k.a. "raise") from Intake Tower (Diversion Tunnel No. 3; May 1934)

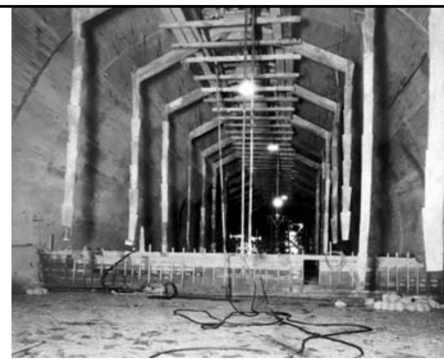
535

Upstream tunnel plug construction in Diversion Tunnel No. 3. This view shows the downstream face of the completed section of the plug with the lower pours of the next lift in place (June 1934)

536

Left: looking upstream in the Diversion Tunnel No. 3 Plug and raise, showing plug concrete in place (cooling headers above and rail extension for moving steel pipes; November 1934).
Above: placing concrete in upstream tunnel plug (Diversion Tunnel No. 2; November 1934)

537



View taken from the upstream end of No. 4 Plug, looking downstream (showing method of pouring; April 1935)

538

Foundation Excavation

539

Left: looking down into the dam foundation excavation (from near Lookout Point on the Nevada rim). This view shows the benching at the sides and the middle gorge (May 1933).
Above: excavating in river bed (April 1933)

540

Left: operations at the downstream end of foundation excavation. (looking downstream towards the Lower Cofferdam; April 1933)
Above: general view looking upstream of foundation excavation (deeper middle channel is shown prior to any disturbance by blasting; April 1933)

541

Drill crews on the Nevada bench of the dam foundation excavation. Fifty-six drills were in operation in this relatively small area (June 1933).

542

Cliffhangers

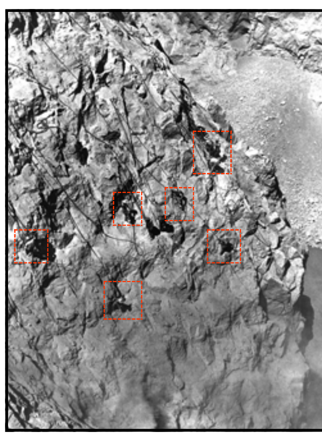
543

In order for the dam to rest on solid rock, it was necessary to remove eroded soil and other loose materials in the riverbed until solid rock was found. Being an “arch-gravity” dam, the canyon’s side-walls bore the horizontal “thrust” of the impounded water in the reservoir exerting its tremendous compressive force against the convex shape of the concrete arch. Thus, to prevent water seepage and provide solid bearing/keying, the side-walls were excavated as well to remove any loose, weathered etc. rock until “virgin” rock was exposed. This required men to hang suspended from ropes along the cliff side/s to loosen the rock with Jackhammers and/or dynamite – they were known as “High-Scalers.” Since the leading cause of accidental death on the BCP worksite were falling objects, the work of the High-Scalers was critical and their death-defying feats became legendary during and after the construction of Hoover Dam.

544

High-Scaler going over the side on the Arizona rim of Black Canyon (left). Millions of years of weather eroded the canyon walls and water (freezing and thawing in cracks and crevices) split the rock. This loose rock had to be removed and it took very special men to do the job. All of them were agile, unafraid to swing out over empty space on slender ropes. It was physically demanding and dangerous work. The men who chose to do this work came from many diverse backgrounds. The risk and high visibility of the job lent it a certain status which appealed to certain types of men. When the foremen weren’t looking, they would swing out from the cliffs and perform stunts for the workers below. Contests were even held to see who could swing out the farthest, the highest, or who could perform the best stunts.

545

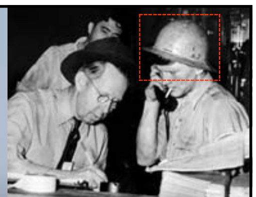


High-Scalers at work (at the location for the Arizona Intake Towers; August 1932). Moving about on the cliffs was difficult and dangerous. Compressed-air hoses, ropes, electrical lines etc. hung down the face of the cliffs. The High-Scalers had to carefully pick their way through the resulting maze. The danger from falling rocks and dropped tools was extreme. In fact, the most common cause of death during the building of the dam was being hit on the head by a falling object.

546

Hard-Boiled Hats

In order to protect themselves from falling rock, the High-Scalers dipped cloth hats in tar and let them harden. After several workers were struck on the head by falling objects while wearing the improvised helmets (a.k.a. "Hard-Boiled Hats") and sustained no serious injuries, Six Companies ordered several thousand commercial "Hard-Hats" for use by their workforce at Hoover Dam. Thereafter, wearing of safety headgear became commonplace at the BCP site (and a standard safety measure on construction sites thereafter).



Left: composite Hard Hat (a.k.a. "Hard-Boiled Hat")
Above: workman wearing a hard hat (talking on the phone)

All In A Day's Work

For several weeks, High-Scaler *Louis* "The Human Pendulum" *Fagan* transported a crew around a projecting boulder on the Arizona side of the canyon. The man to be transferred would wrap his legs around Fagan's waist, grasp the rope, and with a mighty leap they would sail out into the air and swing around the boulder. Fagan then returned for the next man in the crew. This acrobatic commute was accomplished twice a day until the job was finished. By far the most famous feat any of the High-Scalers ever performed was a daring midair rescue. *Burl R. Rutledge* - a USBR engineer performing an inspection, fell from the canyon rim. Twenty-five feet below, High-Scaler *Oliver Cowan* heard Rutledge slip. Without hesitation, he swung himself out and seized Rutledge's leg. A few seconds later, another High-Scaler - *Arnold Parks*, swung over and pinned Rutledge's body to the canyon wall. The High-Scalers held Rutledge until a line was dropped and secured around him and the shaken engineer was pulled, unharmed, to safety.

High-Scaler commemorative coin

In 1995, local sculptor ***Steven Liguori*** and Hoover Dam ***Spillway House*** concessionaire ***Bert Hansen*** decided to create a bronze High-Scaler statue in the likeness of ***Joe Kine***, one of the last surviving High-Scalers. A clear picture of Joe Kine existed showing him in his working environment and was used as a guide to create the bronze figure. Upon completion, the life-size statue was presented to Joe Kine on September 30th 1995; Hoover Dam's sixtieth anniversary. In 1998, Liguori and Hansen discussed the construction of a ***High-Scaler Monument*** dedicated to the builders of Hoover Dam. Once the decision was made to proceed with the project, Liquori set to work making a larger-than-life statue. The statue was placed near the dam's new concession facility; ***The High-Scaler Café*** (at right).

553

Statue of Joe Kine – last of the High-Scalers

554

Controlled Blasting

555

In 1912, the U.S. government ordered the break-up of *DuPont* (which dominated the explosives market in the U.S.) as part of its anti-trust activities. This led to much innovation and competition in the now wide-open explosives industry. In 1913, an industry organization was formed: *Institute of Makers of Explosives* (IME), to inform the public regarding the proper use of explosives, set standards to maintain high/uniform explosive manufacturing standards and gather/distribute information about the industry. The first portable *Seismograph* appeared in 1917 and continued to evolve into the 1920s. The IME launched a blasting cap safety program in 1926 and by the time of the BCP, "Controlled Blasting" methods were in wide use in the construction and mining industries. Using delay primers, the entire blast did not occur in one instant but, rather, was staggered incrementally improving blast results and limiting detrimental vibrations.

556

Blasting canyon walls (left; ca. 1932). Laden with tools and water bags, the High-Scalers would descend the canyon walls with ropes. Jackhammer drills were lowered to them, and powder holes were drilled deep into the rock. The Jackhammers weighed forty-four pounds and had to be maneuvered into position by hand, often with great difficulty. Once the holes had been drilled into the rock, they were loaded with dynamite. After the shot, broken rocks often had to be set free using crowbars.

557

Left: blasting in power plant location/s (in dam foundation excavation and on canyon walls above power plant location). This was the last of the major blasts prior to the beginning of actual concreting operation in the dam structure proper (May 1933).
Above: workmen loading holes with dynamite, in preparation for a blast on a cableway bench excavation (August 1932)

558

Workmen loading hole with dynamite preparatory to blasting (in the Nevada power plant site; March 1934) 559

Grout Curtain

560

To control uplift forces on the finished dam, the underlying bedrock foundation of the dam site was reinforced with a *Grout Curtain*. Holes as deep as 150-feet were drilled into the base and/or side-walls of the canyon and any cavities encountered were filled with grout. This served three purposes;

- Prevented water from seeping under the dam causing uplift (upward water pressure);
- Prevented water from seeping around the dam's rock abutments;
- Stabilized the foundation/side-walls rock;

The work was done under serious time constraints due to pressure to begin pouring the dam's concrete. When the workers encountered cavities and/or hot springs too large to fill, they simply moved on without resolving the situation. Of three-hundred and ninety-three holes encountered, fifty-three (15%) were left incompletely filled during construction. Once the dam was completed and the reservoir began to fill with water, significant leaks began to appear causing the USBR great concern. They determined that the work was done improperly (due to an inadequate knowledge/understanding of the canyon's geology) and incompletely (having left so many voids unfilled with grout). From 1938 to 1947, the USBR very discreetly remedied the situation by drilling new grout holes from the dam's inspection galleries deep inside the dam thus completing the Grout Curtain. 561

Diamond drill crew working on center hole A-4 (located at the approximate center of the inner gorge in the 553 gallery; June 1939)

562

The quantity of water (entering the 553 gallery) exceeded the capacity of the temporary pumps. The excess was collected and delivered to the 647 gallery (June 1939)

563

Close up of drain hole A-4, showing the water pressure present. Two hundred and thirty sacks of cement were injected into five drain holes to stop the leakage (June 1939).

564

Unobstructed flow (from hole A-9) was 225gpm (as measured with a cubic foot box and stop watch; July 1939)

565

Drilling grout hole (December 1940). Drill rods were in ten-foot sections. These sections could be put together, making possible drilling depths of plus 1K-feet.

566

A Damn Big Dam

567

"Now this is just a dam, but it's a damn big dam"
William Henry Wattis – Principal, Utah Construction Company

568

The BCP would require 4.4 million cubic yards of concrete; an unprecedented amount requiring many innovations. The manufacture of *Portland Cement* – the key ingredient in concrete, had improved greatly by the turn of the century with improvements to rotary kilns, ball mills etc. *Wet Kilns* were in use prior to 1928 when the *Grate Pre-Heater Kiln* was first introduced providing a major increase in thermal efficiency. By the 1930s, roller mills were being used in the manufacture of cement. In 1913, the *American Concrete Institute* (ACI) was established (succeeding the *National Association of Cement Users*). By the 1920s, diverse technical committees of the ACI were providing guidelines for evaluation of design and arrangement of site mixing plants/machinery, material handling/delivery and concrete placement/reinforcement/formwork. One such technical committee of the ACI reported (in 1927) on the advantages of "Field Control of Concrete." Recommendations were made on a wide range of topics including:

- **Supervision of all the processes of concrete manufacture;**
- **Quality of constituent materials;**
- **Design of the mixture;**
- **Mixing, placing and curing;**
- **Field Testing**

Central concrete mixing plants first appeared in the 1920s proving quickly their economic viability; the *Ready-Mix* concrete industry was born.

569

A source of aggregate near the BCP site was necessary in order that it would not have to be transported too great a distance. USBR prospecting parties searched the desert around Black Canyon for months, looking for a suitable/adequate supply of aggregate. Eventually, an *Alluvial Lens* (just over six miles upstream on the Arizona side of the river) was chosen as the source. Floodwaters had been depositing stones there for millions of years. Some of the rounded stones were as large as twelve-inches in diameter and had been washed down from as far away as the Grand Canyon. The deposit covered more than one-hundred acres thirty to thirty-five feet deep. A dragline was used to excavate the aggregate and load it into rail cars. The cars hauled the aggregate to a screening and washing plant on the Nevada side of the river at *Hemenway Wash*.

570

BCP *Concrete Consulting Board* at Arizona gravel deposit (January 1931)

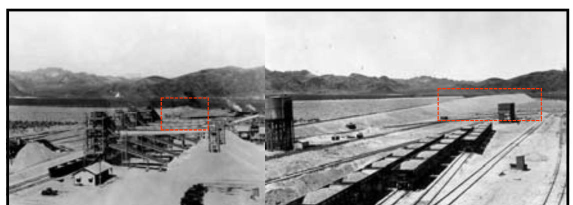
571

Since gravel (aggregate) and sand were the only materials _not_ provided by the federal government, Six Companies had to provide these key ingredients for the concrete mix. Thus, an aggregate washing, classification and storage plant was established (at Hemenway Wash). Aggregate up to nine-inches in diameter was used in BCP concrete. 572

Top Left: Stock piles accumulated during plant test at the Six Companies' gravel screening plant (February 1932)
Top Right: thirty cubic yard/s side dump car (from the gravel pits) dumping into depressed track hopper at the gravel plant (March 1932)
Left: dumping raw aggregate at gravel plant (April 1932) 573

Course aggregate passed through Six Companies' gravel screening and washing plant in test run (February 12th 1932). Concrete consists of four ingredients; sand and stone aggregate, water and Portland Cement. These must be mixed in the proper proportions to yield strong concrete. Aggregate is perhaps the most important of the materials in the concrete because it made up as much as three-quarters (75%) of Hoover Dam's mass. As well, the aggregate must be clean and free of clays, salts and organic matter. 574

Gravel screening plant (view from the crusher bin; April 1932). Live storage of aggregates on the left, screening towers on the right. At the screening plant, four screening towers separated the aggregate into different sizes: _fine, intermediate_ and _coarse_ gravels, and _cobbles_ (three-inches to nine-inches in diameter). Anything over nine-inches was run through a crusher and screened again. The separated gravel and cobbles were transported to the mixing plants by train. 575



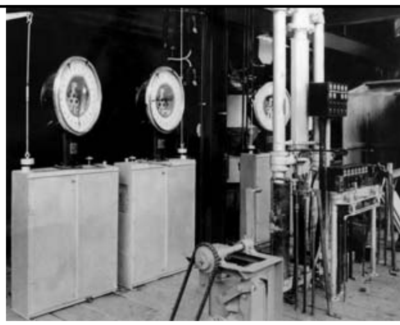
Left: view of the gravel plant, showing the live storage of screened aggregate and sand in the foreground. Storage pile for raw aggregate in the background (March 1932)
Right: raw aggregate storage piles at Six Companies' gravel screening and washing plant (April 1932)

576

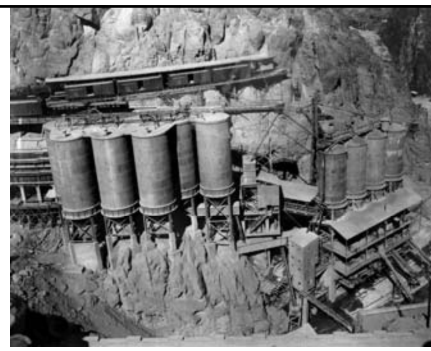
Aggregate bins at Six Companies' Low-Level concrete mixing plant. Conveyor to mixing plant operates from end (at left; Dec. 1931) 577

Sand and coarse aggregate batchers on upper batching deck at Six Companies' Low-Level concrete mixing plant (April 1932)

578



Main batching and mixer control station, Low-Level concrete mixing plant. The operator at this station controlled the discharging of all aggregates, cement and water into two mixers and also controlled the charging and discharging of the two mixers (February 1932). 579



Hi-Mix and cement blending plants (with unloading track and aggregate bins above; April 1934) 580

Aggregate delivery into mixer hopper at Six Companies' High-Level concrete mixing plant, (cement batcher and delivery seen at left; April 1933)

581

Cement batcher assembly over aggregate hopper at the Six Companies' High-Level concrete mixing plant (feed mechanism and lever arm connection to scales seen at top; April 1933)

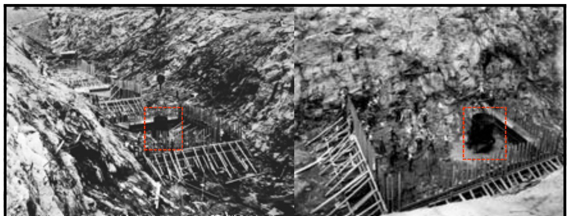
582

With the successful diversion of the river well ahead of schedule, the first concrete pour was made on June 6th 1933. Superintendent Crowe utilized the concept of "High" and "Low" concrete mix batch plants working simultaneously to effectively double the available supply of concrete wherever/whenever needed (efficiently delivered by the aerial cableway). Combined with the year-and-a-half saved on the four Diversion Tunnels, the efficient concrete production/distribution allowed the BCP to be completed two years ahead of schedule. Each plant was capable of mixing 16.5-tons of aggregate with cement and water in one minute allowing 160K cubic yards per month to be delivered to the dam site. On their best day, the plants produced 10,462 cubic yards of concrete. Prior to constructing Hoover Dam, the USBR had used 5.8 million barrels or 23.2 million bags of cement (four bags = one barrel) for all of its twenty-seven year history. Hoover Dam alone would consume 3.25 million cubic yards of concrete.

583

Low-Level (Lo-Mix) Mixing Plant

584



The first bucket of concrete was placed in Hoover Dam at 11:20AM on June 6th 1933. This eight cubic yard batch was placed in Panel J-3 (Elevation 430). The initial concrete required for the dam was mixed in a river-level mixing plant which was located approximately three-quarters of a mile upstream from the dam site This plant (Low-Level) provided the concrete for the linings in the Diversion Tunnels and for the lower levels of the dam. It went into operation on March 3rd 1932. The concrete was loaded into buckets which were transported to the site initially by agitator truck. Eventually, the concrete buckets were transported by electric trains. For the first year of operation, nearly all of the concrete produced at the Low-Level plant; almost 400K cubic yards, went into the linings of the Diversion Tunnels.

585

Left: the Low-Level concrete mixing plant (looking upstream from the cliffs on the Arizona side of the river; March 1932)
Right: looking downstream from the cliffs on the Arizona side of the river at the Low-Level concrete mixing plant (on right; June 1932)

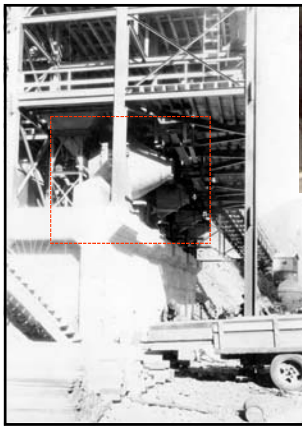
586

Left: view looking downstream at the site of the Low-Level mixing plant. Track hopper and gravel conveyor to mixing plant in the center. Six Companies' locomotives engaged in hauling tunnel muck from the dump hopper (in background; January 1932)
Right: thirty-yard bottom dump gravel cars spotted over the track hopper for the Low-Level concrete mixing plant (March 1932)

587

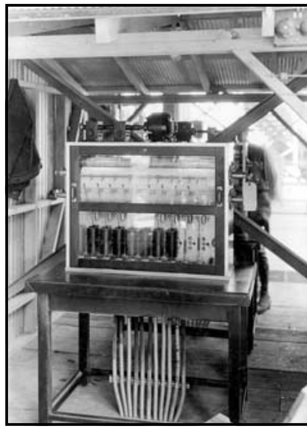
The Low-Level concrete mixing plant nearing completion. Silos for the storage of cement and bunkers for gravel storage were installed in the upper stories (January 1932).

588




Mixer deck at Six Companies' Low-Level concrete mixing plant in Black Canyon (showing battery of (four) Smith four-yard mixers; February 1932)

589



Automatic graphic recording devices at Six Companies' Low-Level concrete mixing plant (April 1932)

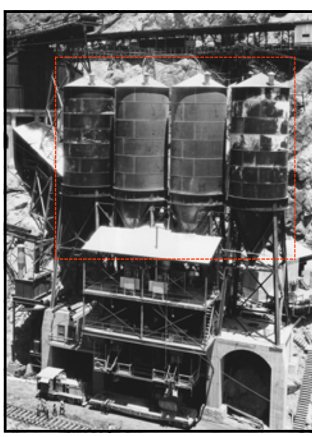
590


Left: unloading cement at Six Companies' Low-Level mixing plant (note that workmen are wearing respirators; May 1932)
Above: agitator truck used to haul concrete from Low-Level concrete mixing plant to forms (March 1932)

591

High-Level (Hi-Mix) Mixing Plant

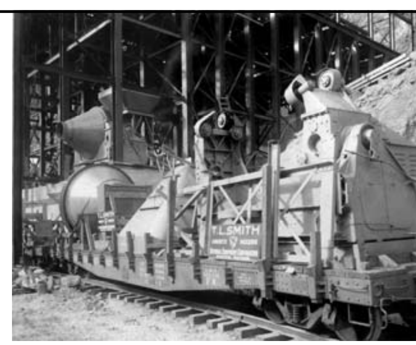
592



As the dam rose in height, a new concrete mixing plant was constructed on the canyon rim. Completely automated, the High-Level plant measured the ingredients then mixed and dispensed the concrete. It was capable of producing twenty-four cubic yards of concrete every three and a half minutes. The Hi-Mix plant was used to produce all of the concrete placed in the dam above the 992 foot level. The ultimate capacity of the plant would be served by a four-mixer installation.

Left: Six Companies' High-Level concrete mixing plant (cement silos for four mixers are shown; June 1933)

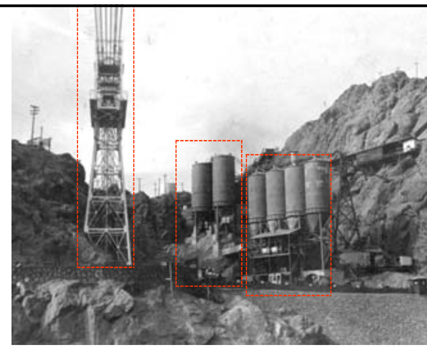
593



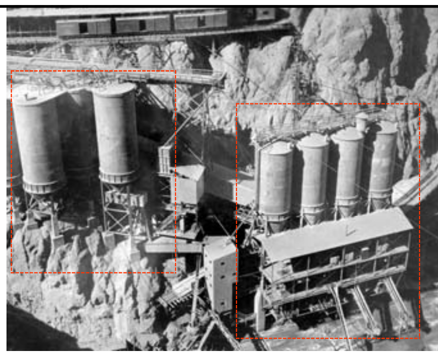
Mixers (for High-Level mixing plant) being unloaded from railroad cars. These mixers were four cubic yards capacity and had a cycle of three-and-a-half minutes for loading, mixing, and discharging (Jan. 1932). 594

Hi-Mix Gulch

595



Looking into "Hi-Mix Gulch" from skip on 150-ton cableway. View shows, left to right: Head-Tower for 150-ton cableway; cement blending plant and High-Level concrete mixing plant (October 1933) 596

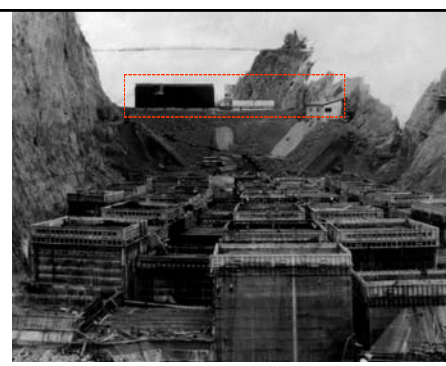


General view of Hi-Mix concrete plant (right) and cement blending plant (with unloading track and aggregate bins above at left; April 1934) 597

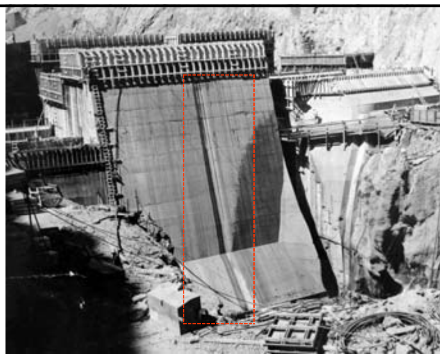
The Big Chill

598

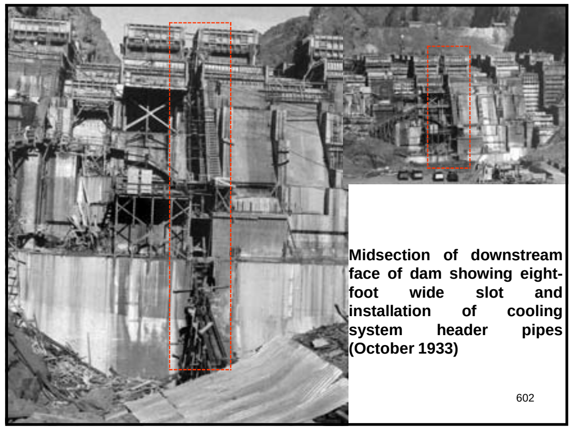
Because concrete heats as it cures (*Heat of Hydration*) due to the chemical combination of water and cement, uneven cooling/contraction posed a major problem at Hoover Dam (concrete has the tendency to cool very slowly and unevenly). USBR engineers calculated that, if the dam was made in one continuous pour, the 3.25 million cubic yards of concrete would require 125 years to cool-down and the resulting stresses and cracks would cause the dam to fail. The solution was to provide cooling during the curing process and cast the concrete in sections rather than as one heterogeneous mass. A total of 230 five-foot high forms averaging 25-feet square on the downstream face and 25x60-feet on the upstream face of the dam would form the wedge shape of the dam. These "concrete blocks" were stacked one atop the other forming vertical columns and cement grout injected into the spaces between the blocks created a monolithic structure. To fill the hairline joints between columns and increase their strength, the joints were grooved. Each five-foot form contained a series of embedded one-inch diameter steel pipes through which first cool river water then ice-cold (42-degrees) water (from the 825-ton capacity refrigeration plant) was run. Without this cooling system, the temperature of the curing concrete would have been 40 degrees higher. Once a block had cured and stopped contracting, the pipes were filled with grout. Concrete work was completed on May 29th 1935. 599



Cooling Tower and Refrigeration Plant (atop crest of the downstream cofferdam; September 1933) 600

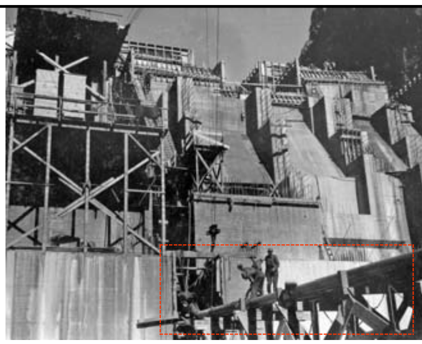


Upstream face of dam structure. The large panel to the left of the eight-foot wide slot for cooling pipe installation is Panel J-1 (Sept. 1933). 601

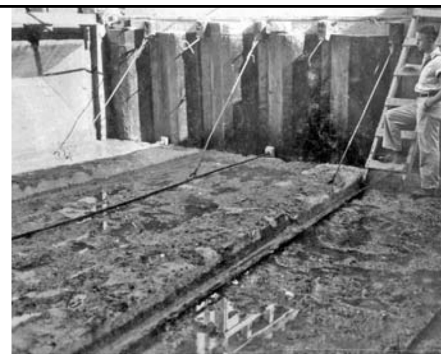


Midsection of downstream face of dam showing eight-foot wide slot and installation of cooling system header pipes (October 1933)

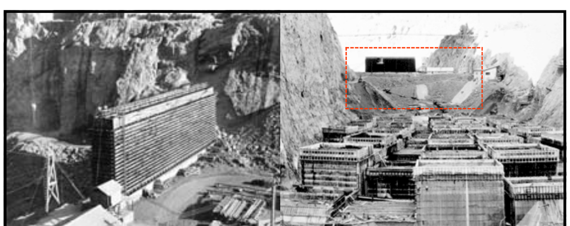
602



Section of downstream face of dam showing installation of cooling system header pipes. Lead lines from refrigeration plant and evaporation tower are seen in lower right (October 1933). 603



Cooling system pipes installed on top of five-foot pour (note horizontal construction joint-key construction joint-key; October 1933) 604



Left: Evaporation Tower for dam concrete cooling system (as seen from the Nevada canyon wall outlet works site; November 1933)
Right: the Evaporation Tower was located on the crest of the downstream Cofferdam (September 1933)

605

Cooling system header pipes in eight-foot wide slot through middle radius of dam structure. View looks downstream through slot at Elevation 680 (November 1933).

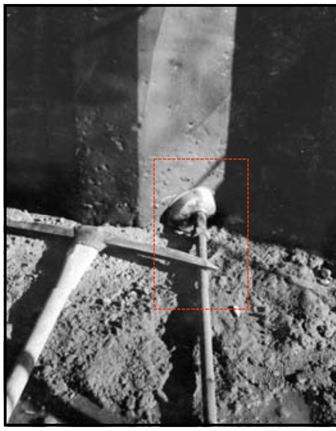
606

Photo showing installation of pre-cooling header pipes in eight-foot wide slot through middle of dam (both the lead and return pipes are shown). Over 582 miles of cooling pipes were placed within the concrete of Hoover Dam (February 1934).

607

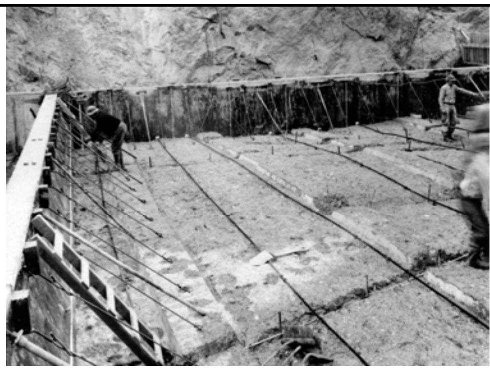
Detail showing connection from header pipe to circulating system in the dam's pre-cooling system (February 1934)

608



Detail showing typical connection of pre-cooling distribution pipes through forms (February 1934)

609



Close up of cooling pipe layout in Panel H3 (February 1934) 610

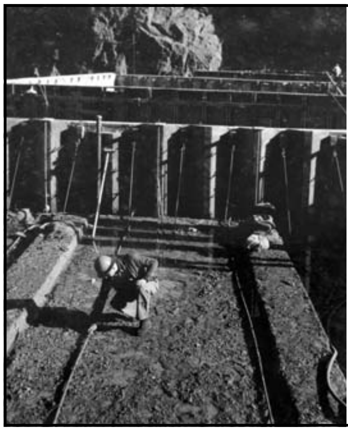
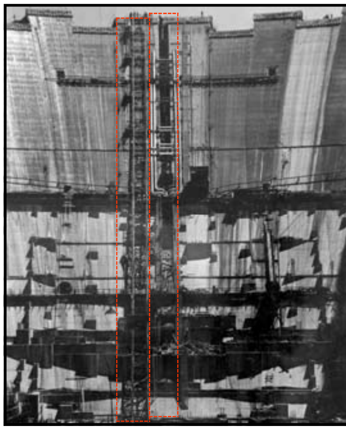


Photo showing the manner in which pre-cooling distribution pipes were installed on top of the concrete pour (March 1934)

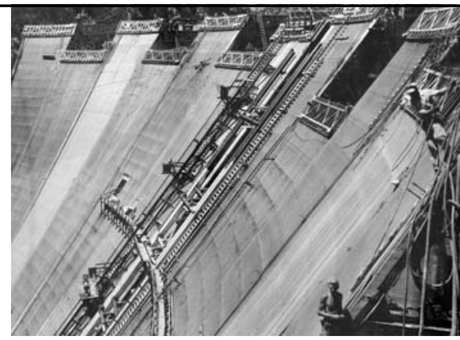
611

Booster pump and pipe connection into dam cooling system (at Elevation 795; April 1934) 612



Middle portion of the downstream face of the dam showing skid-way elevator and cooling system slot with header pipes. Cooling pipes were aluminized to reflect the intense sunlight and heat of Black Canyon (June 1934).

613

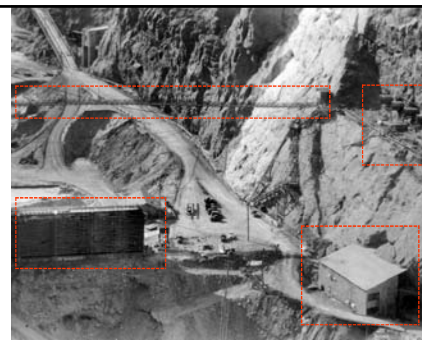


Looking across the downstream face of the dam at top of forms (toward Nevada side). Cooling system header pipes seen in middle (July 1934).

614

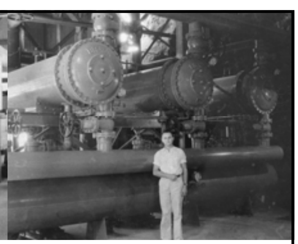
Mid-section of the downstream face of the dam showing eight-foot wide cooling system header slot and header pipes (top forms on dam at Elevation 1170; November 1934)

615



Downstream Cofferdam with view showing low-level suspension catwalk, Nevada canyon wall outlet works and compressor house and evaporation tower for dam cooling system (December 1934)

616

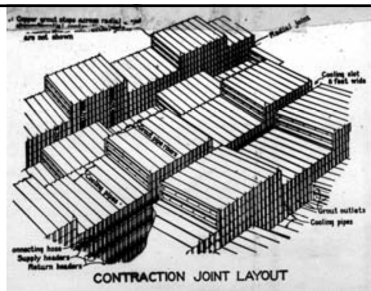


Left: pump units for cooling system (Compressor House; July 1935)
Right: exchange units for cooling system (Compressor House; July 1935)

617

Sealed Tight

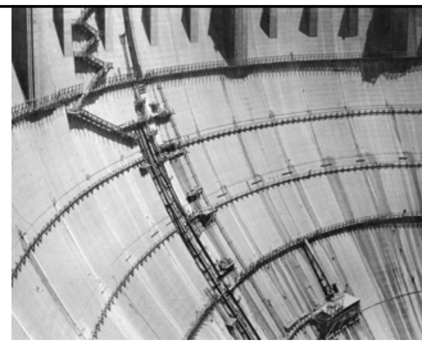
618



To prevent the hairline fissures between the blocks from weakening the dam, the upstream and downstream faces of each block were formed with vertical interlocking grooves (the faces turned toward the canyon walls with horizontal grooves). When the concrete had cooled, grout was forced into these joints, thus bonding together forever the entire structure into a monolithic whole. 619

Detail of construction joint cleanup showing cooling system pipes and horizontal construction joint keys (test pour in Column H-5, Elevation 630; August 1933) 620

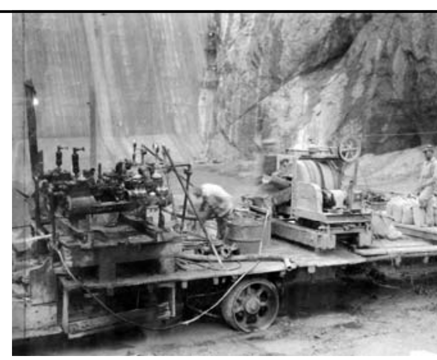
Construction joint (at base of side-wall) along vertical curve transition into inclined Spillway tunnel (Nevada Spillway; September 1933) 621



Upper section of downstream face of dam showing catwalks and grout distribution pipes installed. Elevation 1025 and 1075 grout lines are seen between two construction catwalks (April 1935). 622

<u>Left</u>: valve connection at joint on lower (Elevation 1025) grout line (April 1935) <u>Above</u>: grout line showing catwalk and distribution line with valves (Elevation 1075; April 1935)

623



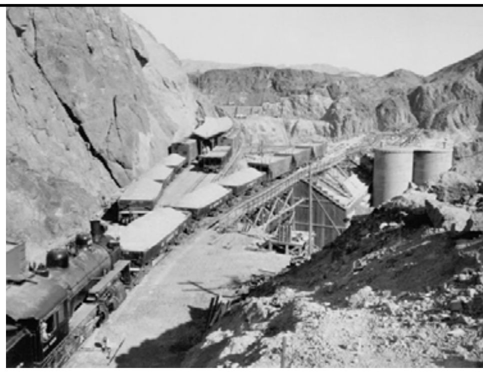
Grout Rig on upstream face of dam. This rig is forcing grout into holes in the Nevada abutment (December 1934). 624

Building Blocks

625

Concrete was delivered to the dam's forms via the aerial cableway with four and/or eight cubic yard capacity buckets. Each (eight cubic yard) full bucket-load held 16.5-tons of concrete and was seven-feet high by nearly seven-feet in diameter (Frank Crowe held two patents for the bucket's design). The buckets were filled at the two batch plants and brought to the site in special railway cars. The aerial cableway picked up the bucket off the railcar and delivered it to whichever specific column was ready for the pour. There were a total of nine cableways used to place the concrete. Five of the cableways were connected to moveable towers which allowed them to be repositioned to work on different parts of the dam when necessary. Since the size of the aggregate varied from pea-sized to nine-inches in diameter (depending on where it was being used in the dam structure), it was critical that the right bucket with the right aggregate be delivered to the right form. Once the bottom of the bucket was released (typically adding one-inch to the concrete level in the form), a team of seven workmen known as "puddlers" manually distributed it by stamping with their feet or with hand and/or power tools (i.e. pneumatic vibrator to prevent air pockets). The dam consumed 3.25 million cubic yards of concrete and an additional 1.11 million cubic yards were used in the appurtenant works (i.e. power plant).

626



Train at concrete mixing plant

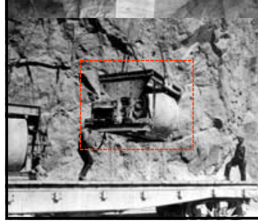
627

Left: eight cubic yard capacity bottom dump bucket used in placing concrete. The dump bottom is in the open (dumping) position
Above: "Puddler" crew at work

628

One of the main problems faced was, that, in order to produce the concrete strength required, a very dry mix had to be used. Thus, there was very little time available to move the concrete from the mixing plant to the dam. If too much time was taken, the concrete would take its initial set still in the dump buckets and would have to be chipped out by hand. For this reason, the men who operated the cableway's cranes (which moved the buckets into place) were some of the highest paid workmen on the project, earning $1.25 per hour. As each bucket was dumped, the puddlers used shovels and rubber-booted feet to distribute the concrete throughout the form and pneumatic vibrators to eliminate voids.

629



Top Left: control tower of 150-ton cableway on Nevada rim of Black Canyon (view from skip on cableway; October 1933)
Top Right: control station for 150-ton cableway.
Left: Cableway handling transit mixers (four cubic yard capacity) for transport into canyon (from High-Level concrete mixing plant via railcar; September 1933)

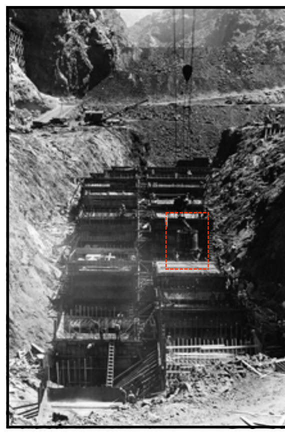
630

Evolution of a Dam

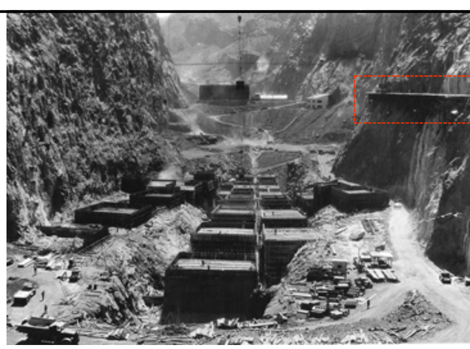
631

632

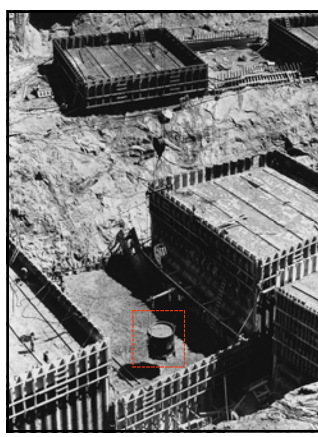
First forms for Hoover Dam (looking downstream; June 1933) 633



__Left__: placing concrete in column forms (near the downstream toe of dam foundation). An eight cubic yard bucket is shown in use (June 1933).
__Above__: bottom row of concrete forms (July 1933) 634



Looking downstream across dam construction (from upstream cofferdam). Trestle over which electric trains operated can be seen against the canyon wall (at right; July 1933). 635



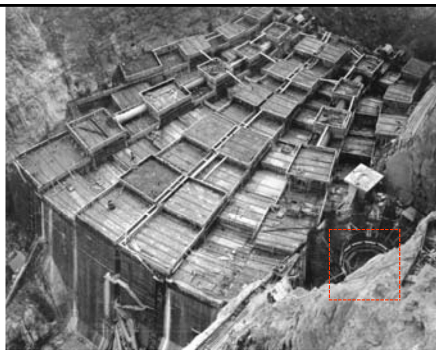
__Left__: concrete bucket being lowered into a form block
__Above__: *Slump Test* (on test pour in Column H-5, between Elevation 630 and Elevation 635). Throughout the main portion of the pour, slumps of between 2-¼” and 3” were maintained (August 1933). 636


Left: washing surface concrete in dam pour using compressed air and water
Right: top surface of test pour in Column H-5 at Elevation 635. Photo was made twelve hours after pour was finished and after surface was given its first washing (September 1933).

637


Left: progress as of August 1933
Above: upstream face of dam structure (as seen from crest of upstream Cofferdam; September 1933)

638



The dam as seen from construction trestle above Nevada Intake Towers (downstream Nevada Intake Tower seen in lower right; Nov. 1933)

639



Top: upstream face of dam (as seen from upstream cofferdam). Top forms at Elevation 715 (December 1933).
Left: Close-up of Hoover Dam. The top blocks are at Elevation 715 (November 1933).

640


Left: view looking along upstream face of the dam (toward Nevada abutment). Top forms at Elevation 735 (December 1933).
Above: upstream face of dam (as seen from the crest of upstream cofferdam). Top forms at Elevation 735 (December 1933).

641

The "One Millionth" bucket of concrete poured into a dam form; January 7th 1934

642


Left: downstream face of the dam (as seen from the crest of the downstream cofferdam). Top forms at Elevation 760 (January 1934).
Above: Arizona side of the downstream face of the dam. Top forms at Elevation 760 (January 1934).

643


Left: brushing top of concrete to remove laitance preparatory to pouring next higher lift (January 1934)
Right: cleaning top of concrete with water under air pressure preparatory to placing next pour (January 1934)

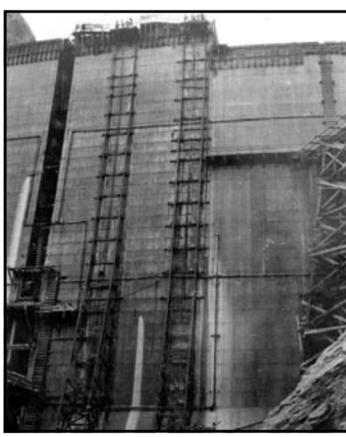
644


Left: middle section of the downstream face of the dam looking toward the Arizona side. Top forms at Elevation 765 (January 1934).
Above: upstream face of the dam (as seen from the crest of the upstream cofferdam). Top forms at Elevation 765 (January 1934).

645


Above: looking across dam structure from Nevada abutment. Top forms at Elevation 785 (February 1934).
Left: downstream face of the dam (as seen from crest of downstream Cofferdam). Top forms at Elevation 785 (February 1934).

646

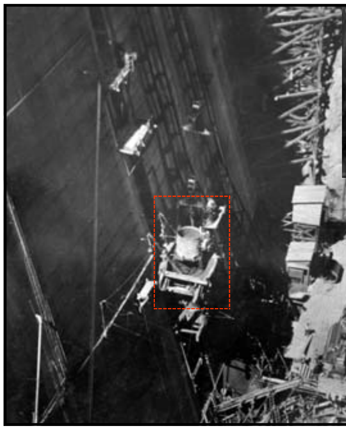



Left: middle-section of the upstream face of the dam showing eight-foot wide middle slot and passenger and material elevators. Top forms at Elevation 790 (February 1934).
Above: upstream face of dam (as seen from the crest of upstream Cofferdam - near Arizona side). Top forms Elev. 790 (February 1934).

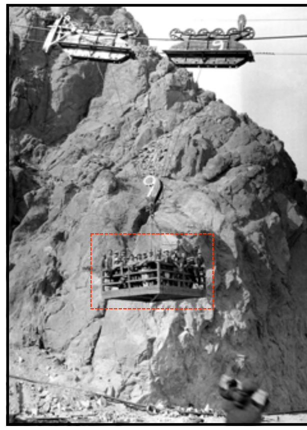
647


Upstream face of dam structure (as seen from cableway skip operating between Intake Towers). Top forms at Elevation 810 (March 1934).

648




Left: placing concrete in middle cooling pipe slot from upstream face of dam using eight cubic yard capacity bucket (via cableway and crane; March 1934)
Above: looking downward at upstream face and top of dam structure from railway trestle of Nevada Intake Towers (downstream tower seen in lower right). Top forms at Elev. 825 (March 1934). 649



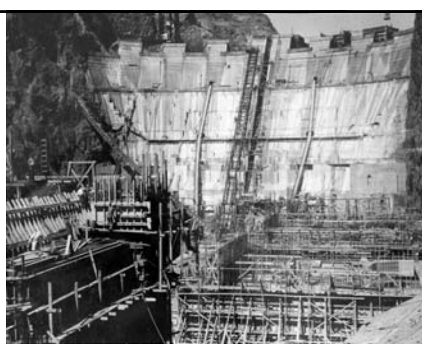

Left: workman going on shift in cableway skip
Above: workmen raising forms from one pour to the next higher pour on dam structure (April 1934)

650

651

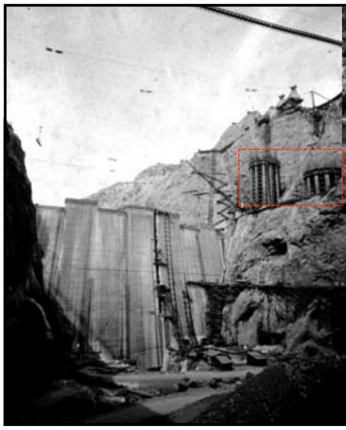

Left: progress as of April 1934 (note the trapezoidal shape of the dam)
Above: view (as seen from cableway) from the Arizona side. Top forms at Elevation 845 (April 1934).

652



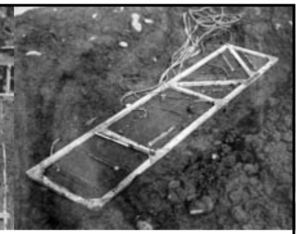
Downstream face of dam structure (looking across Powerhouse construction from downstream Cofferdam near Arizona side). Top forms of dam at Elevation 855 (April 1934). 653


Left: the dam as seen from Look-out Point on the Nevada rim of Black Canyon. Top forms at Elevation 865 (April 1934).
Above: upstream face and top of dam (as seen from high point on the Arizona rim of canyon above the upstream Cofferdam). The downstream Nevada Intake Towers seen in upper right. Top forms on dam at Elev. 865 (April 1934). 654




Left: view showing the upstream face of the dam and the Nevada Intake Towers above (right). Top forms at Elevation 880 (May 1934).
Above: downstream face of dam and Powerhouse (looking upstream from the downstream Cofferdam; May 1934)

655

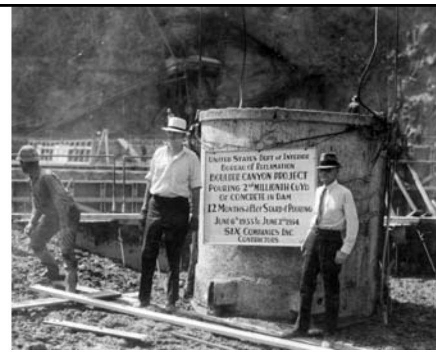



Left: installation of *Strain Meters* (in Panel J-7 at Elevation 900). Photograph shows the digging of the trench in newly poured concrete (meters in cases and cables seen at lower right; May 1934).
Right: installation of Strain Meters (in Panel J-7 at Elevation 900). Photograph shows the meters in position as determined by use of a template (May 1934).

656

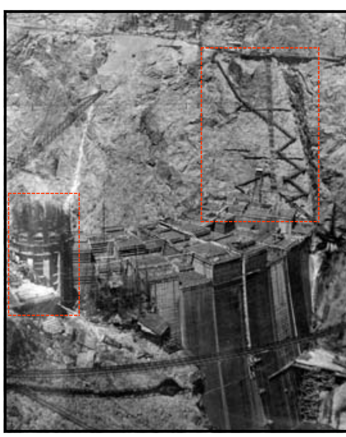

Left: installation of Strain Meters (in Panel J-7 at Elevation 900). Photograph shows the meters in position with template removed (May 1934).
Right: installation of Strain Meters (in Panel J-7 at Elevation 900). Photographs shows the backfilling of the trench in the newly poured concrete by hand methods (May 1934).

657



Pouring the "Second-Millionth" cubic yard of concrete; June 2nd 1934

658




Left: view from high point upstream (on Arizona rim). Arizona Intake Towers are seen at left. Top forms of dam at Elevation 935. "Monkey Slide" (top-right, atop Nevada abutment; June 1934).
Above: general view looking upstream through Black Canyon (from point on lower portals construction road). The top forms of dam are at Elev. 935 (June 1934)

659


Left: looking across top forms of dam from Arizona side with Nevada Intake Towers in background (July 1934)
Right: upstream face of dam (as seen from the upstream Cofferdam). Top forms at Elevation 955 (July 1934).

660


<u>Left</u>: downstream face of dam and Powerhouse construction (as seen from low-level catwalk). Top forms on dam at Elevation 990 (August 1934).
<u>Above</u>: Powerhouse wing/s construction (as seen from the crest of the dam; July 1934)

661


<u>Left</u>: progress as of August 1934
<u>Above</u>: general view looking upstream through Black Canyon (from point on construction road into lower portals). Top forms on dam at Elevation 1055 (September 1934)

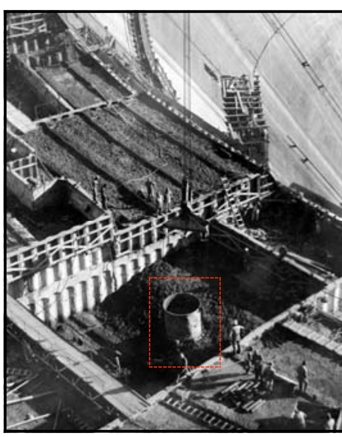
662


<u>Left</u>: Nevada side of the upstream face of dam (as seen from the upstream cofferdam). Top forms at Elevation 1055 (October 1934).
<u>Above</u>: The downstream face of the dam and a portion of the Powerhouse (as seen from the low-level catwalk). Top forms on dam at Elevation 1055 (October 1934).

663


<u>Left</u>: night view of the downstream face of the dam and operations in power plant (from crest of downstream Cofferdam; October 1934)
<u>Right</u>: looking across top of dam from Nevada abutment. (Arizona Intake Towers in background). Top forms at Elevation 1060 (October 1934).

664




<u>Left</u>: pouring concrete in the dam forms at Elevation 1100 (downstream face of the dam seen in upper right; October 1934)
<u>Above</u>: top workings of dam as seen from the break in the Nevada abutment. High forms at Elevation 1100 (October 1934)

665


<u>Left</u>: top workings of the dam and Nevada Intake Towers (as seen from break of Arizona abutment. Top forms at Elevation 1125 (November 1934).
<u>Above</u>: view from hill (on Nevada side of Black Canyon) showing upstream face of dam, Nevada Intake Towers and Nevada Spillway. Top forms on dam at Elevation 1165 (December 1934).

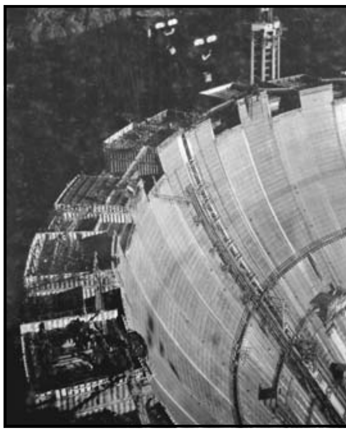
666

Placing the "third-millionth" cubic yard of concrete in Hoover Dam; December 5th 1934

667

Left: view from hill on Nevada side of Black Canyon (showing upstream face of the dam, Nevada Intake Towers and Nevada Spillway. Top forms on dam at Elevation 1170 (December 1934).
Above: general view looking upstream through Black Canyon (from point on construction road into lower portals). Top forms on dam at Elevation 1170 (December 1934).

668

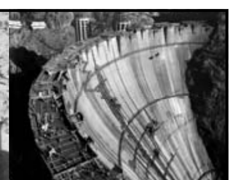


Left: top workings on dam at Elevation 1185 (as seen from high point on Nevada rim (above break in abutment; December 1934)
Above: view from hill on Arizona side of Black Canyon (showing upstream face of dam and Intake Towers). Top forms on dam at Elevation 1185 (December 1934).

669

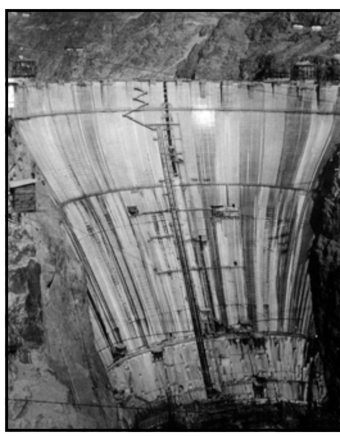
Downstream face of dam (top forms; January 1935)

670



Left: the upstream face of the dam and the two downstream Intake Towers (as seen from Arizona rim of Black Canyon). Top forms at Elevation 1232 (February 1935).
Above: looking down on top of Hoover Dam (note the bucket pouring the roadway on "R" block (at Elevation 1232; February 1935)

671

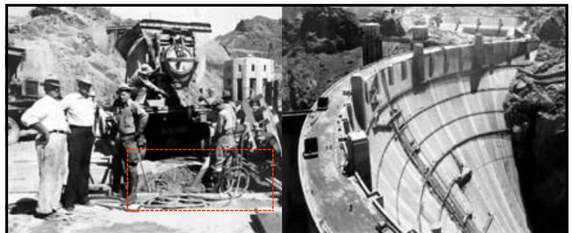


Left: downstream face of the dam as seen from Look-out Point (on the Nevada rim of Black Canyon). Top forms on dam at Elevation 1235 (February 1935).
Above: looking down on the dam (showing the finished roadway, and the intake bridge girders in place (March 1935).

672

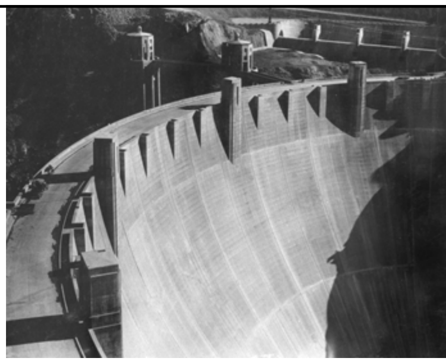
Looking upstream from the lower portal road (April 1935)

673



<u>Left</u>: on the crest of Hoover Dam; May 29th 1935 (looking toward the Nevada side). Photo shows final pour in the eight-foot wide center slot, which essentially completed the concrete work for Hoover Dam.
<u>Right</u>: view of Hoover Dam (from the Nevada side). The road, towers and parapets are complete (June 1st 1935).

674



Crest of Hoover Dam (Elevation 1244) as seen from high point above the Nevada abutment (December 1935)

675

A Work for the Ages

676

Concrete cores were taken in 1995 for testing finding: *"Hoover Dam's concrete has continued to slowly gain strength…a durable concrete having a compressive strength exceeding the range typically found in normal mass concrete."* Because non-reactive aggregate was used, the concrete of Hoover Dam is not subject to *Alkali-Silica Reaction* (ASR) which can/does cause deterioration in concrete structures such as occurred at downstream *Parker Dam*.

677

Hoover Dam was the first man-made structure to exceed the masonry mass of the *Great Pyramid of Giza* in Egypt. The dam contains enough concrete to pave a highway sixteen- feet wide and eight-inches thick from San Francisco to New York City. The dam is 726.4 feet (from foundation rock to the roadway on the crest of the dam). The towers and ornaments (on the parapet) rise 40-feet above the crest. Hoover Dam weighs more than 6,600,000-tons and can resist a maximum water pressure (at the base of the dam) of 45K pounds per square foot (a concrete arch-gravity dam carries the water load by both gravity action and horizontal arch action). There are 4,360,000 cubic yards of concrete in the dam, power plant and appurtenant works (3.25 million in the dam alone). Approximately 160K cubic yards of concrete were placed in the dam each month. Peak placements were 10,462 cubic yards in one day and slightly over 275K cubic yards in one month. The daily demand for cement during construction of the dam was from 7,500 to 10,800 barrels (+5,000,000 barrels was required for the project). Concrete placement in any one block was limited to five feet in 72 hours. The refrigeration plant could produce 1K-tons of ice in 24-hours. Cooling was completed in March 1935. Additionally, 410K linear-feet of grout and drainage holes were drilled and 422K cubic feet of grout were placed under pressure. More than 5,500,000 cubic yards of material was excavated and another 1,000,000 cubic yards of earth and rock fill placed.

678

Part 5

The Power to Serve

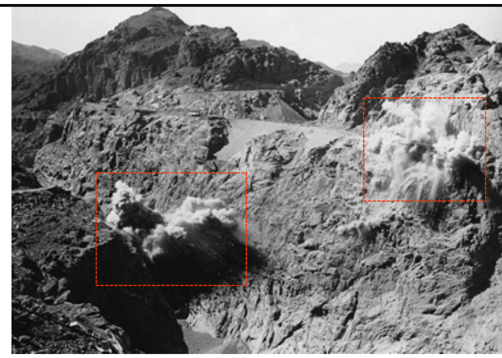
679

Intake Towers

680

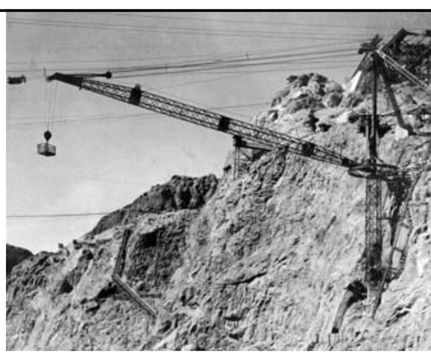
The Intake Towers are four reinforced-concrete structures located above the dam (two on each side of Black Canyon). The outside diameter of each tower is 82-feet at the base, 63-feet, 3-inches at the top with a uniform inside diameter of 29-feet. Each tower is 395-feet high and controls one-quarter of the supply of water for the power plant turbines. All four towers contain 93,674 cubic yards of concrete and 15,299,604 pounds of steel.

681



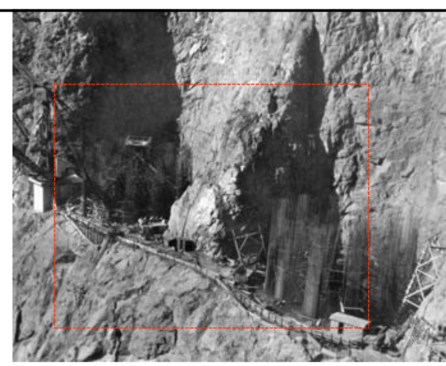
Blast/s being fired simultaneously in Arizona and Nevada Intake Tower location/s (October 1932)

682



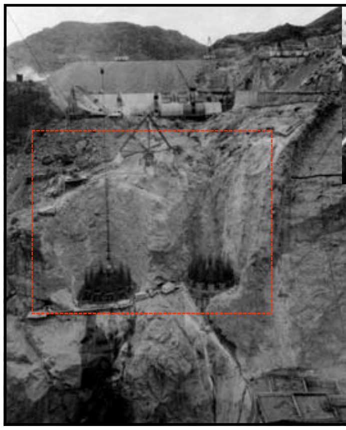
Twelve-ton capacity crane erected by Six Companies to handle concrete and materials for Nevada Intake Towers and outlet raises (September 1933)

683



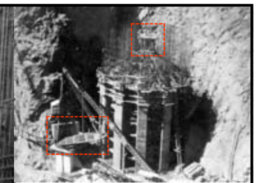
Nevada Intake Towers construction showing reinforcing steel in place at tower bases (December 1933)

684



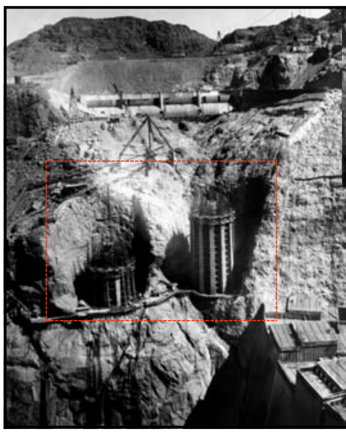
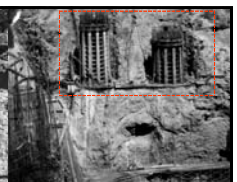

Left: view of Arizona Intake Towers and Spillway (from Nevada Hi-Mix Trestle; February 1934)
Above: Arizona Intake Towers (December 1933)

685

Left: construction progress on Nevada Intake Towers. Upstream tower at right shows lower concrete section and steel bar reinforcement (February 1934).
Above: Nevada Intake Towers under construction. Concrete was dumped into the central hopper (at top) and chuted into pier or fin forms. The crane seen on rim is the 20-ton capacity installation used in handling dam concrete (March 1934).

686

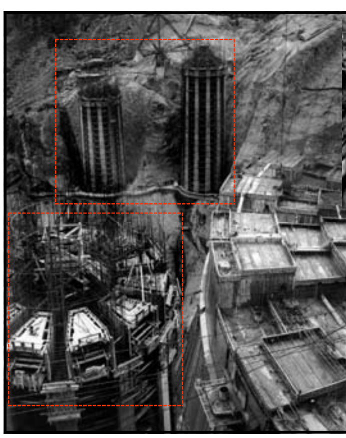
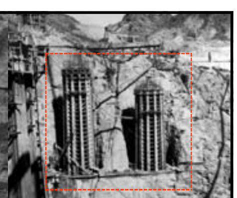



Left: Arizona Intake Towers (from the Nevada side; May 1934)
Above: Nevada Intake Towers (from the Arizona side; May 1934)

687

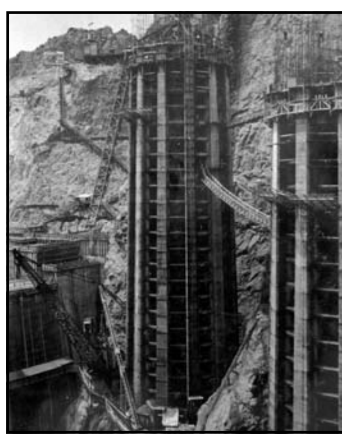

Left: close-up view of the Arizona Intake Towers (from the High Catwalk; July 1934)
Above: Close-up of No. 3 Arizona Intake Tower (showing the cylinder gates being installed; July 1934)

688

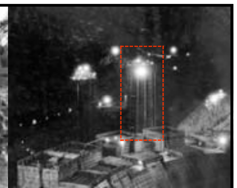
Left: Arizona Intake Towers (from the Nevada side). Nevada Intake Tower No. 5 in lower-left foreground, with upstream face of Dam shown at right; August 1934)
Above: Nevada Intake Towers (from the Arizona side, upstream face of Dam to left; August 1934)

689




Left: Nevada Intake Towers (as seen from the high-level catwalk).. Top of downstream tower (left) at Elevation 1135 (August 1934).
Above: looking from the Arizona side (toward the Nevada side) showing all four Intake Towers, three derricks, Dam (to the left) and the Nevada Spillway (upper right; September 1934)

690

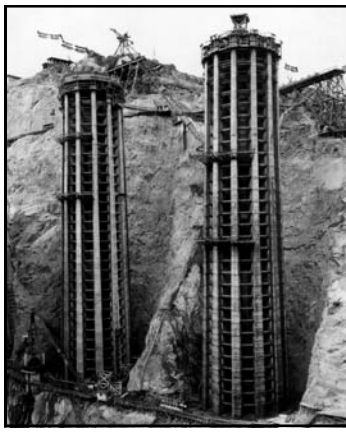


<u>Left</u>: Nevada Intake Towers (from the Arizona side; October 1934)
<u>Above</u>: night operations (looking across dam toward Arizona Intake Towers from Nevada rim; October 1934)

691

View looking upstream along Arizona canyon rim (showing the Arizona Intake Towers; November 1934)

692



<u>Left</u>: Nevada Intake Towers (view taken from the high catwalk; November 1934)
<u>Above</u>: Arizona Intake Towers (as seen from upstream Cofferdam). The twelve-ton capacity crane (at center; Dec. 1934).

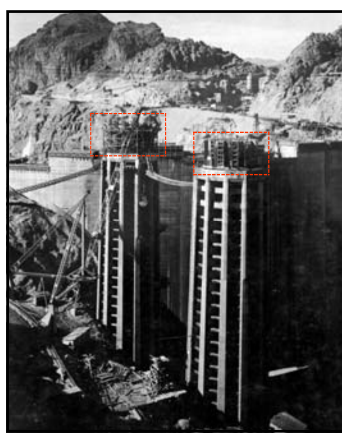
693

Upstream face of Dam and the Arizona Intake Towers (January 1935)

694

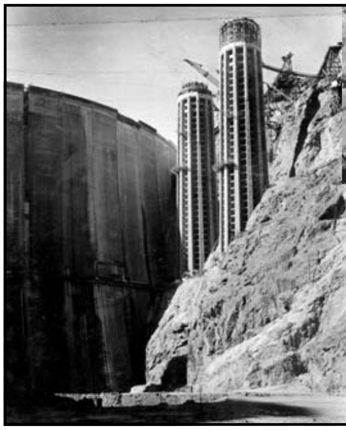
Upstream face of Dam and the Nevada Intake Towers (January 1935)

695



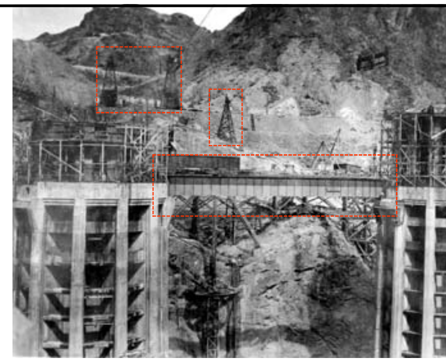
Arizona Intake Towers (as seen from Arizona rim of Black Canyon). Towers were topped out at Elevation 1232 (work on the tower/s' superstructures in progress; February 1935).

696



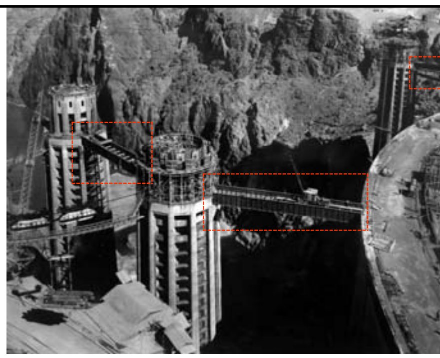
Left: Nevada side of the upstream face of the dam and Intake Towers (as seen from crest of upstream Cofferdam; February 1935). Above: all four Intake Towers and the upstream face of Hoover Dam (taken from the Arizona side; March 1935)

697



Double cableway hook-up placing bridge beam between Nevada Intake Towers (March 1935)

698

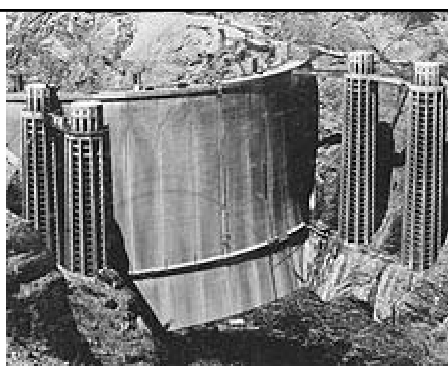


Looking upstream toward the Nevada Intake Towers (showing the Intake Bridge Girders in place; March 1935).

699

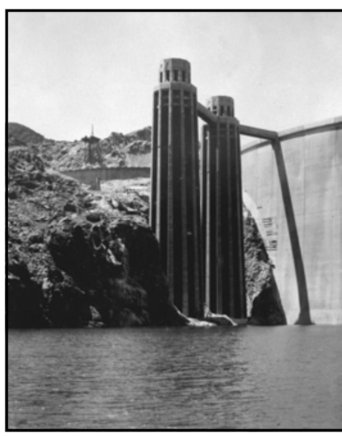
Left: the Arizona Intake Towers (as seen from point near Arizona dam abutment; May 1935) Above: all four Intake Towers and the upstream face of Hoover Dam (taken from the Arizona side; April 1935).

700



The upstream face of Hoover Dam slowly disappears as Lake Mead fills (looking downstream from the Arizona rim; May 1935)

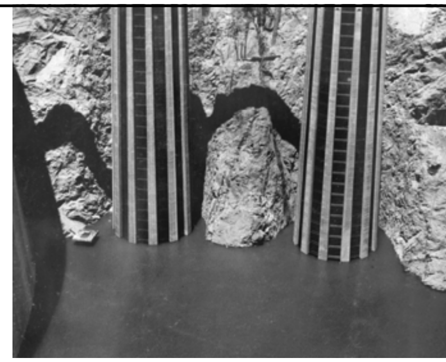
701



Arizona Intake Towers (as seen from surface of reservoir). Water surface at Elevation 884. Base of Intake Towers at Elevation 895 (June 21st 1935). Filling of the reservoir (Lake Mead) began on February 1st 1935, before the last concrete for the dam was poured (on May 29th 1935).

702

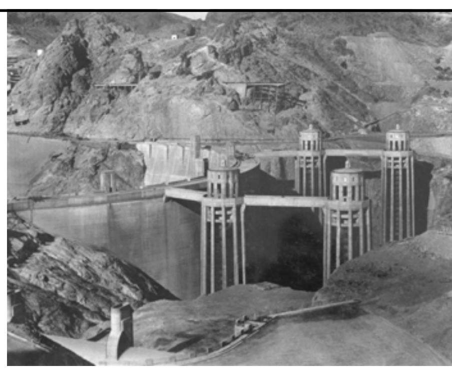
Riverbed immediately downstream from outlet of Diversion Tunnels during time when entire flow of river was being retained in reservoir (February 1935) 703



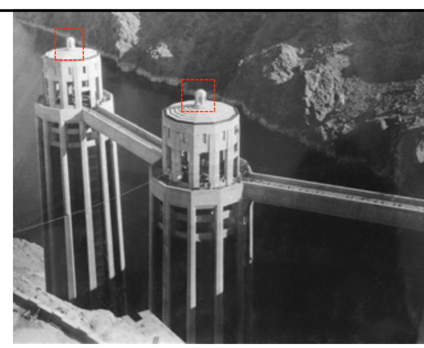
Base of Nevada Intake Towers with water surface at Elevation 913 (July 1935) 704

Hoover Dam and Intake Towers (from the Arizona side; August 1935) 705

Looking downstream (from the Nevada side) showing Hoover Dam, spillways, Intake Towers, etc. Note the general clean-up and road work; also the Intake Tower lanterns in place (September 1935). 706



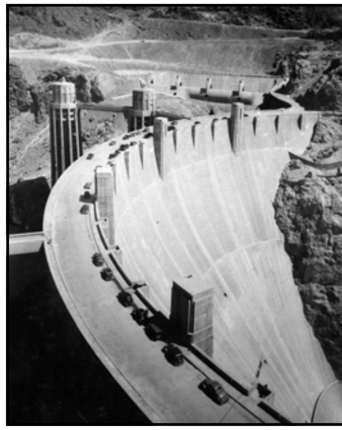
View looking across dam and Intake Towers (from saddle on Arizona Spillway; December 1935) 707



Nevada Intake Towers (as seen from point above Nevada abutment). View shows connecting bridges and aluminum lanterns on roof (December 1935). 708

View looking downstream of the reservoir, Intake Towers, and Spillways (March 1936). The reservoir surface was near its lowest stage preceding the spring runoff of 1936

709

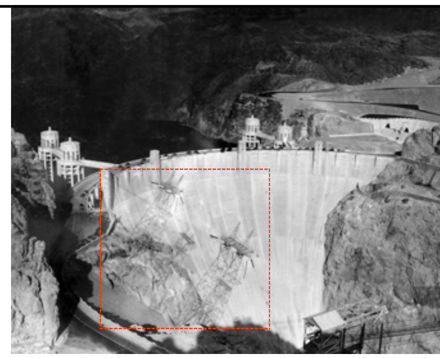


Top of dam, Arizona Intake Towers and Arizona Spillway (from Nevada rim; May 1936).

710

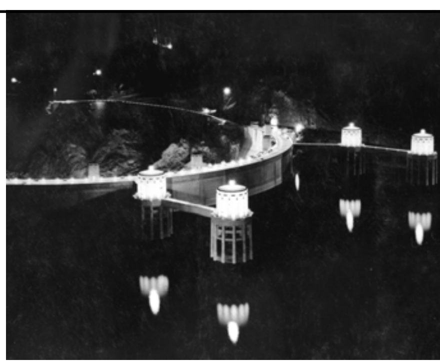
<u>Left</u>: the Arizona Intake Towers as seen from the crest of the dam (September 1936).
<u>Above</u>: Boulder Canyon. Looking upstream from the top of Hoover Dam. Arizona Intake Towers at left (April 1938).

711



Boulder Canyon. Hoover Dam, Intake Towers and the rim towers (for Units N-1 to N-4). View form the Elks' *Flag Pole Point* (April 1938)

712



The Intake Towers of Hoover Dam are reflected like giant candles by the rising waters of Lake Mead (May 1940).

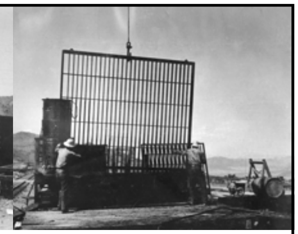
713

Outlets

714

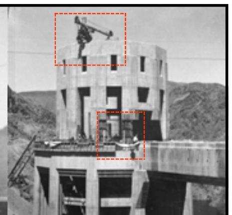
Before water from Lake Mead reaches the turbines, it enters the four Intake Towers and from there enters four gradually narrowing *Penstocks* which funnel the water down towards the powerhouse. The intakes provide a maximum hydraulic head (water pressure) of 590-feet as the water reaches a speed of about 85mph. The entire flow of the Colorado River thus passes through the seventeen generator's turbines. Thirty-foot diameter penstocks were installed in 37-foot and 50-foot diameter concrete-lined tunnels. The upstream Intake Towers were connected to the inner Diversion Tunnels by 37-foot-diameter inclined tunnels (37-foot-diameter tunnels also connect the downstream Intake Towers to Penstocks and *Outlet Works*). Water flow is controlled through two cylindrical gates, each 32-feet in diameter and 11-feet high. One gate is near the bottom and the other near the middle of each tower. The gates are protected by *Trashracks*. Total weight of the gates is 5,892,000 pounds; the Trashracks weigh 7,024,000 pounds.

715

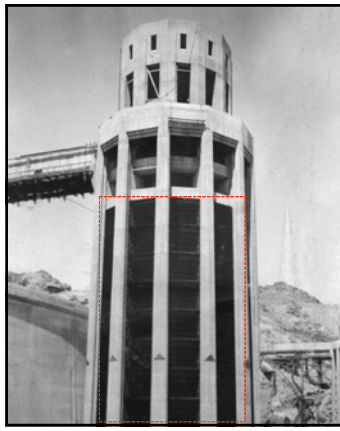
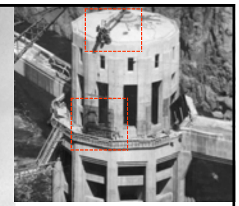
Left: Intake Tower Trashrack steel stock-piled in Boulder City storage yards prior to coating (May 1935)
Right: Intake Tower Trashrack steel being given final pitch coat (unit has already received primer coat; June 1935)

716

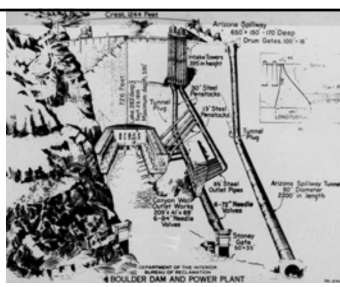
Left: showing manner in which Intake Tower Trashrack units were lowered into place through slots in floor Intake Tower superstructure (June 1935)
Above: lowering Intake Tower Trashrack steel into place by means of crane operating from roof of tower (through slot; June 1935)

717

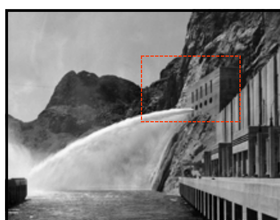
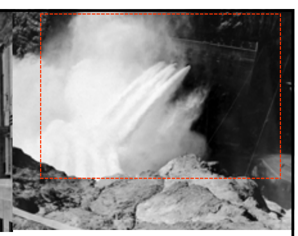
Left: mid-section view of upstream Arizona Intake Tower showing Trashrack steel in place (June 1935)
Above: top of downstream Nevada Intake Tower showing installation of Trashrack steel. Handling rig traveled from center of top of tower to slot position (June 1935).

718



Scaled drawing showing details of the dam; particularly the Penstocks and tunnels. Four 68-inch *Jet Flow Gates* (inner diversion tunnel plug outlet) and two 90-inch Jet Flow Gates (each in the Arizona and Nevada canyon wall Outlet Works – a.k.a. "Valve Houses") provide outlets. The Jet Flow Gates in the canyon walls are about 180-feet above the river. The gates were designed to bypass water around the dam under emergency or flood conditions, or to empty the Penstocks for maintenance work.

719

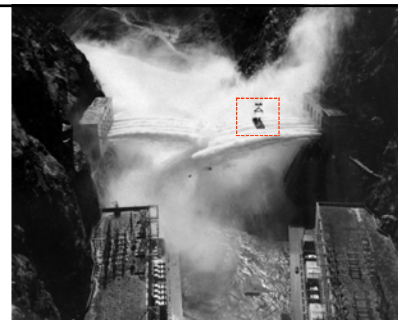



Jet Flow Gates are devices designed to operate under high-pressure. They include a steel plate that can be raised or lowered to either prevent or allow water to be discharged from a structure (much like the faucet in a sink controls the flow of water from the outlet). The eight gates in the lower Valve House/s are 68-inches in diameter and each is capable of discharging approximately 3,800cfs (28,424 gallons per second). When a gate is closed, the force of the water behind it is 248psi, (900,736 pounds per gate) The four gates in the upper Valve House/s are 90-inches in diameter and each is capable of discharging approximately 5,400cfs (40K gallons per second).

720

Twelve obsolete needle valves were replaced with new Jet Flow Gates in the outlet works at Hoover Dam to meet criteria that requires the dam to release 73Kcfs without using the Spillways. Previously, the Outlet Works had a release capacity of about 50Kcfs (one cubic foot equals 7.48 gallons). In June 1998, a "Jet Flow Test" was performed in order to obtain water release data from the new Jet Flow Gates and ensure there was no loss of efficiency to the generators during their operation. The speed of the water coming out of each of the lower gates (at maximum flow) was calculated at 120mph. At maximum opening, each gate discharged about 28,424 gallons of water per second. The upper gates are situated 180-feet above the river. Water from the gates shoots across the canyon to strike the wall on the other side. The water exits the gates at 120 feet per second (83mph).

721

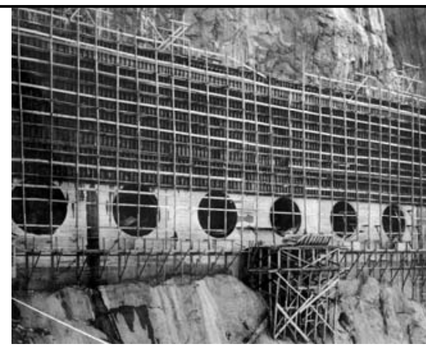


Looking downstream from the crest of Hoover Dam showing water flowing from all of the canyon wall Outlet Works' valves (both sides, full force). Radio newspaper, and newsreel men are being lowered on the cableway skip for a close-up view (September 28th 1940).

722

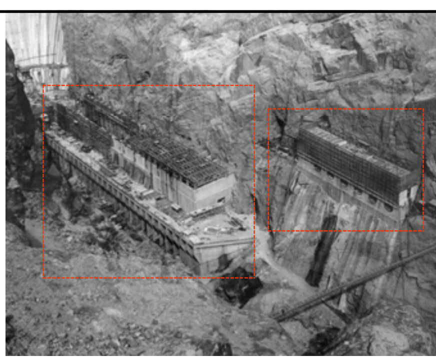
__Left__: view of the Nevada canyon wall Valve House showing all of the 84-inch needle valves open (September 28th 1940)
__Right__: a few visitors braved the spray on the central section Powerhouse ramp to watch the Valve Houses' needle valves in full operation (September 28th 1940)

723



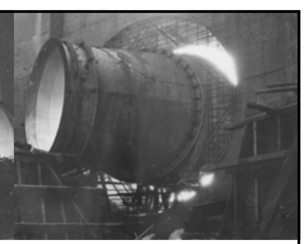
Nevada canyon wall Outlet Works construction (as seen from low-level catwalk). Lower section of forms stripped away showing discharge cone outlets (March 1935).

724



Arizona wing of Powerhouse (left) and Arizona canyon wall Outlet Works structure (right). As seen from the Nevada rim downstream from dam (May 1935).

725

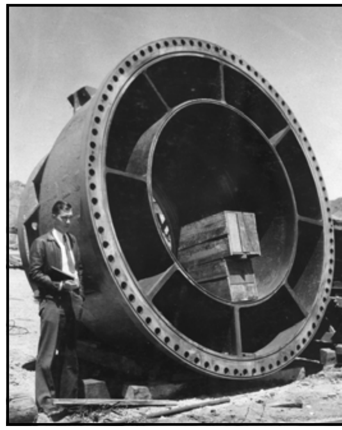


__Left__: portion of front wall of Nevada canyon wall Outlet Works structure showing discharge guide tubes for 84-inch balanced needle valves (July 1935)
__Right__: discharge guide tube for 84-inch balanced needle valve (July 1935)

726

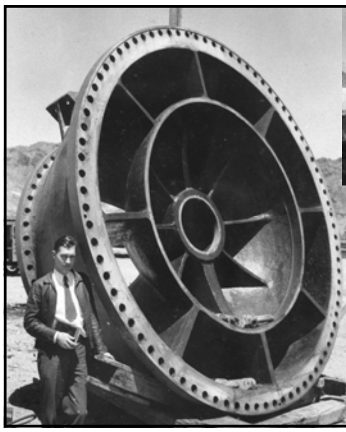
<u>Left</u>: intake end of needle for 84-inch balanced needle valve (on flat car in storage yard near Hoover Dam; May 1935)
<u>Above</u>: side view showing outlet end of needle for 84-inch balanced needle valve

727



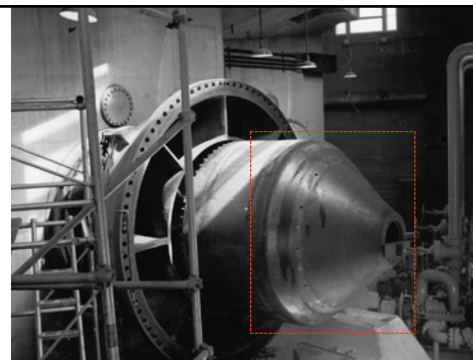
<u>Left</u>: interior structure of 84-inch balanced needle valve nose casting (view of middle joint face; May 1935)
<u>Above</u>: nose casting for 84-inch balanced needle valve (on flat car in storage yard near Hoover Dam; May 1935)

728



<u>Left</u>: interior structure of 84-inch needle valve body casting. (view of middle joint face; May 1935)
<u>Above</u>: body casting for 84-inch balanced needle valve (on flat car in storage yard near Hoover Dam; May 1935)

729

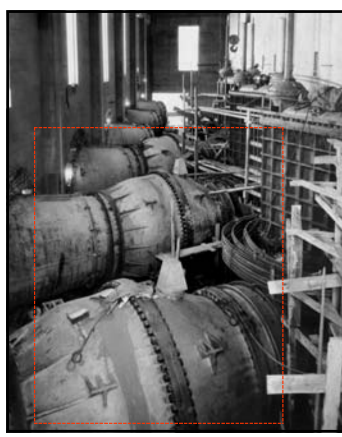


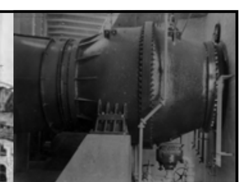
Needle valve N2 (with the front half of the body removed and the needle still in place; February 1978)

730

<u>Left</u>: needle valve model
<u>Above</u>: body points for 84-inch balanced needle valves (on flat car in storage yard near Hoover Dam; May 1935)

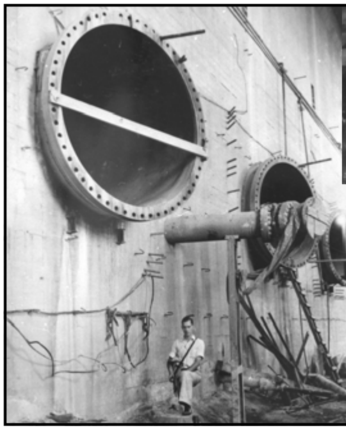
731

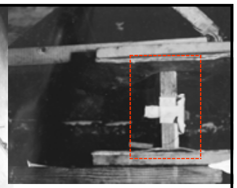




<u>Left</u>: looking upstream in the Arizona Valve House. Note three gates and needle valves have been installed (September 1935).
<u>Above</u>: 84-inch diameter internal differential needle valve in place in the Nevada Valve House (May 1936)

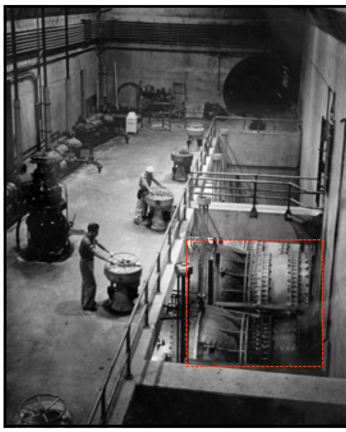
732



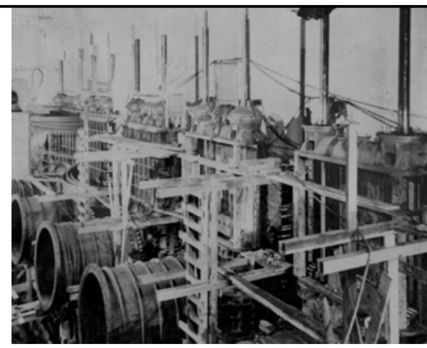


<u>Left</u>: portion of back wall of Nevada canyon wall outlet works structures showing manifold conduit inlet (July 1935)
<u>Above</u>: detail of radium capsule housed between lead sheets in gamma ray exploration of welded seams in outlet works manifold (June 1935) 733

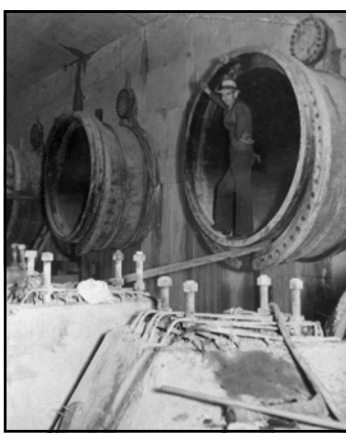
Outlet conduits for 72-inch needle valves (downstream tunnel plug, Tunnel No. 2; November 1935) 734



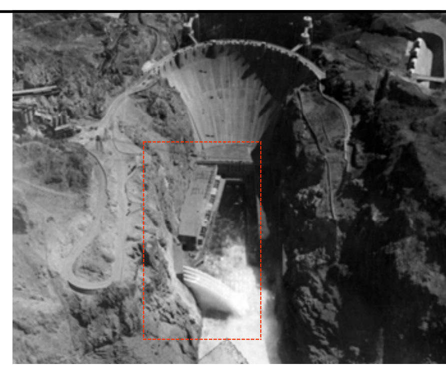
<u>Left</u>: view from crane of the Nevada tunnel plug outlet works in the downstream plug in tunnel No. 2. (needle valves below operating floor (right; September 1937).
<u>Above</u>: Operating platform on Nevada canyon wall outlet works showing left to right; valves, manual control for valves, and *Paradox Emergency Gate* operators (May 1936). 735



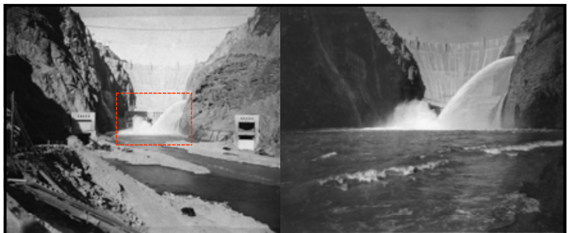
Interior of the operating room of the Nevada lower plug Outlet Works (showing progress of installation of the Paradox Emergency Gates; July 1936) 736



<u>Left</u>: ninety-inch conduits (between Paradox Emergency Gates and needle valves) in the downstream plug in tunnel No. 2. Bases for 72-inch needle valves shown in foreground (January 1937).
<u>Above</u>: assembly of Paradox Emergency Gates (in the downstream plug of tunnel No. 3 on the AZ side). Note the quantity of reinforcing steel employed Sept. 1936). 737



The downstream face (from 2K-feet) showing Nevada wing of Powerhouse and Nevada upper (canyon wall) Outlet Works (July 1936) 738

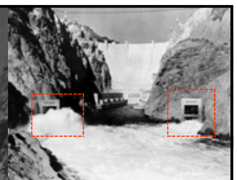


Left: view looking upstream of the dam, Powerhouse, canyon wall Outlet Works, and outlet portals of three Diversion Tunnels. The flow from the Arizona Valve House is approximately 4000cfs and through the plug gates of No. 1 tunnel, 4800cfs (March 8th 1936).
Right: waves three-feet and higher were produced by the discharge of 400cfs from the outlet works (March 8th 1936)

739

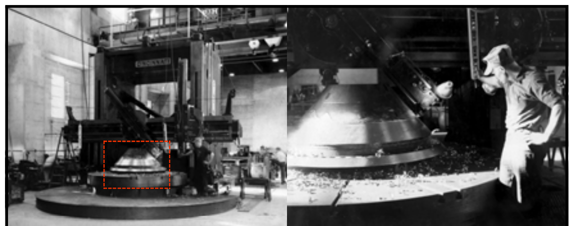
Left: 9Kcfs pouring from the Arizona Outlet Works 180-feet to river below (October 25th 1936)
Right: Six valves in Arizona valve house discharging 23Kcfs (valves were 100% open; April 12th 1937)

740



Left: discharge from two 84-inch needle valves in Nevada valve house (April 12th 1938)
Above: 25Kfps (feet per second) of water being discharged through the tunnel Outlet Works of Hoover Dam (February 1939)

741



A needle valve cone being refaced on the ten-foot boring mill located in the central section of the Powerhouse (October 1939)

742

Hydraulic control board installed in the Water-master's control room for giving indication of the position of the lower tunnel plug needle valves and the position of the Intake Tower cylinder gates (May 1936)

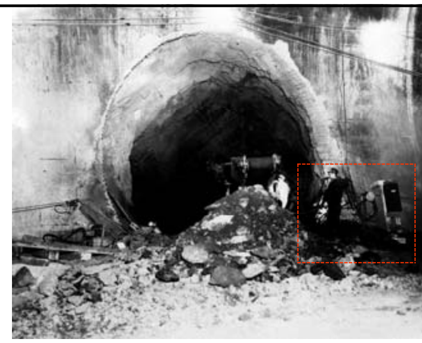
743

Tunnels

744

Excavating invert material near outlet portal of Arizona Penstock tunnel. View looking upstream (February 1932).

745



Start of operations on driving of 18-foot Penstock Adits (from Diversion Tunnel No. 2) to Nevada Powerhouse (showing *Conway Mucking Machine* removing muck; December 1932).

746

Collapsible timber form with which concrete in the 18-foot diameter Penstock tunnels were placed. These tunnels carried 13-foot diameter steel penstocks (September 1933).

747

<u>Left</u>: concrete lining and form in Penstock tunnel. Pipe carries concrete from pressure gun (outside tunnel). Concrete was painted with asphalt compound (*Hunt Process;* October 1933).
<u>Above</u>: wooden form for concrete lining in the 18-foot Penstock branches (January 1933)

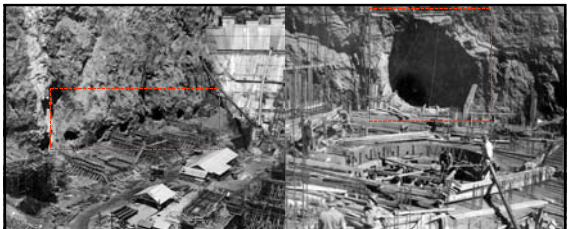
748

<u>Left</u>: formwork for transition from Penstock header tunnel through which Penstock will descend to Powerhouse (January 1934)
<u>Right</u>: Looking upstream toward Nevada Powerhouse, showing eighteen-foot Penstock openings (February 1934)

749

<u>Left</u>: carpenters at work on transition forms to be used in Penstock system tunnels (March 1934)
<u>Right</u>: looking upstream in No. 5 Penstock tunnel; showing Penstock outlets, man-ways and pedestal recesses (April 1934)

750

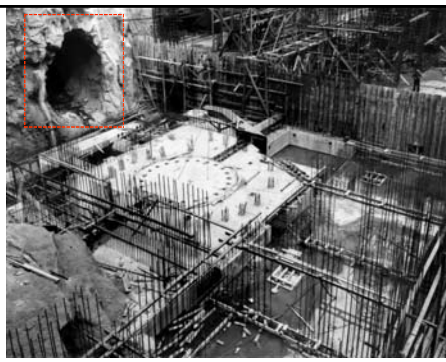


Left: Nevada power-plant site showing formwork for substructure and Penstock tunnel outlets (April 1934)
Right: looking across forms for power-plant substructure toward canyon wall with Penstock tunnel seen in background (April 1934)

751

Timber formwork for intersection transition between Diversion Tunnel No. 3 and Penstock tunnel (June 1934)

752



Nevada Powerhouse Unit No. 8 (view from the Nevada retaining wall) showing turbine base and Penstock tunnel (August 1934).

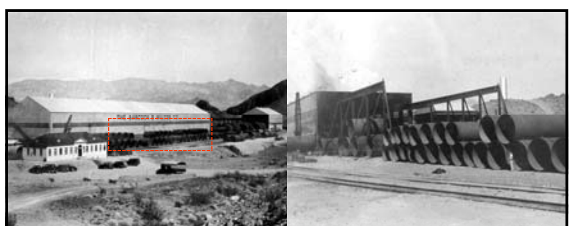
753

Penstocks & Pipes

754

Forty-four thousand tons of steel were formed and welded into 14,800-feet of pipe varying from eight to thirty-feet in diameter. Each length of the largest pipe; twelve-feet long, thirty-feet in diameter and two-inches thick, was made from three steel plates, of such weight that only two plates could be shipped from the steel mill to the fabricating plant on one railroad car. Two such lengths of pipe welded together made one section weighing approximately 135-tons (at intersections with the Penstocks they weigh as much as 186 tons). Reservoir outlet piping included 4,700 feet of thirty-foot-diameter pipe and 2K-feet of 8.5-foot-diameter pipe. Maximum thickness of the largest pipe was about three-inches. The thirty-foot diameter Penstock pipes were connected to the Powerhouse turbines by sixteen thirteen-foot-diameter plate-steel Penstocks installed in eighteen-foot-diameter concrete-lined tunnels. The total length of these Penstocks was 5,800 feet.

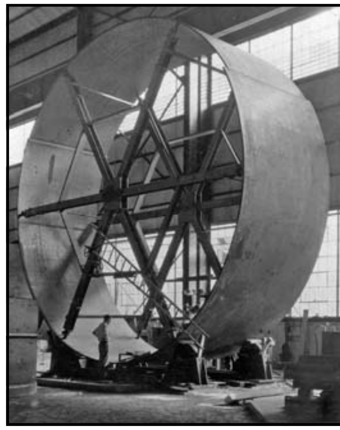
755



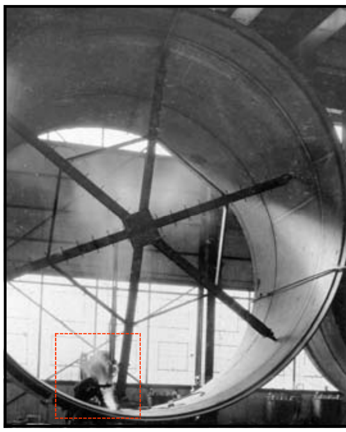
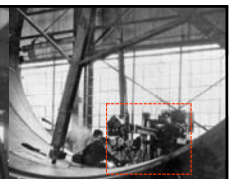
Left: plant and office of the Babcock and Wilcox Company where steel Penstocks for the pressure outlet and power system were fabricated. It was located about one mile from the dam site. Steel Penstock and outlet pipes of various sizes are seen awaiting installation (April 1934).
Right: storage yard at Babcock and Wilcox Company plant. View shows 8.5-foot diameter conduit and thirteen-foot diameter Penstock in storage awaiting installation (September 1933).

756

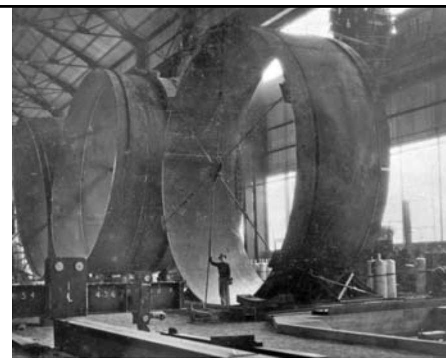

Left: 300-ton press, Babcock & Wilcox Co. plant. This press was used for making initial bend in heavy plate used in fabrication of Penstock pipes (October 1933). Above: handling plate to be fabricated into thirty-foot diameter Penstock pipe (Babcock & Wilcox Co. plant: October 1933). 757



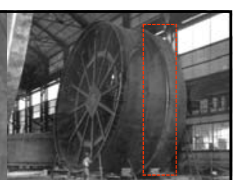

Left: thirty-foot diameter Penstock pipe assembled for longitudinal seams (Babcock and Wilcox Co. plant (October 1933). Above: longitudinal seam assembly for thirty-foot diameter Penstock pipe (Babcock & Wilcox Co. plant; October 1933). 758

Automatic welding machine in use on a longitudinal joint of a thirty-foot diameter Penstock pipe section at the Babcock & Wilcox Co. plant. The spreader jacks used for holding alignment are seen inside the pipe (December 1933). 759

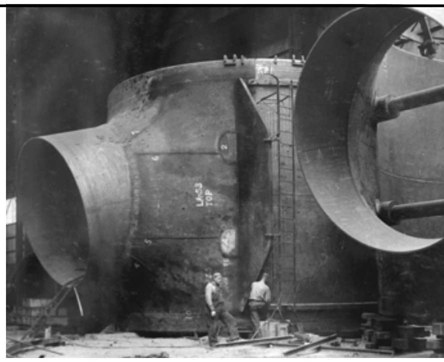


Thirty-foot diameter steel Penstock pipe set up for joint assembly at the Babcock & Wilcox Co. plant (December 1933) 760

Lining up a "Girth Joint" on a bend section of thirty-foot diameter Penstock pipe at the Babcock & Wilcox Co. plant. The "spider" (inside the pipe) was used in securing pipe alignment (December 1933). 761

Interior view of the Babcock & Wilcox Co. plant showing the fabrication of thirty-foot diameter steel Penstock sections (August 1934) 762



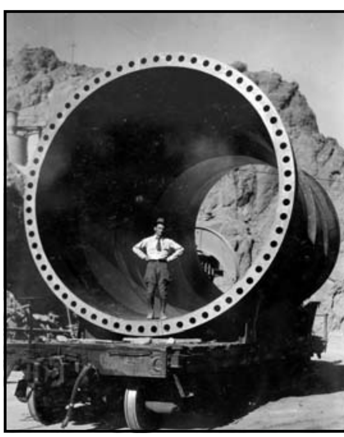
Fabrication of thirty-foot to thirten-foot diameter branch Penstock sections at the Babcock & Wilcox Co plant; June 1935) 763

View looking (longitudinally) through the Babcock & Wilcox Co. plant showing the fabrication of thirty-foot diameter steel Penstock sections; August 1934) 764

<u>Left</u>: first thirty-foot Penstock pipe section being lifted from trailers via cableway crane with lifting rig (July 20th 1934).
<u>Above</u>: hauling first section of thirty-foot diameter Penstock pipe along the parapet roadway on Nevada rim of Black Canyon (July 1934) 765

Section of thirty-foot diameter Penstock pipe being transported to tunnel via 150-ton cableway (1934)

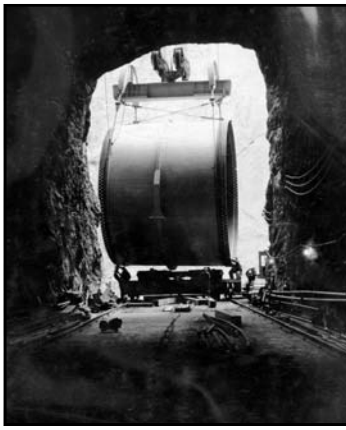
766



Section of thirteen-foot diameter Penstock pipe on railcar awaiting handling into Penstock tunnel (October 1934)

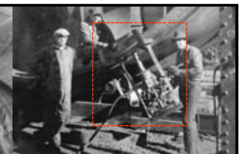
767

<u>Left</u>: thirty-foot diameter Penstock pipe spreader on bench at mouth of adit leading into penstock header tunnel No. 5 (upper level Nevada tunnel; November 1934)
<u>Above</u>: thirty-foot diameter Penstock section awaiting transportation into header tunnel No. 3 (showing typical spreader jacks in place) 768



30-foot diameter penstock pipe section being lowered by cableway crane onto car at entrance to Penstock header tunnel (December 1934).

769

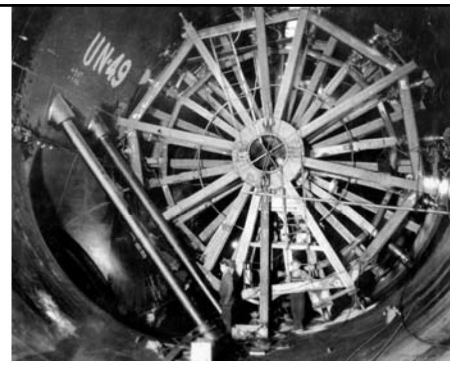


Left: Thirty-foot diameter Penstock pipe section ready for hoisting into position beneath intake tower in Penstock header tunnel No. 3. View looks downstream in Diversion Tunnel No. 3 from intersection with incline to Intake Tower (November 1933). **Above**: reaming pin holes in bell of thirty-foot diameter Penstock section (prior to broaching which takes place after section is in position in tunnel; February 1935)

770

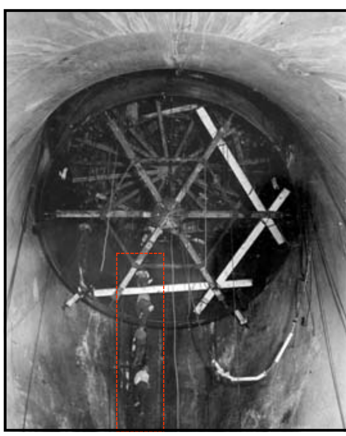
Left: pinning rig in operation in upper Nevada Penstock header (April 1935)
Above: broaching and pinning rig in upper Nevada header Penstock (April 1935)

771



Interior view through upper Nevada header Penstock at branch section (pulling rig in background; April 1935)

772

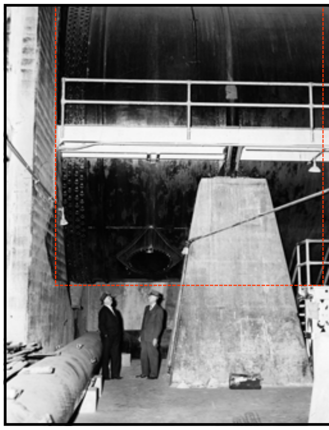


Thirty-foot diameter steel Penstock section being installed on vertical curve below Intake Tower in Nevada Penstock header tunnel. View looks upward from base of tunnel. (note man ascending ladder; August 1934)

773

"T-section" of Penstock pipe where thirty-foot section branches to 13-foot section leading to Nevada wing of Powerhouse (note stiffener shafts; May 1936)

774



View of one of the thirty-foot Penstocks at the Hoover Dam Powerhouse (February 1947)

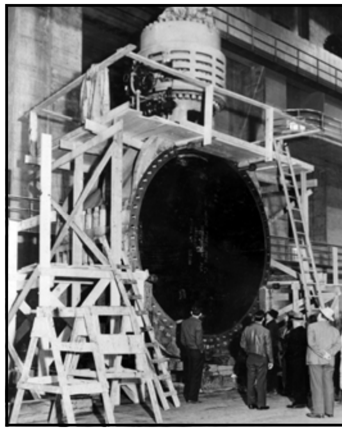
775

View of the 25-foot pipe in the upper Arizona Penstock header tunnel from the construction adit. The ventilating pipe can be seen in the upper portion of photo (July 1937)

776

Left: view of 25-foot pipe (in the upper Nevada Penstock header) from the junction of the tunnel and the construction Adit (December 1937)
Above: drain valves for dewatering the thirty-foot diameter Penstock (located in the Nevada downstream tunnel plug (September 1937)

777

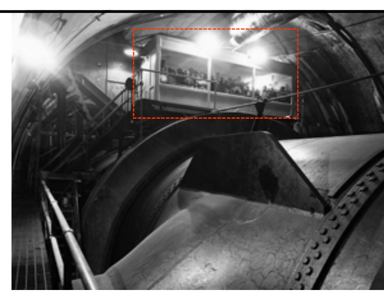


Left: 168-inch butterfly valve ready for installation in Unit A-7 in the Arizona wing of the Powerhouse February 1939)
Above: leaf of 168-inch butterfly valve at outlet of power Penstock (November 1935)

778

Temporary bulkhead (on the thirteen-foot penstock for Generator No. 5; December 1941) in the Arizona powerhouse. The bulkhead was placed on the Penstock at the time of its construction.

779



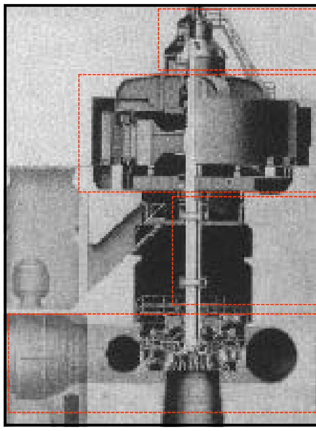
Scene in one of the original diversion tunnels at Hoover Dam showing a portion of one of the Penstocks which conveys water from Lake Mead to the Powerhouse. Each of the branch Penstocks was thirteen-feet in diameter. In the background (near the top of the Diversion Tunnel) can be seen the *Visitor's Gallery*, where the thousands who visit Hoover Dam annually can view the tunnel and Penstock.

780

Power Generation

781

From 1939 to 1949, Hoover Dam's power plant was the world's largest hydroelectric installation and remains one of the largest in the United States. On average, Hoover Dam generates approximately four-billion kilowatt-hours of hydroelectric power – enough energy to serve 1.3 million people, in the states of California, Nevada and Arizona. This awesome power is derived from a U-shaped structure at the base of the dam. Each Powerhouse wing is 650-feet long and rises 299-feet above the Powerhouse's foundations. There are seventeen main turbines in the Hoover power-plants; nine in the Arizona wing and eight in the Nevada wing. The original turbines were replaced through an upgrading program (1986-1993). Water reaches the turbines through four Penstocks, two on each side of the river (*Wicket Gates* control water delivery to the units). Maximum head (the vertical distance the water travels) is 590-feet; minimum, 420-feet; average, 510 to 530-feet. The installation of the last generating units was completed in 1961. Power plant machinery and all heavy/bulk equipment was transported from the canyon rim to the power plant/s via the (permanent) 150-ton cableway. In fact, the cableway is still used to span the 1,200-foot wide canyon. The main units have a combined rated capacity of 2,991,000 horsepower and two station-service units are rated at 3,500 horsepower each thus, the Hoover Dam power-plant/s have a total rated capacity of 2,998,000 horsepower. 782

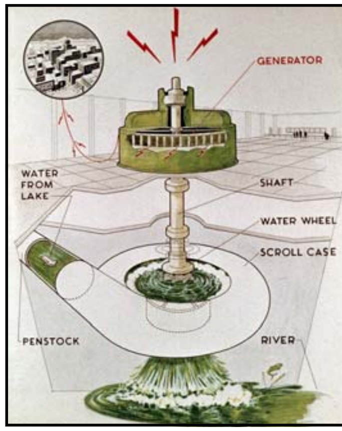


The ***Exciter*** is itself a small generator that makes electricity, which is sent to the Rotor, charging it with a magnetic field

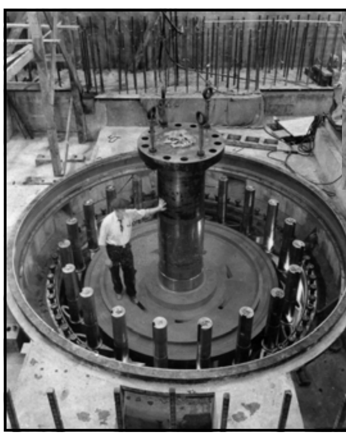
The ***Rotor*** is a series of electromagnets (also called poles). The Rotor is connected to the Shaft, so that the Rotor rotates when the Shaft rotates. The ***Stator*** is a coil of copper wire. It is stationary.

The ***Shaft*** connects the Exciter and the Rotor to the turbine

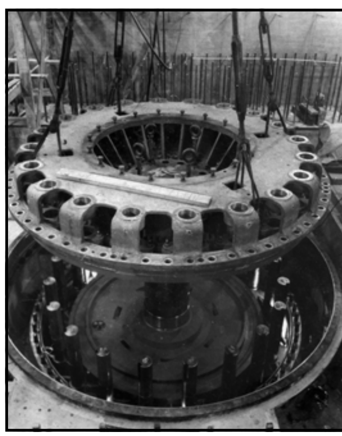
Water flows through large pipes and turns a large wheel called a ***Turbine***. The Turbine turns the Shaft which rotates a series of magnets past copper coils and a generator to produce electricity. 783

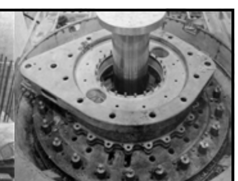


<u>Left</u>: diagram explaining operation of hydraulic generator
<u>Above</u>: lowering one of the twenty-four Wicket Gates or (a.k.a. "Guide Veins") into place in the turbine of A-2 in the Arizona Powerhouse (March 1942) 784

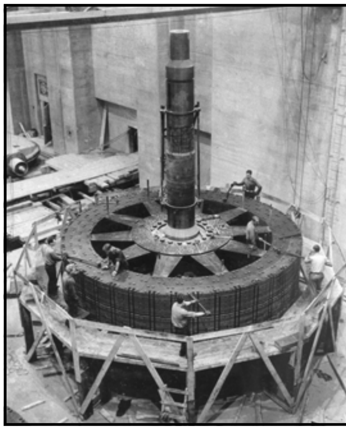


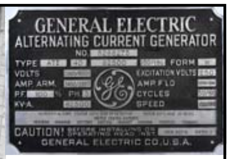
<u>Left</u>: 55K-HP turbine (in unit A-8) encased in concrete. The *Turbine Runner* and Wicket Gates are shown in place ready for the *Crown* piece to be lowered (June 1936).
<u>Above</u>: overhead view of 55K-HP turbine (in Unit A-8 of the Powerhouse; May 1936) 785





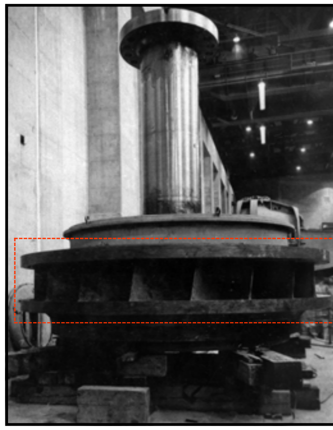
<u>Left</u>: Crown section of 55K horsepower turbine being lowered into place over Wicket Gates (a.k.a "radical") in unit A-8, Arizona wing of Powerhouse (May 1936)
<u>Above</u>: the Wicket Gates and *Master Ring* have been placed in the turbine (of unit N-2) ready to be connected to the pistons which are operated by a *Woodward Governor* (controlling the hydrostatic pressure on the runner; June 1936). 786

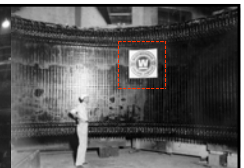




Left: assembly of generator rotor for 82,500 Kva unit being installed by the *General Electric Company* in Hoover Dam Powerhouse (November 1935)
Above: General Electric unit plate, 82,500 Kva. The units were upgraded in the early 1980's to 130,000 Kva.

787





Left: Turbine Runner for 115K horsepower turbine waiting to be placed in the Nevada wing of the Powerhouse. The shaft (later to be connected to an 82,500 Kva generator) was 38-inches in diameter (May 1936).
Above: interior view of *Stationary Armature* for 82,500 Kva *Westinghouse* generator unit with upper bracket, which will later support weight of rotor and turbine runner, in place (May 1936).

788

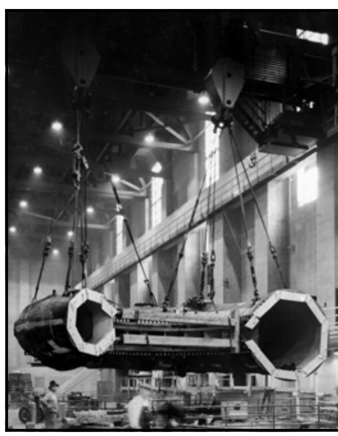
Left: view of rotating field for 82,500 Kva Westinghouse generator (near complete in assembly pit on the Nevada side of the Powerhouse). These rotors were being assembled in the turbine pits of future units (May 1936).
Above: exterior view of stationary armature and upper bracket of 82,500 Kva Westinghouse generating unit ready to be hoisted into place on the generator floor level (May 1936)

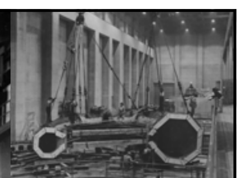
789

Left: interior view of the Nevada wing of the Powerhouse showing progress of generator installations (July 1936)
Above: the installation practically complete on 115K horsepower turbine (Unit N-2), Nevada wing of the Powerhouse (July 1936)

790

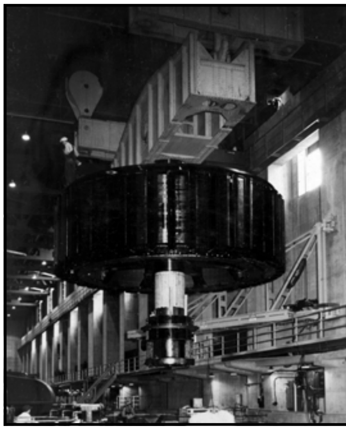
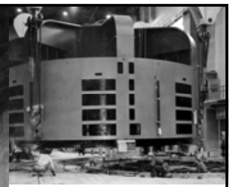
The four 82,500 Kva generators of the initial power installation, in various stages of erection in the Nevada wing of the Powerhouse. Two were furnished by *General Electric*, two by *Westinghouse* (October 1936). 791





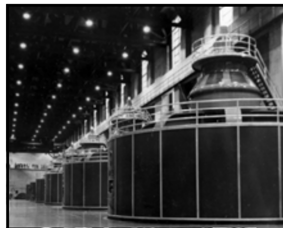
Left: three sections of the turbine scroll case being lifted for placement into Unit A-7 by the 300-ton crane (Arizona wing of the Powerhouse; January 1939)
Above: workmen preparing three sections of a turbine scroll case (for lifting into Unit A-7; Jan. 1939)

792

Left: 600-ton rotor being lifted out of the turbine pit of Unit A-3 (where it was stored) by the two 300-ton cranes. It was assembled in the A-7 stator (May 1939).
Above: view of the stator and upper bearing bracket being lowered to its foundation over the A-7 turbine pit on the generator floor level of the Arizona Powerhouse (May 1939)

793

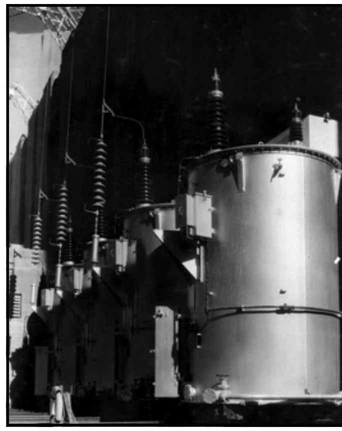
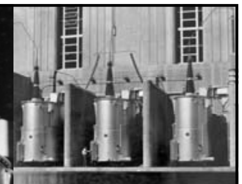


Top Left: Nevada wing of the Powerhouse (December 1939)
Top Right: from the visitors' balcony on the fifth floor of the Powerhouse, the entire row of six original generator units in the Nevada wing can be seen (August 1940)
Left: early morning in the Nevada Powerhouse. The six original generators in operation as seen from the operator's balcony (August 1940)

794


Left: looking downstream on the turbine gallery (Nevada Powerhouse (October 1941)
Above: Bronze plaque commemorating Unit N-7's "Turbine Runner" (a.k.a. "Water Wheel") in use from 1944 to 1982

795

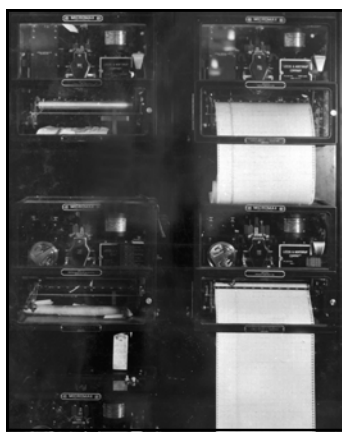



Above: transformer bank for Unit N-1 and N-2 located alongside the Nevada wing of the Powerhouse (Nov. 1939)
Left: view of transformers for Unit A-8 (outside the Arizona Powerhouse (Nov. 1938)

796

General view of the *Main Control Room* located in the central section of the Powerhouse (November 1939)

797

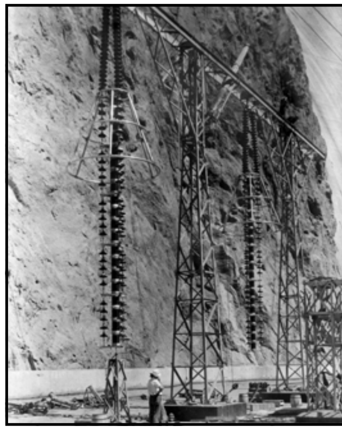



Left: recording instruments located on auxiliary boards in the Main Control Room (central portion of the Powerhouse; October 1936)
Above: supervisory control board furnished by the City of Los Angeles. Located in the Main Control Room (central portion of the Powerhouse; Oct. 1936).

798

Left: ***Bus Gallery*** **of the Nevada wing of the Powerhouse (showing the 4,000-ampere, 23,000-volt enclosed copper busses furnished by the** ***I.T.E. Circuit Breaker Company*** **(September 1936)**
Above: **looking east toward the Arizona wing across face of meter board (in central portion of the Powerhouse; May 1936)**

799



The 287.5 KV lightning arresters erected on Powerhouse roof for the City of Los Angeles lines (September 1936)

800

Left: **a portion of the** ***Take-off Structure*** **(on the roof of the Nevada Powerhouse) showing switches and lightning arrests (April 1941).**
Above: **Take-Off Structures on roof of Powerhouse (for Unit A-8; January 1937)**

801

Leaning towers on the Nevada rim of Black Canyon that carry the power lines from the roof of the Nevada Powerhouse up and over the highway to the switchyards above (August 1939)

802

View of 87.5 KV, 1200 ampere oil circuit breakers in the City of Los Angeles switchyard. The average annual net generation for Hoover power plant/s; 1947 through 2008, was about 4.2 billion kilowatt-hours. The ten-year annual average for 1999 through 2008 was about 4.2 billion kilowatt-hours. The maximum annual net generation at Hoover Dam's power plant/s was 10,348,020,500 kilowatt-hours (in 1984). The minimum annual net generation (since 1940) was 2,648,224,700 kilowatt-hours (in 1956).

803

Electricity from Hoover dam's powerhouse was originally sold pursuant to a fifty-year contract (authorized by Congress in 1934) which ran from 1937 to 1987. In 1984, Congress passed a new statute which set power allocations from the dam from 1987 to the year 2017. The Powerhouse was run under the original authorization by the ***Los Angeles Department of Water and Power*** **and** ***Southern California Edison*****. In 1987, the USBR assumed control. On December 20th 2011, President Obama signed legislation extending the current contracts until 2067 (after setting aside 5% of Hoover Dam's power for sale to Native American tribes, electric cooperatives, and other entities). The new arrangement takes effect in 2017. The current (2012) electrical energy generated is allocated as follows;**

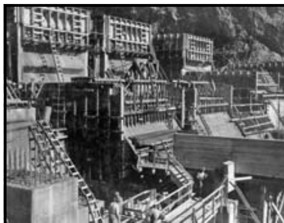
Arizona - 18.95%
Nevada - 23.37%
Metropolitan Water District of Southern California - 28.54%
Burbank, CA - 0.59%
Glendale, CA - 1.59%
Pasadena, CA - 1.36%
Los Angeles, CA - 15.42%
Southern California Edison Co. - 5.54%
Azusa, CA - 0.11%
Anaheim, CA - 1.15%
Banning, CA - 0.04%
Colton, CA - 0.09%
Riverside, CA - 0.86%
Vernon, CA - 0.62%
Boulder City, NV - 1.77%

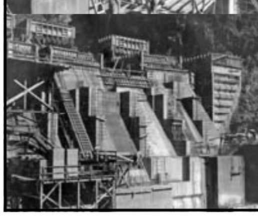
804

Powerhouse

805

With most work finished on the dam itself, a formal dedication ceremony was arranged for September 30th 1935 (to coincide with a western tour being made by President Roosevelt). Excavation for the Powerhouse was carried out simultaneously with the excavation for the dam foundation and abutments. A U-shaped structure located at the downstream foot of the dam, its excavation was completed in late 1933 with the first concrete placed in November 1933. The Powerhouse was one of the projects uncompleted at the time of the formal dedication. A crew of five-hundred men remained to finish it and other structures. With most work completed by the dedication, Six Companies negotiated with the USBR through late 1935 and early 1936 to settle all claims and arrange for the formal transfer of the dam to the Federal Government. The parties came to an agreement and on March 1st 1936, Secretary of the Interior ***Harold Ickes*** formally accepted the dam on behalf of the Federal Government. 806



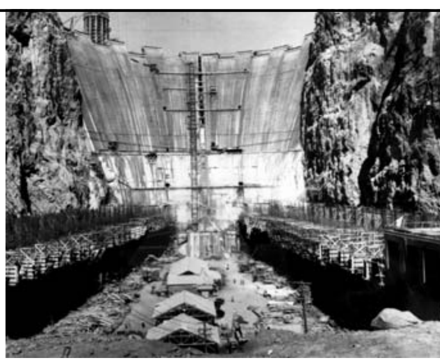


Arizona Powerhouse footings (October 1933)

807

Arizona Powerhouse (from the Nevada *Valve House Bench*; August 1934)

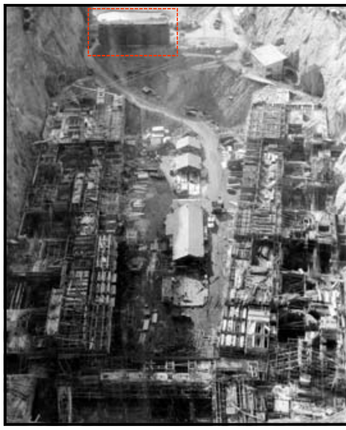
808



Upstream view of the Powerhouse wings (from the downstream Cofferdam; September 1934) 809

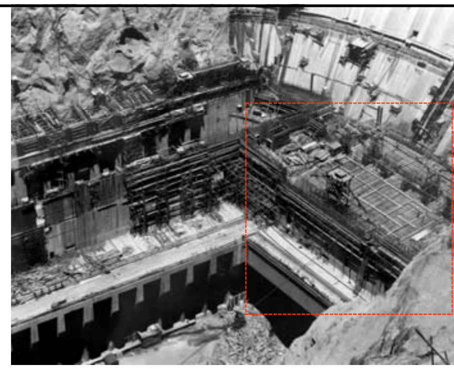
Left: rig used in placing concrete floor slabs in power-plant construction (December 1934)
Above: Arizona Power-house (December 1934)

810



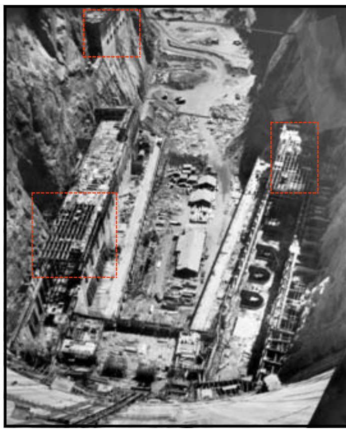
Left: overhead view of Powerhouse construction (as seen from the crest of the dam). View shows downstream Cofferdam with Evaporation Tower atop (December 1934)
Above: overhead view of the Nevada Powerhouse (December 1934)

811



Central section of the Powerhouse (at right; May 1935)

812



View from the crest of Hoover Dam (looking downstream on the Powerhouse). Note the numerous roof trusses in place and the Valve House in background (upper left). To make the Powerhouse roof bomb-proof, it was constructed of layers of concrete, rock, and steel with a total thickness of about 3.5 feet and topped with layers of sand and tar (June 1935).

813

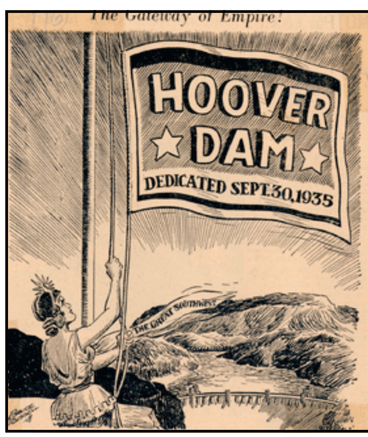
I came, I saw and I was conquered

814

"This morning I came, I saw and I was conquered…We are here to celebrate the completion of the greatest dam in the world, rising 726 feet above the bedrock of the river and altering the geography of a whole region…We know that, as an unregulated river, the Colorado added little of value to the region this dam serves. When in flood the river was a threatening torrent. In the dry months of the year it shrank to a trickling stream. The gates of these great diversion tunnels were closed here at Boulder Dam last February. In June a great flood came down the river. It came roaring down the canyons of the Colorado, through Grand Canyon, Iceberg and Boulder Canyons, but it was caught and safely held behind Boulder Dam…Today marks the official completion and dedication of Boulder Dam. This is an engineering victory of the first order - another great achievement of American resourcefulness, American skill and determination…you who have built Boulder Dam and on behalf of the Nation I say to you, 'Well done.'"

815

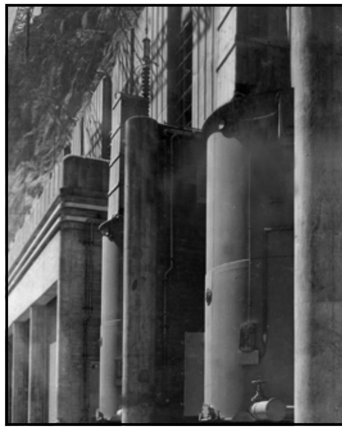
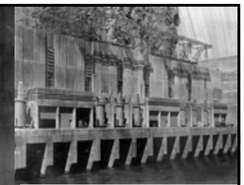
Left: FDR dedicating the Dam: September 30th 1935



Los Angeles Times cartoon "The Gateway of Empire" (September 30th 1935)

816


Left: looking downstream from dam showing crowds on pavement of the Nevada Powerhouse and water falling from outlets of Nevada Valve House (September 1936)
Above: anchoring rock slab operation above Nevada Valve House (taken from the Arizona side) 817

View/s looking downstream of the transformer platform (Nevada wing of the Powerhouse) showing 55K Kva transformers (Sept. 1936)

818


Left: the cableway dropping its passengers to the level of the Powerhouse roof deep in the canyon (February 1939)
Above: study group of the *Third World Power Conference and Second International Commission on Large Dams*, on a cableway skip at Hoover Dam (after inspecting the dam and Powerhouse; Sept. 29^{th} 1936) 819

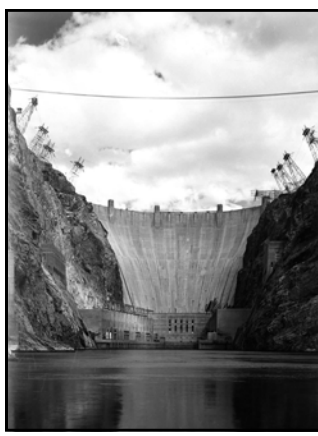
Frank Crowe (right) turns over the dam to the *Department of the Interior* (March 1^{st} 1936)

820



Top: Nevada wing of the Powerhouse (as seen from the roof of the Arizona Valve House; November 1936)
Left: Nevada wing of Powerhouse (as seen from skip on 150-ton cableway; April 1937)

821



Dam and Powerhouse (December 1944). Control of water was the primary concern in the building of Hoover Dam. Power generation has allowed the dam project to be self-sustaining. Proceeds from the sale of power repaid the 50-year construction loan, and those revenues also finance the multi-million dollar yearly maintenance budget. Power is generated via the release of water in response to downstream water demands. Lake Mead and downstream releases from the dam provide water for both municipal and/or irrigation uses. Water released from Hoover Dam eventually reaches the All-American Canal for the irrigation of over one-million acres of land. Ultimately, water from Lake Mead serves eight million people in three states. 822

Lake Mead

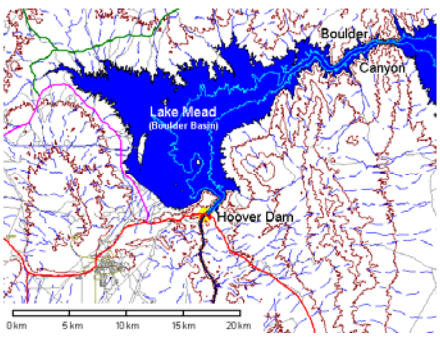
823

Between 1935 and 1963, about 91K acre-feet of sediment was deposited in Lake Mead each year. With the installation of *Glen Canyon Dam* (about 370-miles upstream), the life of the lake is indefinite. Annually, about 800K acre-feet of water evaporates each year (an *acre-foot* is the amount of water required to cover one acre to a depth of one foot, or approximately 326K gallons). The USBR operates and maintains the dam, power-plant and reservoir (Lake Mead). The *National Park Service* administers recreational activities in and around Lake Mead as part of *Lake Mead National Recreation Area*. Lake Mead will store the entire average flow of the Colorado River for two years. At Elevation 1,221.4, Lake Mead contains 28,945,000 acre-feet of water. The reservoir's capacity is allotted as follows (below elevation 1,229);

- **+/-1,500,000 acre-feet of storage capacity is reserved exclusively for flood control;**
- **+/- 2,547,000 acre-feet for sedimentation control;**
- **+/-18,438,000 acre-feet for joint use (flood control, municipal and industrial water supply, irrigation and power);**
- **+/-7,683,000 acre-feet for inactive storage**

Lake Mead extends approximately 110-miles upstream (toward the Grand Canyon). It also extends about thirty-five miles up the *Virgin River*. The width varies from several hundred feet (in the canyons) to a maximum of eight miles. The lake covers approximately 248 square miles.

824



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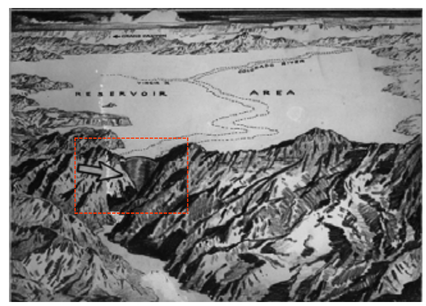

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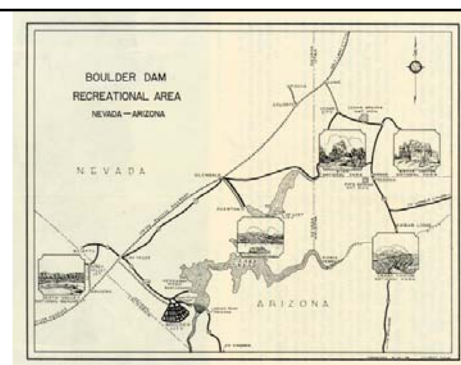
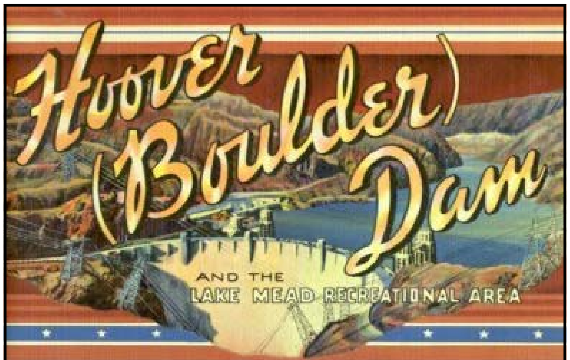
827



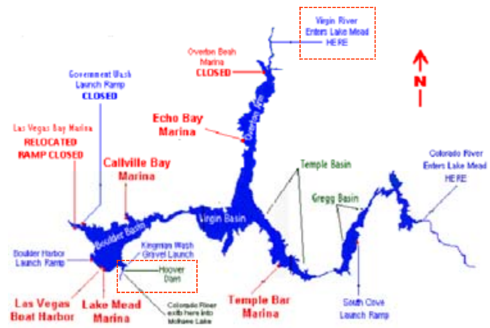
Map of Boulder (Hoover) Dam Recreational Area, Nevada-Arizona (September 1938)

828



Postcard (ca. 1930s)

829



830

<u>Left</u>: Lake Mead from point above Observation Point (January 1937)
<u>Right</u>: the "Temple" (as seen from a boat on Lake Mead). The rising waters of the lake have slowly undermined the formation (December 1938)

831

<u>Left</u>: forty-five foot sailboat on Lake Mead (between Black and Boulder Canyons; July 1938)
<u>Right</u>: forty-five foot sail boat on Lake Mead (above Hoover Dam, as seen from the Nevada shore; July 1938)

832

Proud fishermen gloat over fish caught in Lake Mead. In the catch are represented *Bass, Crappie, Bluegill* and *Perch* (January 1944).

833

<u>Part 6</u>

Great Edifice

834

A Cosmic Event

835

Hoover Dam is a magnificent feat of human labor, courage, skill, daring and engineering prowess. Beyond its practical purpose/s, it has representational value as well. True, it was an investment seeking a return, but it goes beyond the pragmatic in representing the wonder of human creativity in as natural a setting as can be found on planet earth. To put the dam in its proper place in the *Universe of Man*, sculptor *Oskar J.W. Hansen* was commissioned to create sculptural artworks for Hoover Dam that would demonstrate its status as a "cosmic event." Hansen's idealistic, symbolic art – epitomized in his Bronze *Winged Figures of the Republic* (for the dam's plaza/flagpole), demonstrates figuratively man's place between heavenly aspiration and earthbound achievement. Hansen's "Star Map" also lends itself to this heavenward aspiration. Ultimately, Hansen's sculptural program for Hoover Dam would highlight the transcendent qualities of a utilitarian edifice that reflected the spirit of hope for a better tomorrow at the time it was conceived/built.

836

"…A monument to collective genius exerting itself in community efforts around a common need or ideal…interpreting man to other men in the terms of the man himself…In each of these monuments can be read the characteristics of these men, and on a larger scale, the community of which they are part. Thus, mankind itself is the subject of the sculptures at Hoover Dam…The building of Hoover Dam belongs to the sagas of the daring. The winged bronzes which guard the flag, therefore, wear the look of eagles. To them also was given the vital upward thrust of an aspirational gesture; to symbolize the readiness for defense of our institutions and keeping of our spiritual eagles ever ready to be on the wing…"

Oskar J.W. Hansen, Sculptor (at left)

Hansen was a Norwegian-born, naturalized American citizen

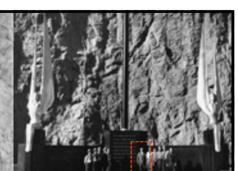
837

The Immutable Calm of Intellectual Resolution

838

Hansen's principal work at Hoover Dam is the monument of dedication on the Nevada side of the dam. Here, rising from a black polished base, is a 142-foot flagpole flanked by two winged figures, which Hansen called "The Winged Figures of the Republic." They express: *"the immutable calm of intellectual resolution, and the enormous power of trained physical strength, equally enthroned in placid triumph of scientific accomplishment."* The winged figures are thirty-feet high. Their shells are 5/8-inch thick, and contain more than four-tons of Statuary Bronze. The figures were formed from sand molds weighing 492-tons. The Bronze that forms the shells was heated to 2,500 degrees Fahrenheit and poured into molds in one continuous, molten stream. The figures rest on a base of black *Diorite*, an igneous rock. In order to place the blocks without marring their highly polished finish, they were centered on blocks of ice, and guided precisely into place as the ice melted.

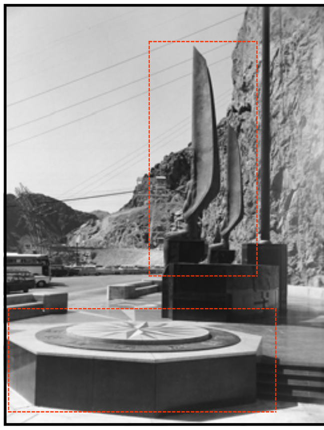
839

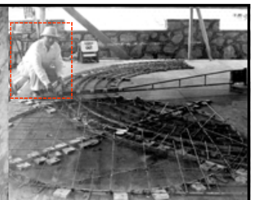


Left: Oskar J.W. Hansen, Sculptor, with his creation "Winged Figures of the Republic" (April 1938)

Above: the "Winged Figures of the Republic" that sit on the marble pedestals on each side of the flagpole base at the west end of the Hoover Dam. The Winged Figures had just been refinished with *Pitt-Glaze* Bronze paint under Mr. Hansen's supervision (Nov. 1965)

840



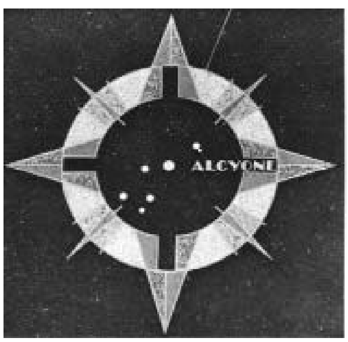


Left: the Star Map's compass and zodiac plaques (foreground) and Winged figures of the Republic (near the Nevada end of Hoover Dam; September 1959)
Above: Oskar J.W. Hansen, checking the fabrication of the *Circle of Precession of the Equinox* showing the platonic year for placement in Terrazzo Star Map (April 1938)

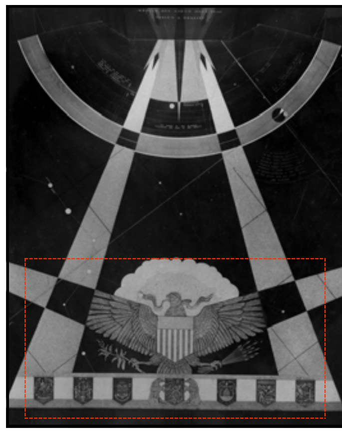
841

After the two Diorite blocks were in place, the flagpole was dropped through a hole in the center block (into a predrilled hole in the mountain). Surrounding the base is a Terrazzo floor, inlaid with a *Star Chart* (Celestial Map). The chart preserves for future generations the date on which President Franklin Delano Roosevelt dedicated Hoover Dam; September 30th 1935. The apparent magnitudes of stars on the chart are shown as they would appear to the naked eye at a distance of about 190 trillion miles from earth. In reality, the distance to most of the stars is more than 950 trillion miles. In this Celestial Map, the bodies of the solar system are placed so exactly that those versed in astronomy could calculate the precession of the *Pole Star* for approximately the next 14K years. Conversely, future generations could look upon this monument and determine, if no other means were available, the exact date on which Hoover Dam was dedicated. Near the figures (and elevated above the floor) is a *Compass*, framed by the signs of the *Zodiac*.

842



843

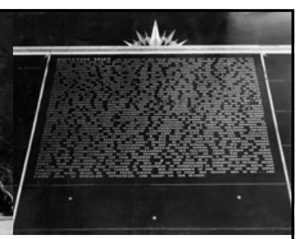


Left: portion of the central section of the Terrazzo Star Map. This view shows the *National Emblem* and the *State Seals* (November 1940)
Above: an overhead view of the Compass and Zodiac Plaques (November 1940)

844

Left: crew applying a coat of sealer to the Star Map's raised Compass and surrounding Zodiac (on octagonal platform; February 1982)
Right: *Scorpio* plaque on Zodiac

845



Top Left: visitors to Hoover Dam show great interest in the star map design on the floor of the *Safety Island* located at the Nevada Approach to the dam (November 1940)
Top Right: inscription (made of Bronze and set in black Terrazzo) is an explanation of the Terrazzo Star Map
Left: a portion of the Terrazzo Star Map (view of the lower left corner of the floor)

846

They Died to Make the Desert Bloom

847

Hansen also designed the plaque commemorating the ninety-six men who (officially) died during the construction of Hoover Dam. The plaque (originally set into the canyon wall on the Arizona side of the dam) is now located near the winged figures. It reads: ***"They died to make the desert bloom. The United States of America will continue to remember that many who toiled here found their final rest while engaged in the building of this dam. The United States of America will continue to remember the services of all who labored to clothe with substance the plans of those who first visioned the building of this dam."***

848

<u>Left</u>: *John C. Page*, USBR Commissioner (at right), and Oskar J.W. Hansen, sculptor, in front of *Memorial Plaque*. (April 17th 1937)
<u>Above</u>: Oskar J. Hansen, sculptor of Memorial Plaque (and other sculptural works) at Hoover Dam, giving explanation and meanings of each part of his work at the unveiling of the memorial (December 17th 1937)

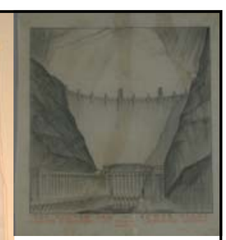
849

Architectural Treatment

850

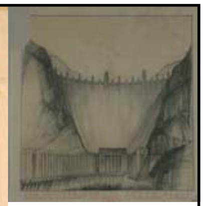
The initial plans for the facade of the dam, appurtenant works and ornamentation conflicted with modern architectural styles of the era. The USBR (more concerned with the dam's functionality than adornment) gave it a Gothic-inspired architectural/artistic treatment. After the initial design was heavily criticized as being unremarkable for a project of such grand scale, Los Angeles-based architect *Gordon B. Kaufmann* (at the time the supervising architect to the USBR) was brought in to redesign the exteriors. Kaufmann streamlined the design, and applied an up-to-date and elegant *Art-Deco* style to the entire project. He designed sculptured turrets rising seamlessly from the dam face and clock faces on the intake towers set for the time in Nevada and Arizona (the two states are in different time zones). At Kaufmann's request, Denver artist *Allen Tupper True* was hired to supervise the design and decoration of the walls and floors of the new dam. True's design scheme incorporated motifs of the *Navajo* and *Pueblo* Native American tribes of the region. Although there was some initial opposition to these designs, True was given the green light and was officially appointed consulting artist. With the assistance of the *National Laboratory of Anthropology*, True researched authentic decorative motifs from Indian sand paintings, textiles, baskets and ceramics. The images and colors were based on Native American visions of rain, lightning, water, clouds, and local animals; lizards, serpents, birds and on the Southwestern landscape of stepped mesas. In these works (integrated into the walkways and interior halls of the dam), True also reflected on the machinery of the operation, making the symbolic patterns appear both ancient and modern.

851



<u>Left</u>: Architectural design drawing; "Scheme A" by Gordon B. Kaufmann (prior to conservation). This is one of five designs by Kaufmann ("Scheme C" was actually built).
<u>Above</u>: after conservation

852

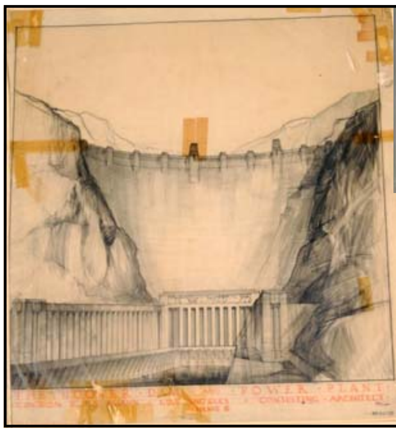


Left: Architect'l. design drawing; "Scheme B" by Gordon B. Kaufmann (prior to conservation) Above: after con-servation

853

Left: Architect'l design drawing; "Scheme D" by Gordon B. Kaufmann (prior to conservation) Above: after con-servation

854



Left: Architectural design drawing; "Scheme E" by Gordon B. Kaufmann (prior to con-servation) Above: after con-servation

855

Visitors Gallery (at Elevation 705) in the upstream end of the Nevada generator room. Terrazzo floor designed by Allen Tupper True complete (December 1936).

856

Native-American terrazzo floor design by Allen Tupper True

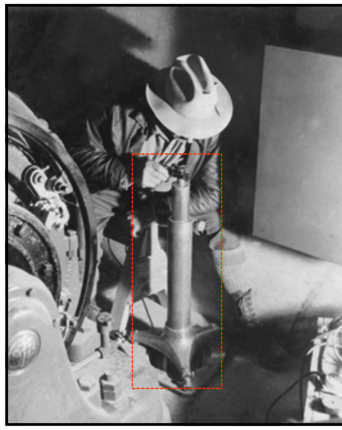
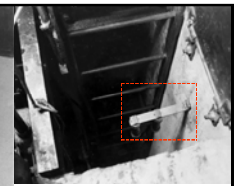
857

Elevators

858


Top Left & Right: looking across top of Hoover Dam (toward the Arizona side), showing the start of the Utility and Elevator Towers (January 1935)
Left: view taken from the Arizona side, (looking across the top of Hoover Dam) showing Elevator and Utility towers (January 1935)

859

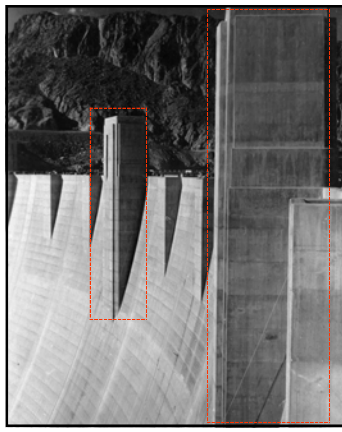



Left: Operator making an observation (through his Plumbing Telescope) of one (of two) dam elevator shaft/s (December 1935)
Above: view showing target used in optical plumbing observations (attached to inset in Nevada wall of elevator shaft at Elevation 974; November 1939)

860


Left: suspension plumb line in Arizona elevator shaft machine room (used in plumbing observations; November 1939)
Above: view showing pan of Mercury (placed in elevator shaft at Elevation 975) used for leveling the optical plumbing telescope (November 1939)

861



The crest of the dam as seen from the Arizona abutment, showing the Arizona Elevator (left) and Utility (right) Tower/s (September 1936)

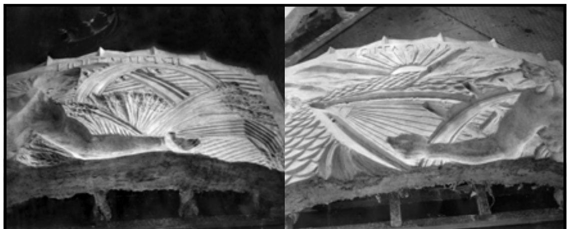
862

Buildeth Again a Nation

863

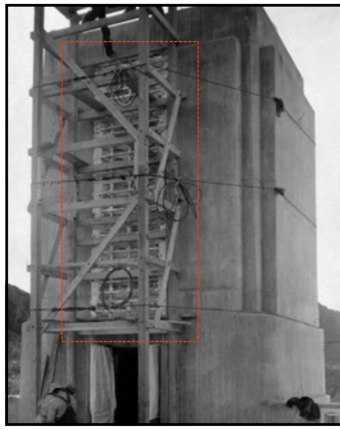
There are four towers protruding from the top of the dam. The middle two are for elevators and they are decorated with bas-relief (done in concrete) sculptures by Oskar Hansen. The five Bas-reliefs on the Nevada Elevator Tower show the multipurpose benefits of Hoover Dam: *Flood Control, Navigation, Irrigation, Water Storage* and *Power* (at left). On the Arizona Elevator Tower are a series of five bas-reliefs depicting: *"the visages of those Indian tribes who have inhabited mountains and plains from ages distant."* Accompanying the illustrations is the inscription: *"Since primordial times, American Indian tribes and Nations lifted their hands to the Great Spirit from these ranges and plains. We now with them in peace buildeth again a Nation."*

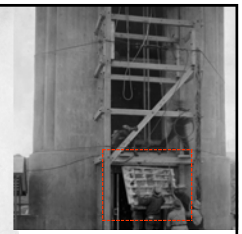
864



Top Left: section of sculpture-casting representative of *Irrigation* for the Nevada Elevator Tower (November 1937)
Top Right: section of sculpture-casting representative of *Navigation* for the Nevada Elevator Tower (November 1937)
Left: section of sculpture-casting representative of *Water Storage* for the Nevada Elevator Tower (Nov. 1937)

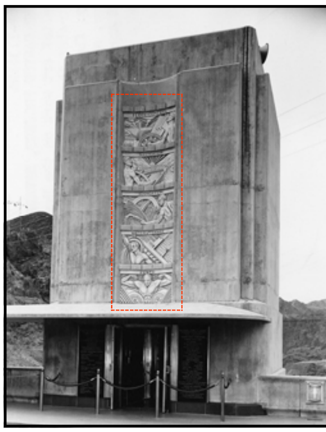
865





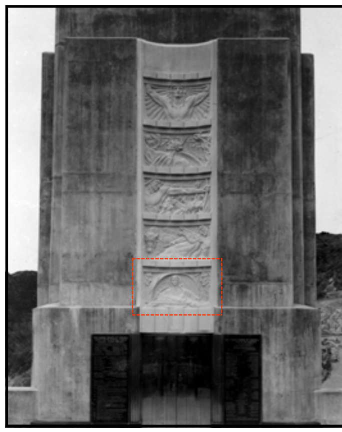
Left: Arizona Elevator Tower with all five sculptured castings in place (ready for pouring of concrete; November 1937)
Above: placing one (of five) sculpture casting section/s in Nevada Elevator tower (November 1937)

866



Bas-relief artwork on the Nevada Elevator Tower illustrates the multi purpose aspects of Hoover Dam, (*Flood Control, Navigation, Irrigation, Water Storage* and *Power*; April 1955)

867



Left: Arizona Elevator Tower with the bas-reliefs and Bronze plaques created by Oskar J.W. Hansen (April 1938)
Above: refurbishing the bas-relief plaque: "Buildeth Again a Nation" (on the Arizona Elevator Tower; March 1955)

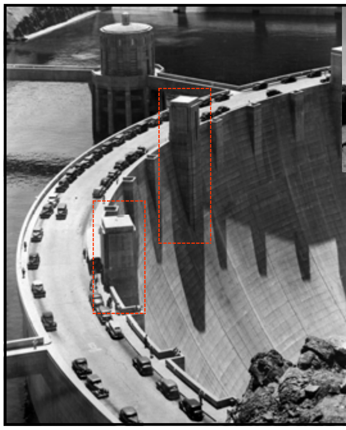
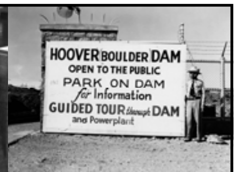
868

Left: Bronze plaque/s on Arizona Elevator Tower. West (left) and East (right) side/s of elevator door/s.
Above: full view

869

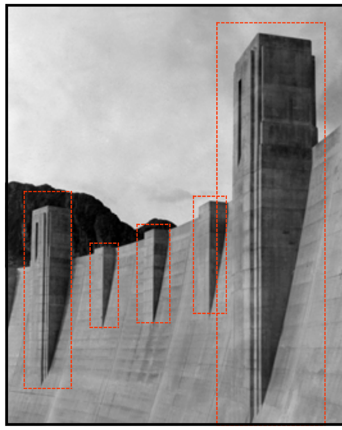
Bronze plaque on Nevada Elevator Tower (West side of door)

870

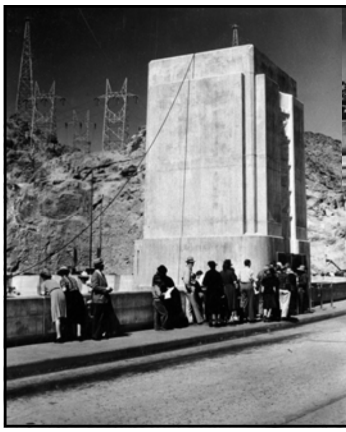
Of the 90,070 persons who visited the Hoover Dam area (as of July 1939), 51,716 made the trip to the Powerhouse via the elevators. This represented an increase of 12,079 persons over the previous year (July 1938).

871



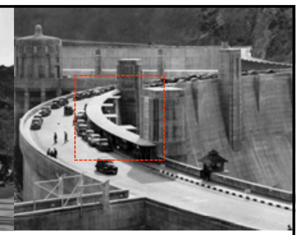

<u>Left</u>: downstream face of dam with Arizona Utility and Arizona Elevator Tower/s (from Arizona canyon rim; April 1938)
<u>Above</u>: tourists to Hoover dam taking photographs from one of several open-air viewing balconies (on the downstream crest of dam)

872




<u>Left</u>: it was found that on busy days, more visitors could be handled if one elevator was used to lower visitors and the other to bring them up (March 1940)
<u>Above</u>: visitors purchasing tickets for the conducted tour of the Powerhouse accessed via the elevators (March 1940)

873

<u>Left</u>: view of the nearly completed *Canopy Shelter* (under construction) between the Arizona and Nevada Elevator Tower/s of Hoover Dam (December 1940)
<u>Right</u>: Hoover Dam (as seen from the roof to the new *Exhibit Building*) providing a good view of the recently completed Canopy Shelter (between the two Elevator Towers; February 1941)

874


<u>Left</u>: Elevator Lobby (at Elevation 1215) in Nevada Elevator Tower showing marble walls, Bronze elevator door/s, ceiling (with indirect lighting) and terrazzo floor (yet to be ground; November 1936)
<u>Above</u>: workman operating *Carborundum Wheel* (for cutting the Terrazzo floor) in the Elevation 705 elevator gallery

875


<u>Left</u>: elevator loaded with visitors (April 1946)
<u>Above</u>: waiting to take the elevator into Hoover Dam. In 1947, 424,175 persons took the guided tour through the dam and power plant.

876

Hoover Dam opened for tours in 1937 but on December 7th 1941, it was closed to the public for the duration of World War II during which only authorized traffic (convoys) was permitted. It reopened September 2nd 1945 and by 1953, annual attendance had risen to 448,081. The dam closed on November 25th 1963 and on March 31st 1969; days of mourning in remembrance of Presidents' *Kennedy* and *Eisenhower*. In 1995, a dramatic new *Visitors Center* was built and the following year, visits exceeded one million for the first time. The dam closed again to the public on September 11th 2001. Modified tours were resumed in December 2001 and a new "Discovery Tour" was added the following year. Annually, nearly a million people take the tours of the dam offered by the USBR. However, increased security concerns in the wake of 9/11 have led to most of the interior structure being inaccessible to tourists.

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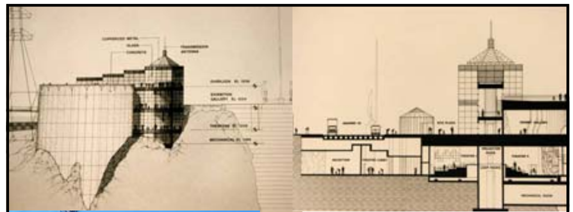

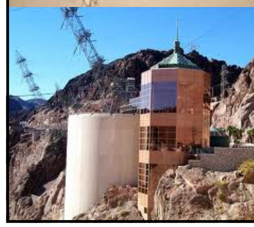

<u>Above</u>: elevation (left) and section (right) view/s of the Visitor's Center (1995)
<u>Left</u>: Hoover Dam Visitors Center

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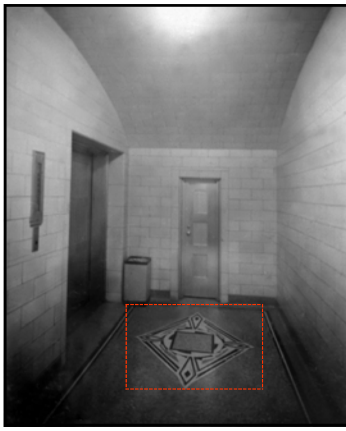

<u>Left</u>: Elevator Lobby (at elevation 705; Arizona side of dam), showing aluminum elevator doors, tile gallery finish, and Terrazzo floor (with Allen Tupper True Native-American inlay decoration; January 1938)
<u>Above</u>: Arizona Elevator Lobby (at Elevation 743) in the central section of the power plant (Allen Tupper True Native-American inlay at lower right; January 1938)

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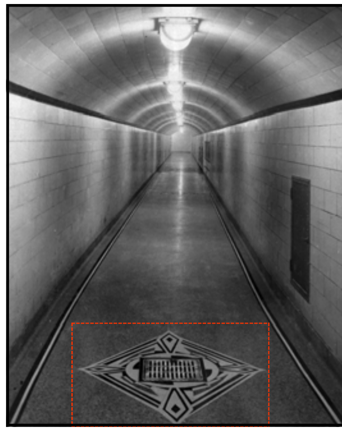
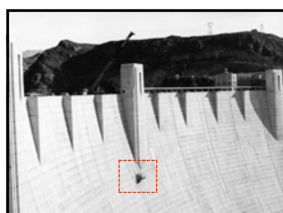


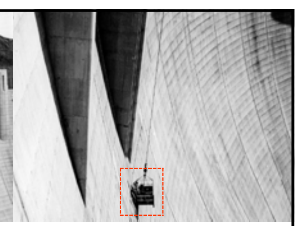
Gallery (at Elevation 705) inside the dam, Arizona side, (leading from the Elevator Lobby to the powerhouse). Note the Native-American decorative floor inlay (by Allen Tupper True; November 1936)

880

<u>Left</u>: downstream portal of the *Powerhouse Highway Tunnel.* This tunnel is 1900-feet long and is vital in transporting men and materials to the powerhouse relieving the demand on the elevators and cableway (June 1936).
<u>Above</u>: view upstream through the Powerhouse Highway Tunnel. At right is seen the pipeline for the Boulder City water supply carrying water to what was the river pumping station for the Boulder City system (June 1936).

881





Workmen in maintenance platform lowered down face of dam to repair construction joint at Elevation 1160 (the joint was leaking rain water into elevator shafts; November 1977)

882

Left: view showing the Hoover Dam Plaque mounted on the Arizona Elevator Tower (November 1972)
Right: ***Herbert Clark Hoover*** **Memorial Plaque**

883

Part 7

Legacy

884

POWER AND WATER PAY THE BILL

LIKE ALL other Reclamation projects, Hoover Dam is a self-supporting and self-liquidating venture. The cost of the dam and power plant is being repaid to the United States Government almost wholly through the sale of electrical energy. A small contribution toward repayment is being made through water storage charges.

Thus the project is an investment, from which the American people will benefit in many ways. Not only will the capital costs be repaid, but power and water necessary for the development of a rich area will be provided. The value of the production thus made possible will circulate to every part of the country. Federal taxes alone on the wealth created by the dam will amount to many times the cost of the dam.

The cost of building the dam, power plant, and appurtenant works is estimated at $174,270,000, of which $25,000,000 has been allocated to flood-control features.

Costs, other than the allocation to flood control, are being repaid with 3-percent interest within 50 years. Repayment of the flood-control cost has been deferred, without interest, until after May 31, 1987.

Since commercial power production began in October 1936, Hoover Dam has returned to the Federal Treasury an average of $5,000,000 annually. Operation and maintenance cost, reserves for replacing project facilities, and amortization of costs of generating facilities are all financed from revenues received.

The United States has contracted to furnish electrical energy from the project to the States of Nevada and Arizona, to the cities of Los Angeles, Pasadena, Burbank, and Glendale, and to the Metropolitan Water District of Southern California, the Southern California Edison Co., and the California Electric Power Co. It also supplies power to Boulder City, Nev.

Contracts for the sale of stored water from Lake Mead have been executed with the States of Arizona and Nevada and with a number of irrigation and water districts in California and Arizona.

Industrial use of power helps pay costs

Controlled water disposal prevents floods

885

POWER

Hoover Dam is one of the world's largest producers of power. Energy generated at the Hoover power plant, which is marketed at low cost, has been a boon to industrial expansion and has made living more comfortable in thousands of homes.

Hoover Dam power has been largely responsible for the rise of a great new industrial region in the Pacific Southwest, a region including some of America's most important aircraft, automobile, tire, textile, rubber goods, and chemical industries.

The power plant is a U-shaped structure built against the downstream toe of the dam. On September 11, 1936, the late President Franklin D. Roosevelt started the first generator in the plant by turning a golden key in Washington, D. C.

Installed in the power plant are 14 generators rated at 82,500 kilowatts each, one unit rated at 50,000 kilowatts, another at 40,000 kilowatts, and two units at 2,400 kilowatts each. The latter two are station service units. The total aggregate generator capacity of 1,249,800 kilowatts is driven by turbines totaling 1,742,000 horsepower. Space is reserved in the Nevada wing of the power plant for an additional 82,500-kilowatt unit. The installed capacity of the Hoover plant is sufficient to supply the normal domestic needs of 7½ million persons.

The United States has executed contracts for disposal until 1987 of all firm and secondary energy generated at the plant. The firm energy output approximates 4 billion kilowatt-hours annually; and it has been estimated that an average of about 750 million kilowatt-hours of secondary energy will be available each year until 1987, which is the end of the amortization period.

The City of Los Angeles Department of Water and Power and the Southern California Edison Company operate the generating equipment under contract with the United States.

Nevada wing of power plant

Sale of hydroelectric power generated by Hoover Dam is used to pay all operating, maintenance and/or replacement costs (including interest expense and repayment of investments) to meet the requirements of the dam. The cost of construction completed and in service (by 1937) was repaid from power revenues by May 31st 1987 (except for costs relating to flood control). Repayment of the $25 million construction costs allocated to flood control will be repaid by 2037. Any features added after May 31st 1987 will be repaid within 50-years of the date of installation (or as established by Congress). In addition, the states of Arizona and Nevada each receive a $300K *PILOT* (<u>P</u>ayment <u>I</u>n <u>L</u>ieu <u>O</u>f <u>T</u>axes).

886

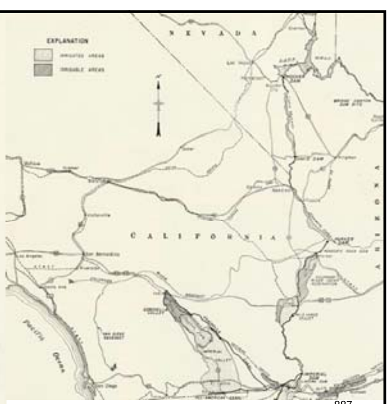
IRRIGATION

Water is the lifeblood of the arid West. The region along the Colorado River below Hoover Dam receives no more than five inches of rain each year and, without irrigation, crop production is out of the question. With irrigation, hundreds of thousands of acres are in cultivation.

An all-year growing season and a stable water supply combine to make this section of the Nation one of its richest producers of vegetables and fruits. Field-scale production of lettuce, cabbage, carrots, other vegetables, and melons afford a variety of foodstuffs for family midwinter dinner tables in all parts of the country. Other specialty crops produced with a dependable supply of water for irrigation include dates, citrus fruits, and early table grapes. There are also large yields of alfalfa, barley, flax, cotton, and other field crops. With the hay and field crops produced annually, cattle and sheep are brought from arid range lands and fattened for markets.

Presently about two-thirds of a million acres of land are in irrigated farming in the Palo Verde Valley, on the Colorado River Indian Reservation about 200 miles downstream from Hoover Dam, on the Yuma and Gila projects another 100 miles downstream, and in the Imperial and Coachella Valleys in southern California.

In some regions along the lower Colorado River, land was irrigated by pumping from underground sources. But continued use of these sources has lowered water tables to the extent that the irrigated acreages are in jeopardy. This was true particularly on the Wellton-Mohawk division of the Gila project, in Arizona, and in the Coachella Valley, in California. Developments now under way on the Gila project will supply water for irrigating 115,000 acres of land on the project; and the Coachella branch of the All-American Canal assures a stable water supply for some 78,500 acres in the Coachella Valley.



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Map of Irrigated Areas (printed by USBR)

Environmental Impact

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The changes in water use caused by Hoover Dam's construction has had a significant impact on the *Colorado River Delta*. The construction of the dam has caused the decline of this *Estuarine* ecosystem. For six years after the construction of the dam (and while Lake Mead filled), practically no water reached the mouth of the river. The delta's estuary (which once had a freshwater-saltwater mixing zone stretching forty miles south of the rivers mouth) was turned into an inverse estuary where the level of salinity was higher close to the river's mouth. The Colorado River had experienced natural flooding before the construction of Hoover Dam but the dam eliminated the natural flooding thus imperiling many plant and animal species adapted to the flooding. The construction of the dam devastated the populations of native fish in the river downstream from the dam. Four species of fish native to the Colorado River; the *Bonytail Chub*, *Colorado Pike Minnow*, *Humpback Chub*, and *Razorback Sucker* are listed as endangered species.

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View upstream from Hoover Dam (July 2009) shows that the water level has decreased drastically

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Postcards from the (Canyon) Edge

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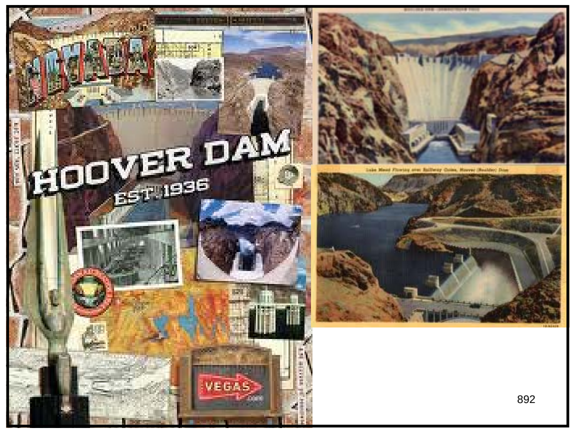

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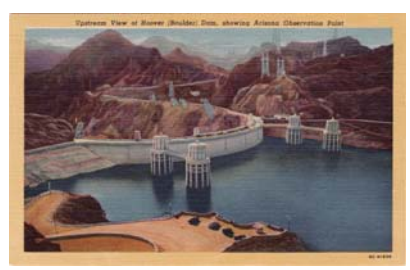

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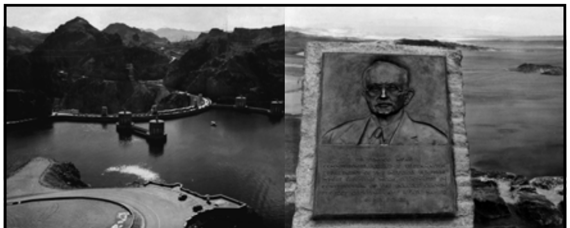

Left: upstream face of Hoover Dam and Intake Towers (from a high point above the Arizona Observation Point). Elevation of Lake Mead was 1219.50 (August 1941).
Right: Plaque in honor of *Dr. Elwood Mead*, late USBR Commissioner (located on Observation Point; April 1938)

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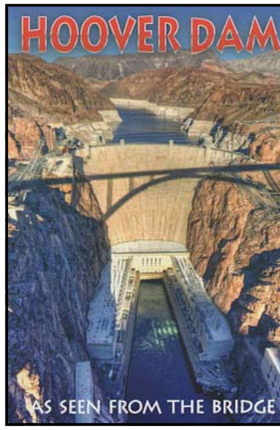

There are two lanes for automobile traffic across the top of the dam (formerly serving as the Colorado River crossing for U.S. Route 93). In the wake of 9/11, authorities expressed security concerns and the *Hoover Dam Bypass* project was expedited. Pending the completion of the bypass, restricted traffic was permitted over Hoover Dam. Some types of vehicles were inspected prior to crossing the dam. Semi-trailer trucks, buses (carrying luggage) and enclosed-box trucks (over 40-feet long) were not allowed on the dam at all, and were diverted to other local roads. The four-lane Hoover Dam Bypass opened on October 19th 2010. It includes a composite steel and concrete arch bridge (1,500-feet downstream from the dam) and was named: *Mike O'Callaghan–Pat Tillman Memorial Bridge*. With the opening of the bypass, through traffic is no longer allowed across Hoover Dam. However, dam visitors are allowed to use the existing roadway to approach from the Nevada side and cross to parking lots and other facilities on the Arizona side.

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Hoover Dam Bypass Bridge

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Hoover Dam by *Ansel Adams* (1942)

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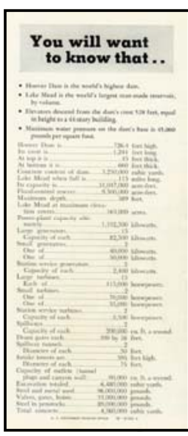

You will want to know that . .

Facts to Know. **Printed by United States Department of the Interior, Bureau of Reclamation; builder/operator of Hoover Dam.**

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