ANDERSON RANCH DAM

BOISE PROJECT, IDAHO

By Fred J. Davis

When the last cubic yard of earth material was compacted in place at Anderson Ranch Dam on October 10, 1947, contractors, under the supervision of Bureau of Reclamation engineers, had successfully completed construction of the highest earth embankment in the world.

To complete such an undertaking, the contractors were required to excavate about 11,300,000 cubic yards of earth and rock materials. This is roughly equivalent to excavating 960 acres, or an area 1 by 1½ miles, to a depth of 10 feet.

Anderson Ranch Dam is located in a relatively narrow rugged canyon of the South Fork of the Boise River, about 30 miles north of Mountain Home, Idaho. Bids for its construction were opened on July 7, 1941, and the contract was awarded to a combine of Morrison-Knudsen Company, Incorporated; J. F. Shea Company, Incorporated; Ford J. Twaits Company; and Winston Brothers Company, Construction Contractors. Active construction work was begun in August 1941, and the embankment, including rock fill and riprap, was completed in December 1947. Labor and material shortages, and the uncertain status of the project during the war years, 1941 to 1946, seriously hampered the progress of construction.

In December 1942, the War Production Board issued an order to cease all activity on the project, except that considered necessary to protect the work already accomplished. This order was later modified to permit construction of the outlet works intake structure and the installation of an emergency discharge regulating device. This work allowed the storage and release of 80,000 acre-feet of water in 1946, and 130,000 acre-feet in 1947, to the Boise Valley, materially aiding the production of foodstuffs in the Boise area.

PURPOSE

Plans for development of the Boise project call for Anderson Ranch Dam initially to provide supplemental storage to prevent a shortage of irrigation water in those project lands lying for the most part between the Boise and Snake Rivers. Later development contemplates diversion of water from the Payette River to that area and Anderson Ranch Reservoir will then serve as a source of supply for irrigation of the 400,000-acre Mountain Home area.

In addition to serving these irrigated lands, Anderson Ranch Dam provides flood control benefits to the Boise Valley and its power plant adds to the power potential of the area. The lower 30,000 acre-feet of the reservoir are reserved for silt control.

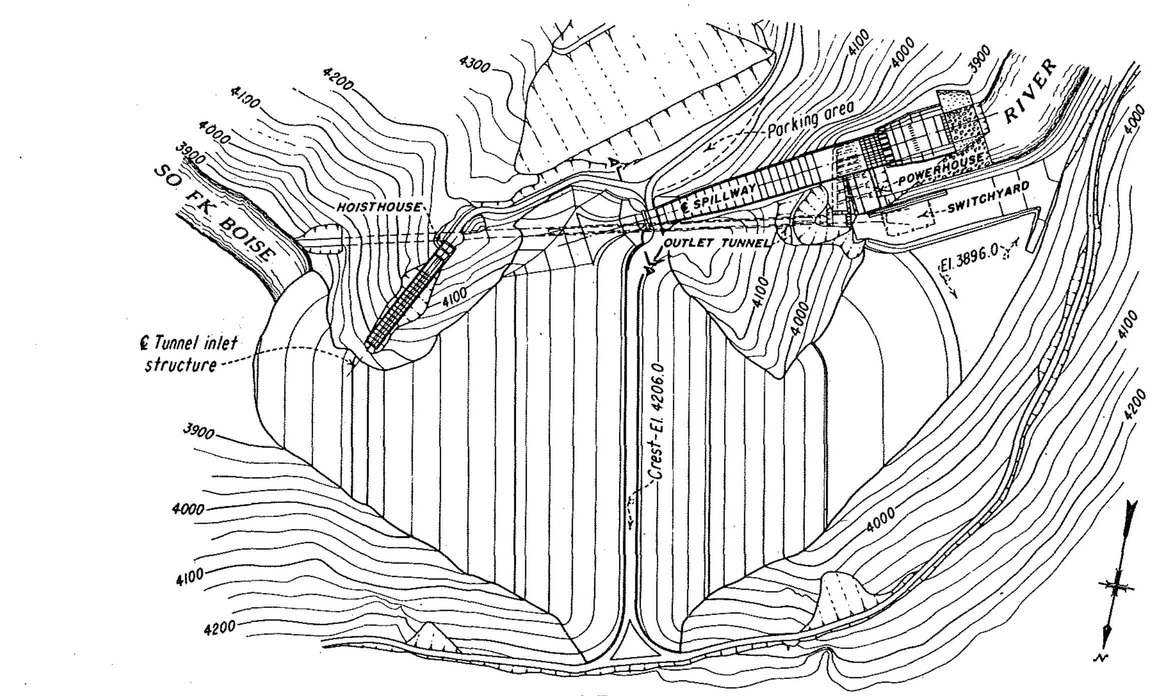
THE DAM

The design and construction of an earth-fill dam considered, at the time of its construction, to be the highest in the world, posed unprecedented problems for both the designers and the constructors. The depth of overburden in the stream channel, the relatively weak and broken bedrock, and the absence of nearby sources of large quantities of suitable concrete aggregates were important factors which influenced the decision to construct the embankment of earth materials. Quantitative considerations called for extensive explorations in the field to locate approximately 10,000,000 cubic yards of embankment materials. In addition to the ordinary laboratory tests performed to determine the physical properties of embankment materials, special testing was necessary to establish placement control procedures which would assure a stable structure. The variety of earth materials available permitted the design of a zoned embankment, particularly desirable for a structure of the height contemplated. The problem of securing a stable structure while utilizing the available materials from the most economical locations was frequently reanalyzed as additional information became available, and the zoning was modified several times between the preliminary design and completion of construction.

Water in the reservoir rises nearly to the spillway level and pours through the penstock into the turbines; and Anderson Ranch Dam is in service.

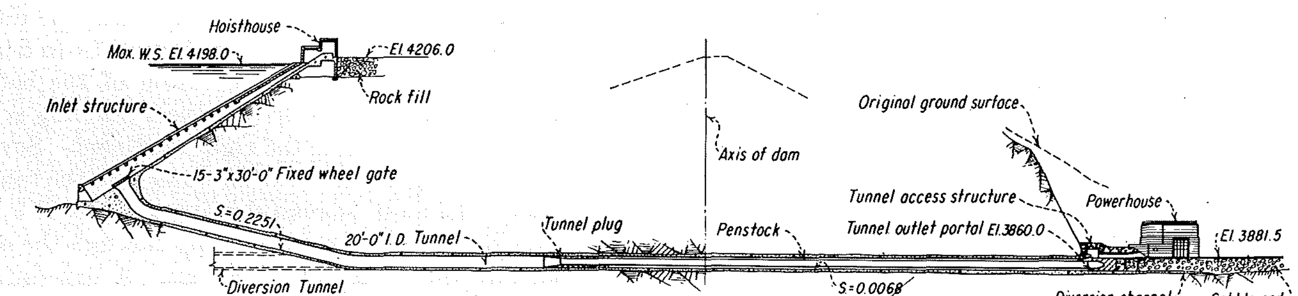
The 40-foot-wide crest of the embankment is approximately 330 feet above stream-bed elevation and 456 feet above the lowest point in the cut-off trench. The crest length is 1,400 feet and the base width is about 3,000 feet in the original river channel section. The central portion of the embankment is constructed of impervious material and functions as the water barrier. A pervious zone is provided downstream to drain the inevitable seepage through the impervious core, and between this pervious zone and the core a transition zone of semipervious material is provided to preclude any possibility of removal of the fine core material by the percolating water. Providing additional safety against failure of the downstream slope is a zone of rock fill. A 6-foot filter blanket of sand and gravel beneath the downstream pervious and rock-fill zones prevents possible loss of fine material from the foundation through these zones. Upstream from the central core, a semipervious transition zone and a pervious zone lend stability to the upstream slope during reservoir drawdown and prevent removal of fines from the impervious zone by wave wash through the 3-foot blanket of protective riprap.

A cut-off trench, 200 feet wide at the maximum section, extends through the river bottom materials and the abutment overburden to bedrock. Two concrete cut-off walls, with a maximum height of 16 feet and with footings extending 3 feet or more into bedrock, are located in the cut-off trench across the bottom of the canyon and up the abutments. These serve to prevent seepage along the contact of the cut-off trench backfill and the bedrock. Cement grout pumped under pressure through vertical holes on 10-foot centers forms curtains under each concrete cut-off wall. These grout curtains extend as much as 150 feet into the foundation rock and,

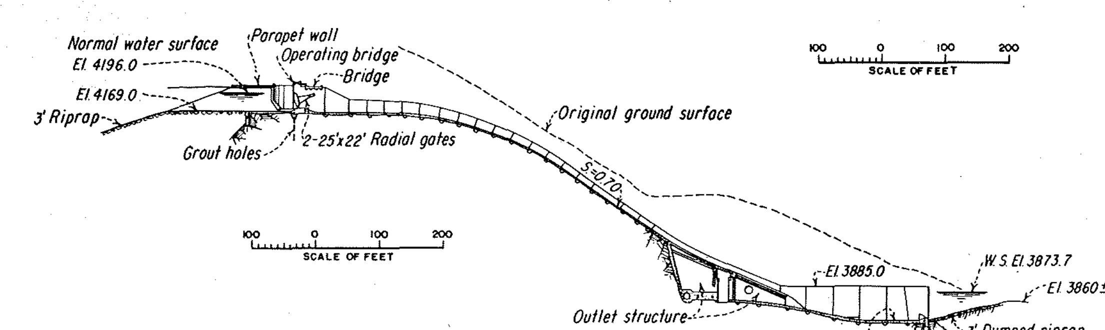


GENERAL PLAN

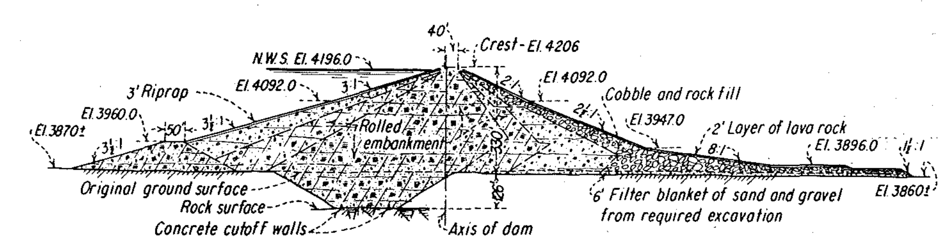
SCALE OF FEET



PROFILE ON ℄ OF OUTLET WORKS

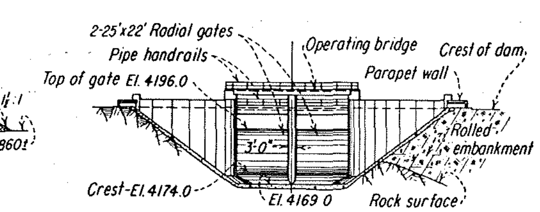


PROFILE ON ℄ OF SPILLWAY



SECTION IN RIVER CHANNEL

SCALE OF FEET



SECTION A-A

together with blanket grouting through holes 30 feet deep on 20-foot centers between the two walls, provide insurance against excessive seepage underneath the dam.

The upstream slope of the embankment is protected from wave action by a 3-foot layer of hard, durable, lava rock riprap. A 2-foot layer of similar rock placed on the face of the downstream rock-fill zone protects the friable granite in this zone from erosional and weathering damage and provides a uniform appearance of the slope.

RESERVOIR

When filled to capacity at elevation 4196, the reservoir is about 13 miles in length and contains 500,000 acre-feet of water, or more than 163 billion gallons. A county road, extending up the river valley, and several Forest Service roads were inundated. To provide access to the ranches, timber areas, mining properties, and recreational areas above the reservoir, more than 30 miles of gravel-surfaced roads were constructed. Much of this was difficult and expensive construction along the steep side slopes forming the reservoir. Nearly 5,000 acres were cleared of all timber and brush. All merchantable timber was salvaged and the remaining trees and brush were stacked and burned. The small village of Pine, Idaho, was purchased, and all usable properties salvaged before storage of water commenced. Three bridges across the river in the reservoir area were salvaged and used on the relocated road.

CONSTRUCTION

An effective means of diverting the river from its channel through the embankment area was provided by driving the 1,500-foot long, 24-foot diameter outlet tunnel through the left abutment. Working from both portals on a three-shift basis, the contractor excavated the tunnel in 80 days. Construction operations were planned so that concreting of the lining could be started while excavation of the tunnel was progressing. Practically all materials from tunnel excavation were placed directly in appropriate zones of the embankment. The original design called for construction of an intake structure at the upstream end of the diversion tunnel. As construction progressed, however, evidences of instability of the left abutment overburden began to appear. After several slides had developed in this area, the location of the intake structure was moved to a ridge of hard rock downstream and to the right of the original location. Construction of the intake structure on the steep slope, and excavation of the inclined tunnel which connects it with the outlet tunnel presented difficult construction problems, which required unique modification of mucking machines and maximum use of cable hoists.

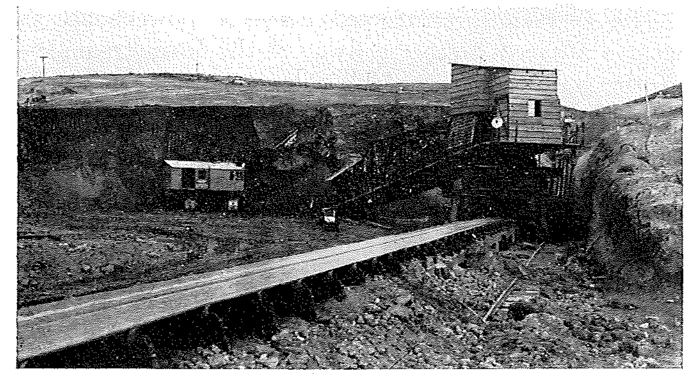
As soon as the diversion tunnel had been lined with concrete, excavation of the overburden from the nearly vertical abutments was started. Top soil, vegetation, and other organic material were stripped and wasted. The remainder of the material was placed in the cofferdam or stock-piled for later use in the main embankment. With the cofferdam in place, the initial diversion of the river was successfully accomplished in spite of the high flows prevalent in the river at that time, and excavation of the river bottom material was begun immediately.

After completion of the intake structure, including the installation of a fixed-wheel bulkhead gate, the diversion tunnel was blocked by a heavy timber bulkhead supported against the upstream end of the tunnel lining and reinforced by three 36-inch steel beams embedded in the concrete lining. Eighty feet of the diversion inlet was then backfilled with concrete and the river was permanently diverted through the outlet tunnel.

It was anticipated that large quantities of water seeping into the cut-off trench would cause much difficulty during excavation of the cut-off trench, preparation of the cut-off wall foundation, foundation grouting, and backfilling. To handle seepage, the contractor dug two vertical shafts—one upstream and one downstream from the axis near the left abutment—to depths into the rock well below the elevation of the bottom of the cut-off trench, with drift tunnels reaching across the valley to a point near the right abutment. Several plans of draining the foundation water into the tunnels were tried, the most successful being a series of 3-inch diameter perforated pipes extending through the overburden into the roofs of the tunnels. A cave-in of a portion of the upstream tunnel filled it with sand and rendered this system largely inoperative. Pumps were maintained at each shaft, however, and a small amount of water was removed by this system. The greater portion of the seeping water was pumped from sumps in the bottom of the trench as the excavation progressed. Well points installed on the trench slopes, and extended downward as the excavation progressed, removed additional water and prevented sloughing of the steep sloping sides of the trench. In general, the anticipated difficulties from seeping water did not materialize, a maximum of about 2,700 gallons per minute being encountered.

Material from the cut-off trench was classified as it was excavated and directed to appropriate sections of the embankment, to waste piles, or to stock piles. About 630,000 cubic yards of material were removed in 110 days of around-the-clock operation.

The two concrete cut-off walls were constructed across the river bottom and partially up the abutments as soon as possible after the foundation had been excavated to bedrock. Drilling and grouting the cut-off curtains



In the borrow pits, powerful shovels excavated selected material and placed it within reach of a pendulum feeder which straddled the conveyor belt leading to the dam embankment. The pendulum feeder could be swung in any direction to pick up material.

through pipes placed in the cut-off wall footings followed immediately.

When the grouting and cut-off walls had been completed, backfilling of the trench was begun. Most of the material for the central zone 1 portion of the embankment, of which the cut-off trench is a part, was obtained from the Dixie borrow pit, located on a high flat about 2 miles downstream from the left abutment and 1,200 feet above river bottom. Because of the cost and difficulty of constructing haul roads to this area, the contractor decided to install a conveyor system to transport the material to the embankment. The material was excavated by two 5-cubic-yard shovels and dumped into a hopper at the end of a "pendulum" belt feeder. From this feeder belt, material was transferred to the first of the six flights of main conveyor belt. The 2-mile-long system of belts moved the material at a speed of 550 feet per minute—a little more than 6 miles per hour—and had a maximum capacity of 900 cubic yards per hour. The material was discharged from the end of the system over the left abutment and allowed to roll down the steep slope to the embankment level. It was found that the most practical method of adding moisture to the material, when needed to insure the desired placement condition, was by jets spraying the soil as it was dumped from the conveyor belt.

Materials for the semipervious and pervious zones were obtained mainly from the Whipple borrow area (a delta deposit upstream from the dam), from the slide area excavation on the left abutment, from required excavation, and a small amount from the Dixie borrow area. Approximately 2,200,000 cubic yards of these materials had to be processed through a separation plant. The plant had an operating capacity of 900 cubic yards per hour and produced three types of material; namely, rock fill, pervious, and semipervious.

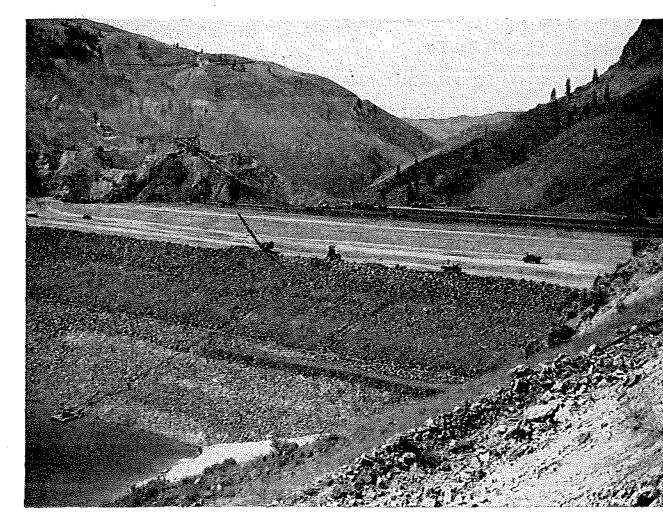
The impervious and semipervious zones were placed in 8-inch loose layers, moistened additionally if necessary to meet the pre-established limits, and rolled 12 passes with ballasted tamping rollers having two 5-foot sections and weighing 20 tons. Lifts that became smooth from truck travel, or that dried out, were scarified and moistened before a new lift was placed. All rocks over 5 inches in maximum dimension were removed from the fill before rolling was allowed. Along the cut-off walls, at abutment contacts, and in other areas inaccessible for the large rollers, compaction was obtained with pneumatic hand tampers and with a job-constructed narrow-drum frameless roller.

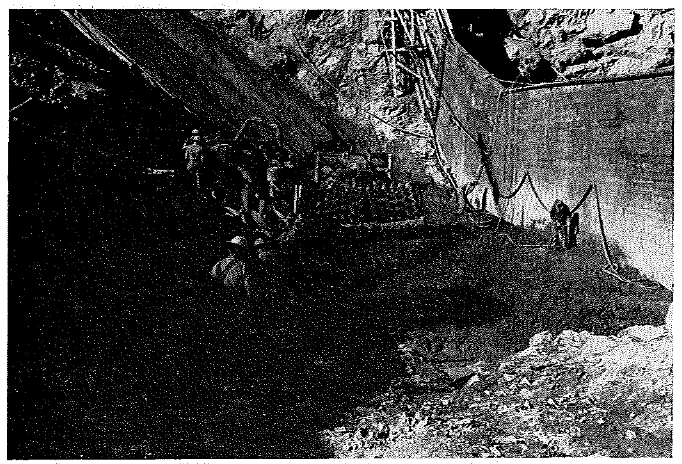
In the bottom of the cut-off trench and up the abutments in the area beneath the impervious zone, the bedrock was carefully cleaned by hand and with air and water jets before embankment material was placed. The foundation area under the rock-fill zone was leveled and rolled before the filter blanket consisting of free-draining, coarsely graded sand and gravel was placed. The material was placed in 12-inch layers, saturated, and compacted by travel of construction equipment.

The pervious zone material was placed in 12-inch layers and compacted by sluicing and travel of the construction equipment. The rock fill was placed in 3-foot layers and covered with a 2-foot layer of lava rock. The riprap rock, ranging in size from one-half cubic foot to one-half cubic yard and larger, was placed on the upstream slope, keeping pace with the embankment placing. Some hand work was necessary to obtain uniform distribution of the larger riprap rock and to dress up the slope.

To maintain control of the placement moisture and

Embankment material from the borrow pits was delivered at the dam by belt conveyor, and spread and compacted by the usual construction equipment. In this photograph, the material being delivered and placed was in the impervious zone of the dam. In the foreground, the upstream slope of the embankment was being surfaced with rock for wave protection.





Placing the earth fill at Anderson Ranch Dam required the use of hand-operated pneumatic tampers near the cut-off walls and against steep rock surfaces where the tractor-drawn tamping rollers could not reach.

density values within acceptable limits, Bureau personnel performed over 3,000 field density tests on material for the compacted zones of the dam. A test pit excavated through a portion of the constructed embankment showed that although inspection forces were hampered throughout the war years by personnel shortage, satisfactory placement of the materials had been achieved.

APPURTENANT STRUCTURES

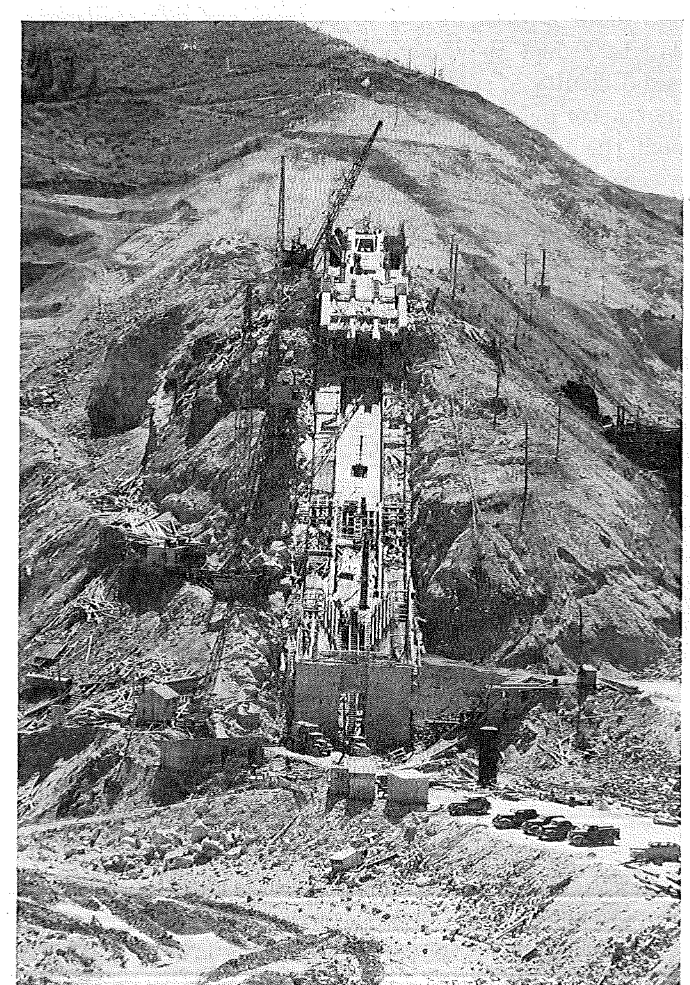
The concrete-lined outlet tunnel, through which water releases are made for power production and irrigation requirements, has an inside diameter of 20 feet for the full length. Average thickness of the lining is about 2 feet. The intake structure is furnished with trashracks and a mechanical rake for removing debris. A hoist house, located at the top of the intake structure, houses a hydraulic winch which, by means of a 6¾-inch diameter steel shaft 380 feet long, operates the bulkhead gate for emergency closure of the tunnel, and also the trash rake.

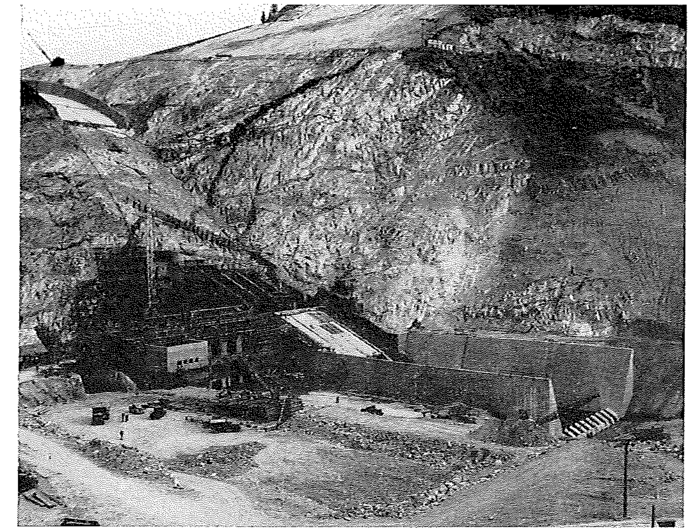
A concrete plug in the outlet tunnel located a short distance upstream from the dam axis encases the upstream end of a 15-foot diameter, plate-steel pipe. Near the downstream toe of the dam, the pipe is curved downward and to the left and tapers to 96 inches in diameter. Each of the five 72-inch outlet pipes leading from the tapering section are provided with regulating valves to control the irrigation discharges. Owing to the limited space available in the canyon bottom, the outlet works are located directly beneath the end of the spillway chute. Heavily reinforced concrete construction adequately supports the spillway over the control house. The outlet works is designed for a maximum discharge of 10,000 cubic feet per second.

The two-story, reinforced concrete powerhouse is located adjacent to the spillway at the downstream toe of the dam. Three 90-inch diameter steel penstocks branching from the tapering section of the outlet pipe provide water releases to the plant. Flow to the turbines is controlled by 100-inch butterfly valves, and the turbines in turn drive the 15,000-kv.-a., vertical-shaft generators. Space is provided for installation of a third unit in the future. The plant is equipped with a 60-ton traveling crane for use in handling heavy equipment.

The spillway, a concrete-lined open channel cut through a prominence of the left canyon wall and down the abutment to the river channel, is designed for a maximum discharge of 20,000 cubic feet per second. The flow is regulated at the crest by two radial gates operated by automatic, float-controlled power hoists. An ice prevention air system consisting of air compressors, distributing pipes, and strategically located dis-

The intake structure of the outlet works was built on a spur of the mountainside on a long slope. Spidery derricks placed concrete delivered to the structure by truck mixer.





Erection of the powerhouse and construction of the downstream portion of the spillway, outlet works, and the stilling basin were carried out simultaneously.

charge nozzles is installed in the gate structure to prevent ice from rendering the automatic controls inoperative. The broken, shattered condition of the rock at the gate structure location required the construction of heavy, counterforted walls in this section, in lieu of lighter walls placed directly against the rock.

The spillway channel chute is unusually steep, having a maximum slope of 0.70 to 1. Steel bars, 1¼-inch square, spaced on 7-foot centers, anchor the floor of the chute to the rock. The channel width flares from 53 feet near the top to 100 feet at the stilling basin in order to spread the sheet of water as it cascades down the incline into the stilling basin. The lower portion of the channel chute extends over, and is supported by, the outlet works control structure described previously. Dentated sills are placed at the end of the stilling basin to further dissipate the destructive energy of the discharging water.

INSTRUMENT INSTALLATION

To determine the behavior of the completed embankment, piezometers and cross arms were embedded in the dam as construction progressed.

CONCLUSION

Anderson Ranch Dam is rendering invaluable service to the Boise region. For the first four years after storage began in 1946 precipitation and river flow were considerably below normal, yet supplemental irrigation water was released to the developed project lands each year and substantial gains in crop production were realized. Precipitation was slightly above normal in 1950 and 1951 and, on April 10, 1951, the spillway operated for the first time. The first of two 13,500-kilowatt capacity generating units (with provision for a third) began operation in December 1950 and the second in July 1951. In 1952, a dry year, the power plant delivered 141,000,000 kilowatt-hours of electrical energy to the area.

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