FLAMING GORGE DAM

A review of design, site conditions, diversion plan, access, and current construction

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IN MAY 1869, Major John Wesley Powell, renowned Western explorer of the Colorado River and its tributaries, wrote in his diary of exploration down the Green River in Utah:

"The river is running to the south; the mountains have an easterly and westerly trend directly athwart its course, yet it glides on in a quiet way as if it thought a mountain range no formidable obstruction to its course. It enters the range by a flaring, brilliant, red gorge, that may be seen from the north a score of miles away. "This is the head of the first canyon we are about to explore—an introductory one to a series made by the river through this range. We name it FLAMING GORGE."

About 25 mi. downstream from the head of Flaming Gorge and some 90 years after Major Powell's famed passage down the Green River, the Bureau of Reclamation is constructing Flaming Gorge Dam and Powerplant to store the river's water for conservation and power production. The dam, in northeastern Utah about 6 mi. south of the Utah-Wyoming state line and about 20 mi. west of the Utah-Colorado state line, is the second major feature of the Colorado River Storage Project to be started. It was preceded by the 700-ft. Glen Canyon Dam on the Colorado River in northern Arizona, started in April 1957.

Construction of the dam and power plant began in July 1958 under a $29,602,497 contract awarded to The Arch Dam Constructors of Omaha, a joint venture firm comprised of Peter Kiewit Sons' Co., Morrison-Knudsen Co., Inc., Mid-Valley Utility Constructors, Inc., and Coker Construction Co., Inc.

The dam is scheduled to be completed in the summer of 1963, and the power plant is expected to be in operation by the fall of the same year.

Project features

Flaming Gorge Dam is a concrete-arch structure having a height of 490 ft. above foundation, a crest length of 1,180 ft., and a volume of 922,000 cu. yd. It is a relatively thin-arch dam; its crest width is 27

LOOKING downstream through the Flaming Gorge Dam site showing the position of the structure and the bend in the canyon that provided the location for the diversion tunnel through the abutment on the right. The dam will be 490 ft. high above lowest point in the foundation.
ft. and maximum base width is 150 ft. Principal quantities of materials required for the dam, spillway, outlets, and power features are shown in the accompanying tabulation. Most of the materials listed will be supplied by the contractor. In addition to these materials, the Bureau will purchase the larger items of special machinery and equipment under separate advertisements to be issued as designs are completed.

**Flaming Gorge Reservoir** will have a total storage capacity of 8,789,000 ac. ft. and will extend 91 mi. up the Green River, nearly to the town of Green River, Wyo. The reservoir will help provide the long-time regulatory storage needed to permit the states of the Upper Colorado River Basin to utilize their apportioned water and still meet their flow obligations at Lee Ferry, Ariz. (the dividing point between the Upper and Lower basins), under terms of the 1922 Compact of the Colorado River. The 108,000-kw. Flaming Gorge Powerplant will generate a portion of the electrical energy needed in the Upper Basin. Surplus revenue from sale of this energy will assist irrigators in the Upper Basin to repay costs of constructing the participating projects which were authorized by the Congress in 1956 to be developed with the Colorado River Storage Project.

**Dam site**

The dam site is near the east end of the Uinta Mountains and is within the Ashley National Forest. The lower 25 mi. of the reservoir are largely within the Flaming Gorge and Red canyons, rugged, steep-walled, and inaccessible canyons having average depths of about 1,500 ft. Bedrock at the dam site, about 25 ft. below the river surface, is a part of the Uinta formation. It consists of quartzite, quartzite conglomerate, quartzose sandstone, and a few thin beds of shale. The shale beds are hard and well cemented with iron oxide and are competent to support the dam. Both abutments are composed of Uinta quartzite and have interlayers of shale, varying from a few inches to 3 or 4 ft. in thickness. The quartzite ranges from moderately hard, coarse material cemented with silica to extremely hard, fine-grained material. Tests indicate the shale is more porous than the quartzite, and foundation treatment by cut-off and backfilling with concrete may be required for the thicker beds.

In its course through the reservoir area, the Green River meanders in a large half-circle. At the dam site, the river’s general direction is southeast, but it makes a 40-deg. curve to the south at the axis of the dam. This curve provides excellent inlet and outlet sites for the diversion and spillway tunnels. Both abutments of the dam rise steeply by steps of vertical ledges separated by gently sloping shelves. A shoulder extends out from the right side, which makes the location particularly suitable for the arch dam.

**Dam construction**

Open-cut excavation for the upstream portal of the diversion tunnel, the first major construction activity at the dam site, began in September of last year. The 1,100-ft. tunnel is being driven through the right abutment rock. It will be concrete-lined and have an inside diameter of 23 ft. and a diversion capacity of 18,000 sec. ft.; minimum thickness of the lining will be 12 in. The tunnel was holed through early in March; concrete lining is expected to be completed early in June. Diversion of the river through the tunnel is scheduled for mid-September of this year.

Closure of the diversion tunnel will be made in the fall of 1962. During the first stage of closure, stoplogs will be inserted in the upstream section of the tunnel, and the reservoir will fill to the elevation of the intake of two 72-in. river outlet conduits. A conduit, 2 ft., 9 in. square, in the closure structure will bypass nominal river flows to meet downstream commitments during this initial period of minor impoundment. For final closure, the bypass conduit will be closed by a high-pressure slide gate, and the tunnel will then be plug-
ged by a concrete plug 62 ft. long.

The dam is to be divided into blocks by radial or transverse contraction joints to confine shrinkage cracks to predetermined planes throughout the mass. As the dam is sufficiently thin, no longitudinal contraction joints are required. The blocks will extend the full thickness of the dam and will average about 50 ft. in width. The contraction joints will be grouted to assure watertightness and monolithic action of the dam and are to be interlocked by keys.

Placement of concrete in the dam is scheduled to begin in June 1960. The contractor will place the concrete in 70-ft. lifts. The maximum differential in the elevations of adjacent blocks is not to exceed 30 ft., and the rate of placing concrete in any block will be restricted so that not more than one horizontal lift can be placed in 72 hr.

Concrete in the dam will be cooled by river water pumped through a system of 1-in. tubing embedded in each lift of concrete. To obtain initial cooling, river water is to be circulated through the cooling system for 12 days, immediately following placement of concrete around the tubing. About 135 mi. of tubing will be embedded in the concrete. Subsequent to the initial cooling period, the cooling of the concrete will be completed by river water circulated through the tubing during the winter months (thus avoiding the use of a refrigerating plant) until the temperature of the concrete has been reduced to 38 deg.

After the temperature of the concrete has been lowered to 38 deg., the open transverse contraction joints will be filled with grout through a system of embedded piping and outlets. The concrete will be successively cooled and grouted in 60-ft. high lifts. When the proper cooling temperature has been attained and the contraction joints grouted, the cooling tubing will be filled with grout.

To seal seams and fissures in the canyon rock in the foundation and abutment areas, initial low-pressure grouting followed by main cutoff high-pressure grouting will be carried out. The low-pressure grouting, preceding placement of concrete, will be done through holes drilled on 20-ft. centers to a depth of about 25 ft. to form an impermeable zone under the upstream portion of the dam. After the concrete has been placed to a sufficient height, holes for the main cutoff grout curtain will be drilled from the floor of the foundation gallery into the formation rock to depths varying from 50 to 200 ft.

A curtain of drainage holes, having depths of from 30 to 60 ft., will be drilled into the foundation rock from the floor of the foundation gallery immediately downstream from the high-pressure grout holes. Formed drain holes to be constructed from the foundation gallery to the crest of the dam will intercept any possible leakage along the 7½-ft. lift planes. Drainage from the foundation gallery will be collected in a sump off the lowest point in the gallery and pumped out of the dam.

Concrete for dam

Laboratory investigations for the interior mass concrete of the dam indicate that a minimum of about 3 sacks of cementitious material per cubic yard of concrete are necessary to meet design strength requirements of 3,000 psi. at 180 days age. Approximate mix proportions for the interior mass concrete (per cu. yd.) are as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cementing material (Type II low-alkali portland cement plus pozzolan)</td>
<td>3 sacks</td>
</tr>
<tr>
<td>Percent pozzolan, by weight of cementing material</td>
<td>20-35%</td>
</tr>
<tr>
<td>Gravel</td>
<td>2,700 - 2,800 lb.</td>
</tr>
<tr>
<td>Sand</td>
<td>800 - 850 lb.</td>
</tr>
<tr>
<td>Water</td>
<td>170 lb.</td>
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Maximum size of aggregate is limited to 6 in. Air entrainment by
an approved air-entraining agent is required in the specifications.

Seven aggregate deposits in northeastern Utah were explored for possible use in the concrete for the dam. Of these, only the deposit on Henry's Fork, a small tributary of the Green River about 15 mi. upstream by road from the dam, contains sufficient quantities of suitable aggregate.

Specifications for concrete in the dam require that unsound, lightweight particles between No. 8 and 1½-in. sizes be removed from the aggregate by heavy media separation or other effective means, as concretes containing aggregates in these sizes exhibit early surface disfigurement in the form of spalling and popouts in freezing and thawing tests.

Essentially, the heavy media separation process consists of introducing the aggregate into a "heavy medium" having a specific gravity between that of the desirable and the objectionable aggregate particles. The lightweight objectionable materials float to the surface and can be carried off as a waste product. The heavier aggregate sinks in the medium and is recovered for use in the concrete.

As petrographic examination indicates the aggregates to be potentially reactive with high-alkali cement, Type II low-alkali portland cement, in conjunction with a suitable pozzolan, was specified. The pozzolan proposed by the contractor is a calcined shale and is now being tested in the Denver laboratories. Also under investigation are water reducing agents which indicate promise of improving concrete quality.

**Powerplant construction**

Flaming Gorge Powerplant is to be constructed at the downstream toe of the dam. It will be a reinforced concrete structure 220 ft. long, 100 ft. wide, and 115 ft. high above foundation. The powerhouse will have a reinforced concrete substructure from foundation to the generating floor and a superstructure of steel rigid-frame bents and 10-in. concrete walls. The roof will be built of lightweight precast concrete slabs.

Construction of the powerhouse will be carried out in two stages. First-stage construction, which is scheduled to begin June 1960, is part of the prime contract for the dam and will include placement of 10,500 cu. yd. of structure concrete, 1,500,000 lb. of reinforcing steel, 850,000 lb. of structural steel, and installation of a 150-ton capacity crane. In addition, 1,750 cu. yd. of mass concrete are to be placed beneath the powerhouse.

Second-stage construction, which will be carried out under a separate completion contract, is to begin in the spring of 1962. It includes placement of 5,500 cu. yd. of concrete and $20,000 lb. of reinforcing steel. With the exception of generators, the completion contract, to be awarded after completion of the major portion of the powerplant under the prime contract, will call for installation of powerplant equipment, exposed piping and electrical conduits, architectural finish, heating and ventilating equipment, and other finish work. The generators will be installed by the generator manufacturer.

**Hydraulic features**

Floodwaters will be passed through a 675-ft. length of tunnel-type spillway extending through the left abutment. The concrete-lined tunnel will have a maximum capacity of 28,800 sec. ft. and will vary in size from 26½ ft. at the upstream portal to 18 ft. at its downstream portal. Part of the tunnel will be inclined at an angle of 55 deg. with the horizontal. Minimum thickness of the tunnel lining will vary from 21 in. at the 26½-ft. section to 15 in. at the 18-ft. section. The spillway intake structure will be controlled by two 16.75 x 51-ft. fixed-wheel gates.

The outlet works for the dam will be comprised of two 72-in. steel pipes through the dam, reducing to 66-in. at the toe of the dam, and continuing downstream to a valve structure on the left river bank where discharges will be directed into the river channel downstream from the powerplant tailrace. The two pipes will have an average length of about 410 ft. Each outlet will be controlled by a 66-in. ring-follower gate at the downstream toe of the dam and a 66-in. hollow-jet valve at the valve structure at the downstream end of the outlet pipe. Maximum discharge through the pipes will be 4,000 sec. ft.

**Access road construction**

Principal access to the dam is by an 18-mi. road which has been constructed between Linwood, Utah, and the left abutment of the dam. The first 7.6 mi. of the road and a 435-ft. temporary timber bridge crossing the Green River were completed in May 1957 by Wangsgaard Construction Co. of Logan, Utah, under a $143,912 contract. The same company completed an additional 7.6 mi. of the road in June 1958 under a $504,642 contract. The remaining 2.8 mi. of road, which extends from the new Government community of Dutch John, Utah, to the dam, and a 1.25-mi. service road to the powerplant are under construction by the prime contractor for the dam.

The nearest railhead is Green River, Wyo., a total haul distance of 63 mi. from the dam site. The distance from Green River to Linwood on a bituminous surfaced road is 45 mi. Haul distance from Vernal, Utah (not a railhead), to the right abutment of the dam is about 45 mi.

**Government community**

The new permanent community of Dutch John, named after a pioneer settler of the area, is about 2 mi. northeast of the dam site in Daggett County, Utah. An essential feature of the Flaming Gorge Unit, the community will provide housing, facilities, and utility services for both the contractor's forces and the Bureau's engineering employees during construction of the dam and powerplant, as well as personnel who will operate the dam and powerplant after they are completed. Maximum population of the town during construction may reach 3,000.

Dutch John occupies about 160 ac. and is about 800 ft. above the Green River. Streets have been laid out in a curving pattern to conform to the topography. The Witt Construction Co. of Provo, Utah, completed early this year a contract for construction of 50 residences, surfaced streets and sidewalks, and construction of water distribution, sewage collection, and surface drainage systems for the town.

**Personnel**

W. A. Dexheimer, whose offices are in Washington, D. C., is Commissioner of the Bureau of Reclamation. The Colorado River Storage Project is in the Bureau's Region 4; E. O. Larson is Regional Director. Jean R. Walton is Project Construction Engineer for the Flaming Gorge Unit; his office is at Dutch John. All designs for the unit are under the direction of L. C. Puls, Chief Designing Engineer of the Bureau.

For The Arch Dam Constructors, Douglas D. Baker is project manager, and Henry C. Scott, project engineer. A tabulation of the unit bids appeared in *Western Construction*, September 1958, page 131.