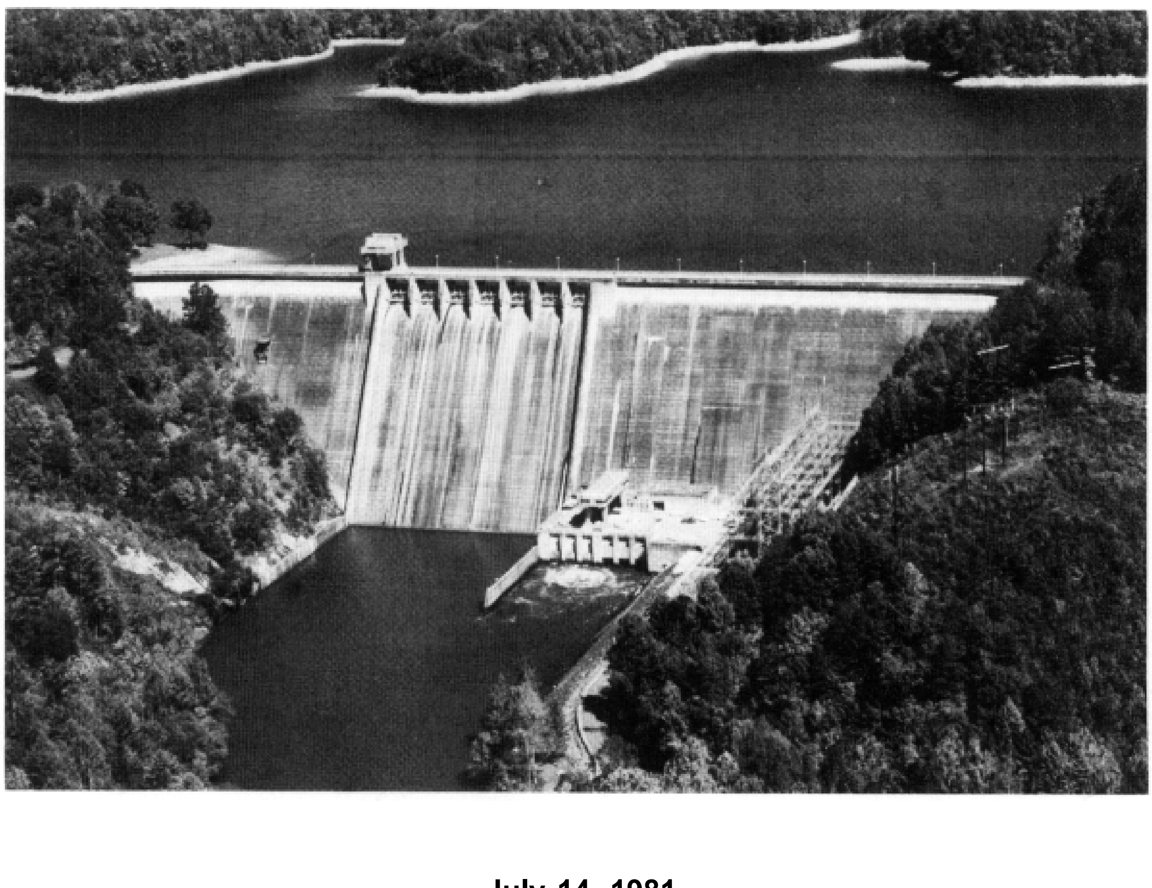
HIWASSEE DAM UNIT 2
REVERSIBLE PUMP-TURBINE (1956)

A National Historic Mechanical Engineering Landmark



July 14, 1981

Murphy, North Carolina

ACKNOWLEDGEMENTS

The East Tennessee Section of the American Society of Mechanical Engineers gratefully acknowledges the efforts of those who helped organize the landmark dedication of the Hiwassee unit 2.

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NATIONAL HISTORIC MECHANICAL ENGINEERING LANDMARK
Hiwassee Unit 2 Reversible Pump-Turbine
1956

This integration of pump and turbine was the first of many to be installed in power plant systems in the United States; it was the largest and most powerful in the world.

As a "pump storage" unit in the Tennessee Valley Authority's system it offered significant economies in the generation of electrical energy.

The unit was designed by engineers of the Tennessee Valley Authority and the Allis-Chalmers Company. It was built by Allis-Chalmers Company.

The Hiwassee unit 2 is the 61st landmark designated by the American Society of Mechanical Engineers. For a complete listing of landmarks, please contact the Public Information Department, ASME, 345 E. 47th St., New York, NY 10017.

HIWASSEE POWER PLANT BACKGROUND

The Hiwassee dam and power plant on the Hiwassee River near Murphy, North Carolina, was built by TVA between 1936 to 1940 as a flood control and electrical generating facility. The initial power installation consisted of a single conventional Francis turbine driving a generator with a rating of 57,600 kW, placed in service in May 1940. Space was provided in the powerhouse for later installation of a second unit.

When studies were begun for the installation of a second generating unit in the late 1940's, a reversible pump-turbine was considered. Installation of a pump-turbine was selected to provide additional generating capacity during periods of system daily peak loads, especially during the months of January through March which at that time corresponded to TVA's seasonal peak period. Apalachia Reservoir, immediately downstream from Hiwassee, provided sufficient storage for approximately 27 hours of pumping with the pump-turbine. The pump-turbine selected has a generator rating of 59,500 kW and a pump capacity of 3900 cfs at 205-foot total head (102,000 hp).

The pump-turbine unit was installed and placed in operation in May 1956 after extensive commissioning tests. Performance tests for both pumping and generating operation were made in April 1957, using the Allen salt-velocity method for measuring discharge, and again in March 1958, utilizing Apalachia reservoir for volumetric flow measurement. These tests showed that both the turbine guaranteed efficiency of 88.4 percent and pump guaranteed efficiency of 90.0 percent were met or exceeded.

HISTORICAL SIGNIFICANCE

Hiwassee unit 2 was the first reversible pump-turbine installed in this country solely for the purpose of storing electrical energy in a pumped storage plant. An earlier pump-turbine, installed in 1954 at the Flatiron Power and Pumping Plant in Colorado, was used primarily for irrigation rather than electrical energy storage. It was much smaller than the Hiwassee pump-turbine and had a somewhat specialized design, providing no control of turbine power output.

Pumped storage plants had been in use for electrical energy storage in Europe for some years prior to operation of Hiwassee unit 2. But these plants employed either completely separate motor-driven pumps and turbine-generators or a pump, a turbine, and a generator/motor all on a single shaft. They did not use reversible pump-turbines which are now standard for pumped storage plants.

Finally, there were a few instances of pumps being retrofitted for reverse operation as turbines prior to the introduction of reversible pump-turbines. These machines were designed as pumps and had less-than-optimum performance when operated as turbines.

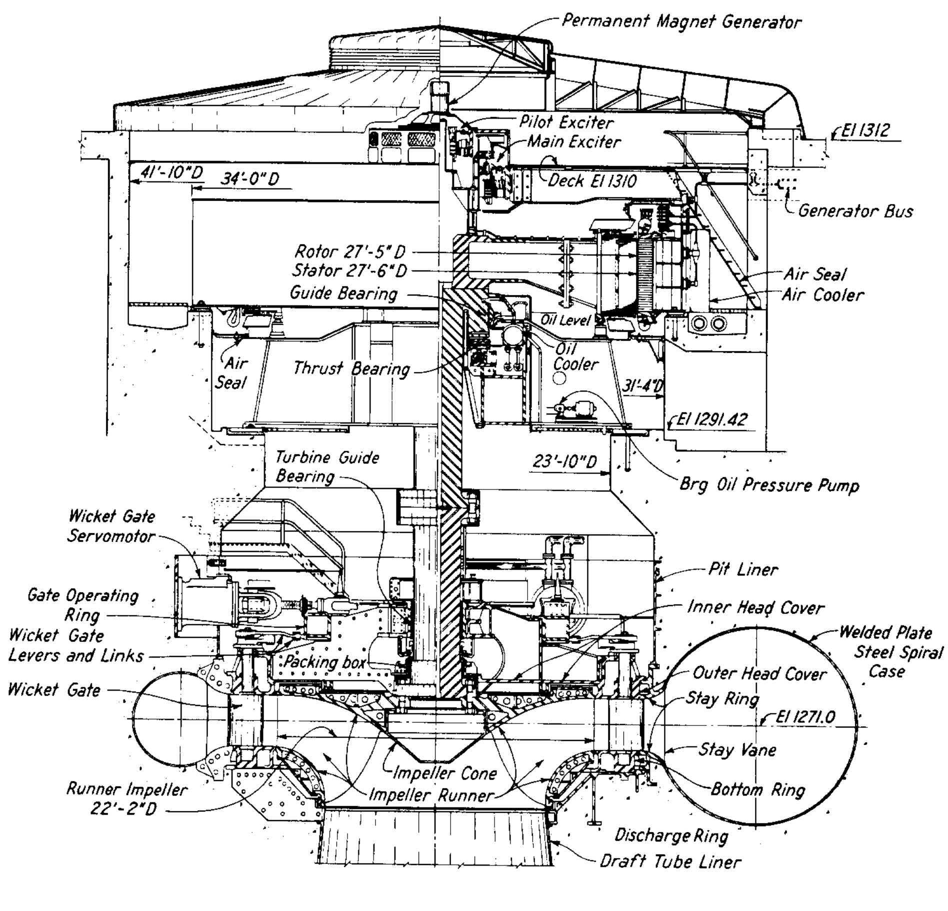
UNIQUE FEATURES

The Hiwassee pump-turbine was the first reversible pump-turbine built and installed in this country using wicket gates for control of turbine output power and improved pump efficiency. The unit also was much larger and more powerful than any reversible pump-turbine in service in the world at the time it went into operation. The rated turbine power output of 80,000 hp was over four times greater than the next largest pump-turbine, installed at the Pederia power plant in Brazil in 1953.

With a diameter of 266 inches, the impeller/runner was the largest water wheel in the world for either a pump-turbine or conventional Francis turbine at the time it was built. The impeller was so large that it had to be shipped in three sections and assembled at the power plant site. Operating as a pump, it had more than three times the capacity of each pump serving the Grand Coulee irrigation project, which then had the world's largest pumps.

CONTRIBUTION TOWARD DEVELOPMENT OF THE NATION

The Hiwassee pump-turbine demonstrated to electric power companies worldwide that reversible pump-turbines could be used in a pumped storage plant to efficiently and economically store electrical energy during periods of low demand to meet peak load demands. Prior to the installation of Hiwassee unit 2, pumped storage plants used separate pumps and conventional turbines for storage and generation. But the size and reversible nature of the Hiwassee unit served as a prototype for design and construction of subsequent pumped storage plants. The 59.5-MW capacity far exceeded the 25-MW ceiling predicted when reversible units were first studied. Larger units meant that pumped storage could better fulfill its promising role in meeting peak demand. The compact physical arrangement also improved opportunities to build pumped storage. Today, reversible pump-turbines have almost completely supplanted the use of separate pumps and turbines in these facilities.



Cross Section of Hiwassee Unit 2 Pump-Turbine

Allis-Chalmers Awarded Contract to Build World's Largest Electric Motor and Reversible Pump-Turbine

Unit Will Serve as Heart Of Pump Storage Project At TVA's Hiwassee Dam

Contracts for the largest electric motor and reversible pump-turbine ever built have been awarded to the Allis-Chalmers Manufacturing Company, according to an announcement by R. M. Casper, manager of the firm's Power department.

The equipment will be the heart of a pump-storage project at Hiwassee Dam in southwestern North Carolina on the Tennessee Valley Authority's power network and is scheduled for completion late in 1955.

Serves Two Purposes

In this installation a single hydraulic machine will operate in one direction as a turbine and in the reverse direction as a pump. A direct-connected electrical machine will serve as a motor for pump operation and as a generator for turbine operation.

When in service, water from the Hiwassee reservoir, driving the unit as a turbine-generator, will add needed energy to the TVA system in peak demand periods. During off-peak periods, when surplus power is available from other plants, the unit will operate as a motor-driven pump to lift water back into the reservoir. It will act, in other words, as a huge storage battery for storing energy.

The project has many unusual aspects. The reversible pump-turbine will utilize the largest Francis type runner ever built. As a turbine it will have a maximum rating of 120,000 horsepower. When motor driven, the unit will have a pumping capacity of 3.3 billion gallons of water per day, or nearly three times as much as New York City requires.

The pump has more than three times the capacity of each of those serving the Grand Coulee irrigation project, which are presently the world's largest.

Motor Rated 102,000 hp

The electrical motor-generator is equally imposing. As a motor it will be the world's largest, rated 102,000 horsepower 106 revolutions per minute. It is approximately 50 percent larger than the motors driving the Grand Coulee pumps. As a generator it is rated 70,000 kva, 13,800 volts.

In a normal cycle of operation, the pump will begin lifting water from Apalachia lake into Hiwassee lake under a head of 135 feet at 5200 cubic feet per second. By the time the upper reservoir is filled, the head will increase to 254.5 feet. The rated pumping capacity will be 3900 cubic feet per second against a 205-ft head.

At the beginning of operation as a turbine, the unit will generate 120,000 horsepower and drop to 36,000 horsepower as the reservoir approaches the low point. Guaranteed efficiencies are 90 percent as a pump and 89.5 percent as a turbine.

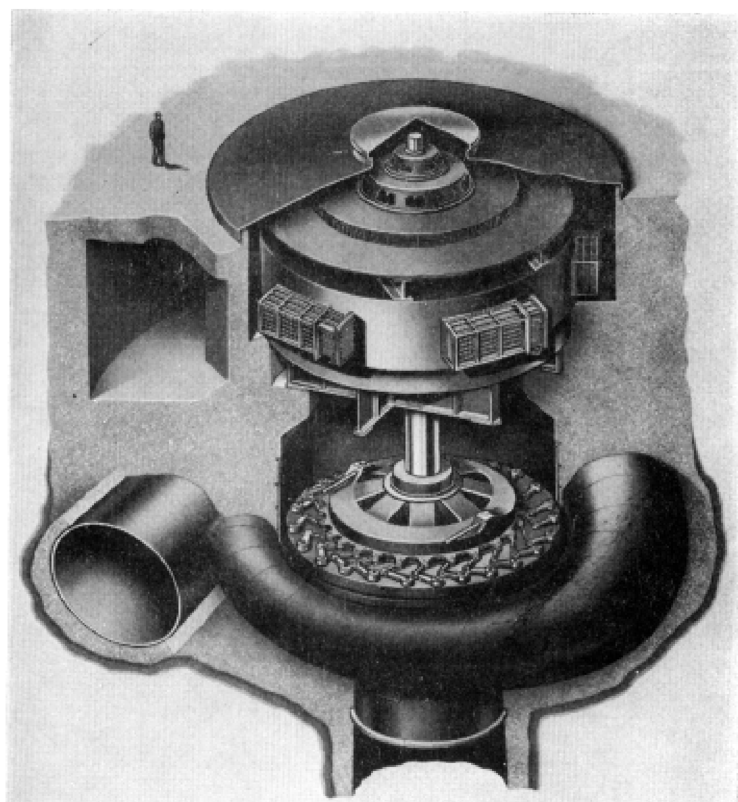
The application of this type of unit is economically feasible and profitable because off-peak power for pumping will cost less and improve the load factor on the system, while the power generated for peak loads will bring in more revenue.

Model tests, standard practice with all new turbine designs, will be made within the next few months at the company's hydraulic laboratory where they will be witnessed and approved by TVA engineers.

A-C is Pioneer of Unit

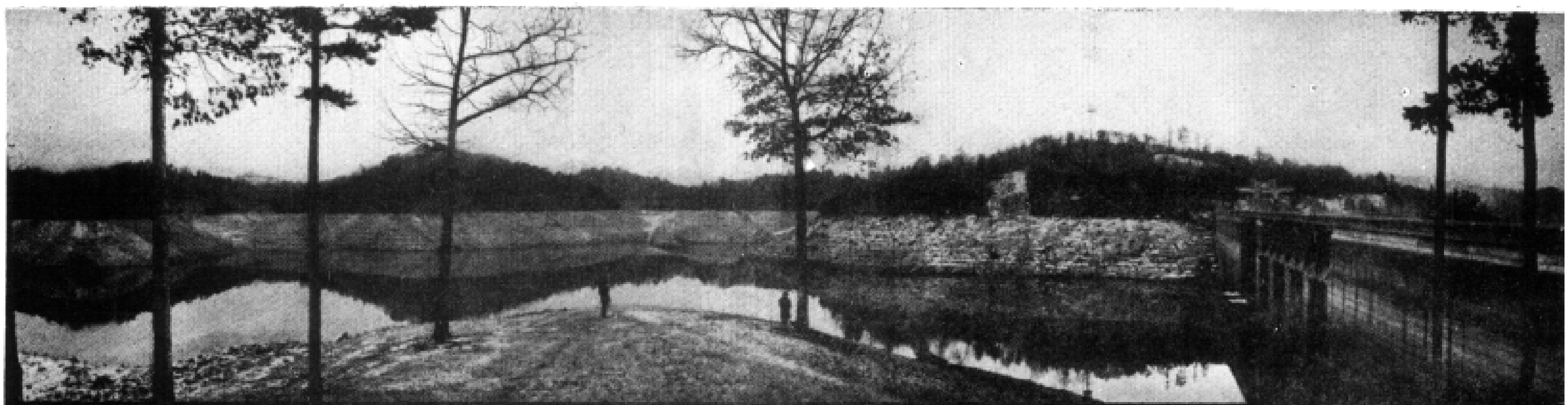
Allis-Chalmers has pioneered the development of the reversible pump-turbine. In June, 1950, the company conducted a conference on pump-turbines at its West Allis Works which was widely attended by hydraulic and power company engineers. Models of pump-turbines were demonstrated at this conference. Following it, the company obtained contracts for three 19,000-hp reversible pump-turbines for the Sao Paulo Light & Power Company Ltd. in Brazil. These units are now under construction at the Canadian Allis-Chalmers plant in Montreal.

Allis-Chalmers is also building a 12,000-hp reversible pump-turbine for the Flatiron power and pumping plant in Colorado for the Bureau of Reclamation. This unit is under construction at the West Allis Works and is a new development in that it will be run at two speeds. It will have a synchronous generator-motor which will run at 257 rpm as a generator when driven by the turbine and at 300 rpm as a motor when pumping.

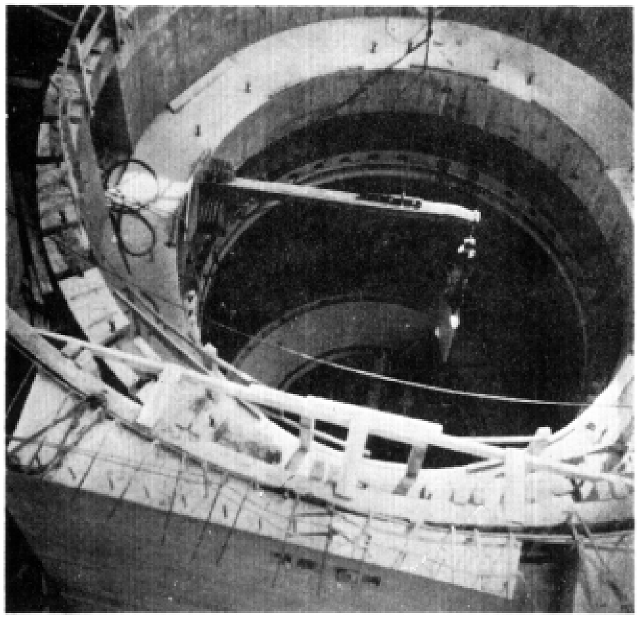


This is an artist's drawing of the largest electric motor and reversible pump-turbine ever built. The equipment, which is being built by Allis-Chalmers, will be the heart of a pump-storage project at Hiwassee Dam in southwestern North Carolina on the TVA's power network. It is scheduled for completion in 1955.

Reprint from A-C Sales News, November, 1952



Installing World's Largest Pump-Turbine

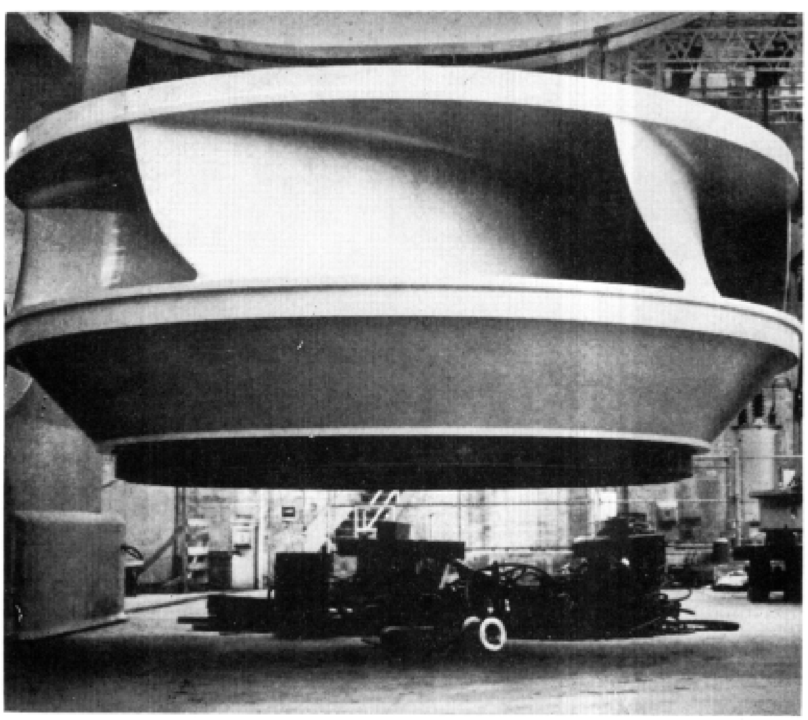


ONE OF 20 wicket gates which will control flow of water from the welded joint scroll case into the runner-impeller is being lowered into place. **(FIGURE 3)**

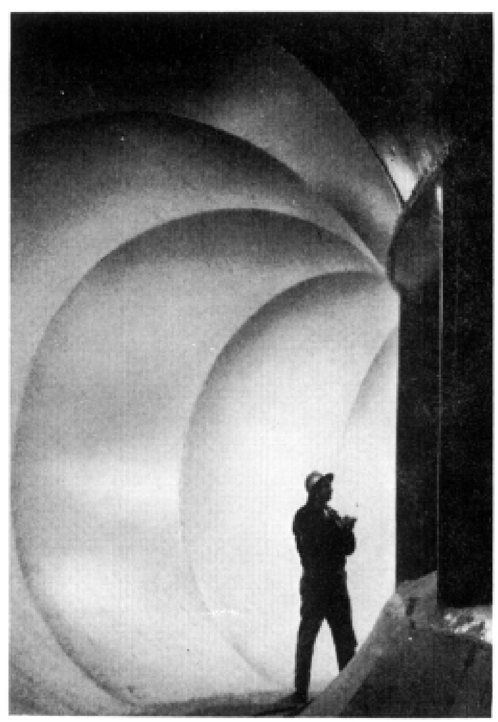
by **R. M. LEWIS**
and
R. S. DOMINICK
Service Section
Allis-Chalmers Mfg. Co.

ERECTION of the world's largest reversible pump-turbine at Hiwassee Dam in southwestern North Carolina began when the inlet pipe connection to the original penstock was positioned for welding in November 1954, about 15 years after the first unit went into service at this 307-ft high concrete gravity dam.

When originally constructed, the dam was built with an open bay adjacent to the 57,600-kw initial turbine-generator. Although this bay was designed to accommodate a unit that would duplicate the first, increasing need for

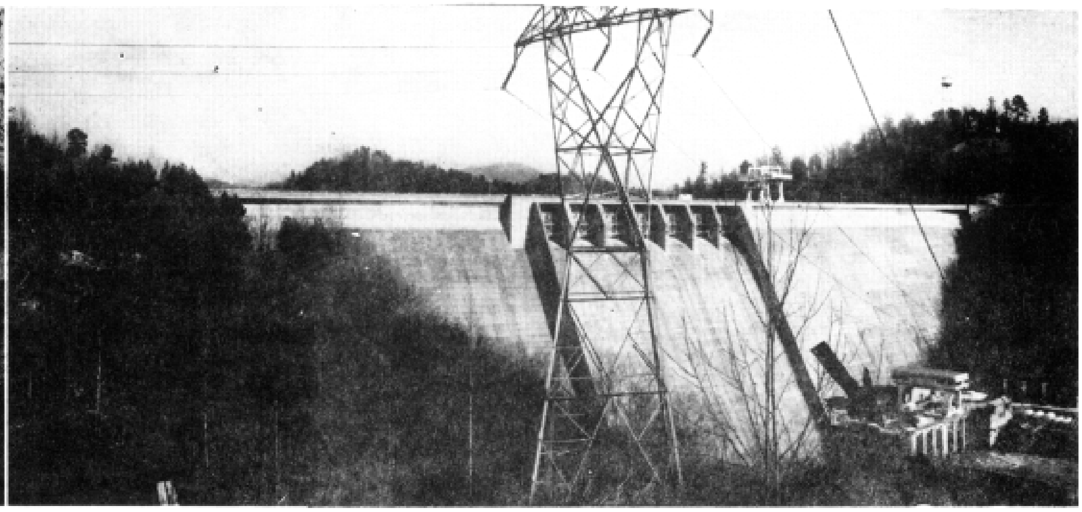


WHEN WEAR RINGS were fitted onto this 266-inch diameter three-piece runner, strip heaters were used to expand the rings, water spray to contract the runner for the shrink-fit. **(FIGURE 4)**



FROM THE 18-FOOT diameter penstock, water will fill the scroll case, surround the stay ring and wicket gates. **(FIGURE 5)**

LOW WATER in Hiwassee Lake during months of high system load will be alleviated by the pump-turbine. **(FIG. 1)**



INSTALLED at the Apalachia Lake side of the powerhouse (see arrow), the pump-turbine unit will lift 3900 cfs of water into Hiwassee Lake or generate 80,000 hp. **(FIGURE 2)**

system peaking capacity during the intervening years made it economically attractive for the Tennessee Valley Authority to install a reversible pump-turbine.*

Vital to any pump-turbine installation is a suction pool or downstream reservoir of sufficient size to permit a pumping cycle. At Hiwassee Dam, the suction pool is Apalachia Lake, with its 58,570 acre-feet of water. Formed by Apalachia Dam, nearly 10 miles downstream on the Hiwassee River, and backing up to Hiwassee Dam, this lake provides controlled storage for 8700 acre-feet of usable water.†

During periods of peak power demand, the pump-turbine will function as a conventional turbine-generator, adding 59,500 kw of rated capacity to the system. During hours of low power demand, especially throughout the season of minimum rainfall, surplus power from the TVA system will be fed into the generator/motor. As a motor-driven pump, rotating in the opposite direction, the unit is rated to pump 3900 cfs from Apalachia Lake back into Hiwassee Lake against a 250-ft head.

In this way, surplus electric power will be stored as additional water in Hiwassee Lake for reuse during the next peak-load period.

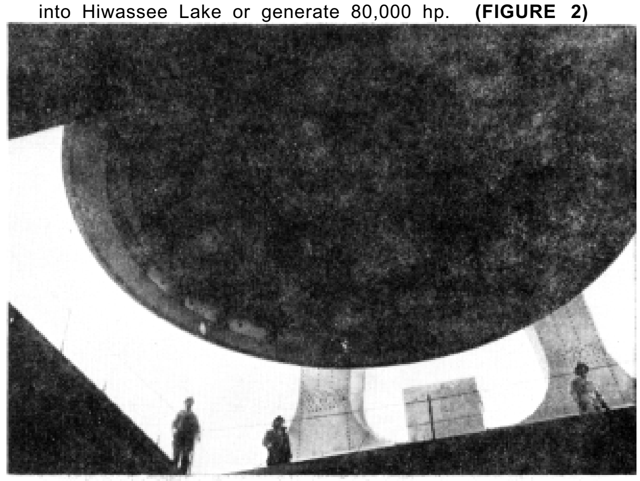
As is the case with almost all large, modern hydraulic installations, size restrictions were imposed by shipping limitations. Clearances along rail right-of-ways from Milwaukee to Turtletown, Tenn., required that the scroll case, the stay ring, and even the Francis-type runner of the pump-turbine be shipped in sections. At Turtletown, parts were transferred to low-bed tractor trailers and hauled the remaining twelve miles to the Hiwassee Dam powerhouse. Generator/motor parts were also shipped in sections: the stator in three sections, wound except for a few coils at each parting, and the fabricated rotor spider in three sections. Laminations were stacked and pole faces were attached to the rotor as a part of field assembly.

In 1955 on April 20th scroll case welding was finished and hydrostatic tests were made. Second-stage concreting was started in May, and 82 percent completed by July, when the cofferdam was removed and generator rotor stacking begun.

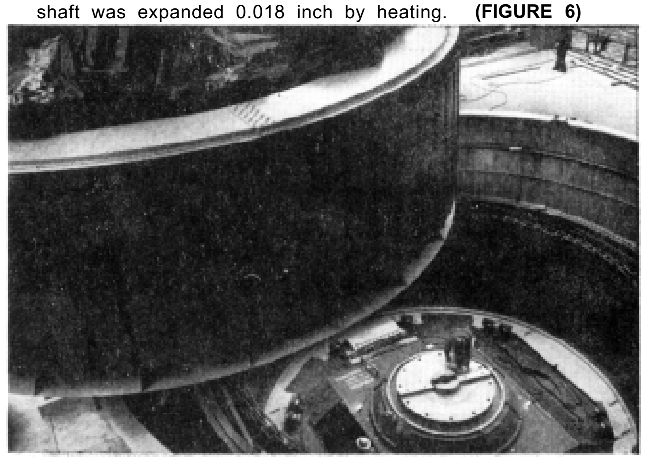
In February of 1956 erection of the pump-turbine and generator/motor was completed. Electrical and hydraulic tests on the world's largest motor and world's largest pump-turbine were then begun.

* "Pump-Turbines . . . 1954 Progress Report," Frank E. Jaski, "Generator-Motor Units for Reversible Pump-Turbines," H. H. Roth, both in 4th Quarter, 1954 Allis-Chalmers *Electrical Review;* and "Pump-Turbine Addition at TVA Hiwassee Hydro Plant," L. R. Sellers and J. E. Kirkland, Jr., March 1956 *Electrical Engineering.*

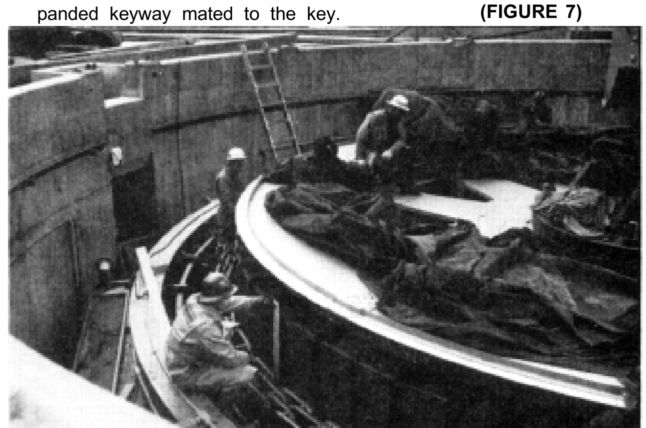
† One acre-foot equals 43,560 cubic feet.



BEFORE LIFTING the rotor from the erection bay, the keyway through which the world's largest motor will drive the pump shaft was expanded 0.018 inch by heating. **(FIGURE 6)**



READY FOR INSTALLATION, the 330-inch diameter rotor will be lowered into the 331-inch diameter stator, the expanded keyway mated to the key. **(FIGURE 7)**



CRUSHING STICKS of ¼-inch plywood, held in the ½-inch air gap between the stator and rotor pole faces, assured proper centering of the rotor as it was lowered. **(FIGURE 8)**

HIWASSEE PROJECT

SUMMARY OF PRINCIPAL FEATURES
January 1978

LOCATION

On Hiwassee River at river mile 75.8; in Cherokee County, North Carolina; 13.6 miles upstream from Apalachia Station on Louisville and Nashville Railroad; 20 miles downstream from Murphy, North Carolina; 60 air miles south of Knoxville, Tennessee; 60 air miles east of Chattanooga, Tennessee; 100 air miles north of Atlanta, Georgia.

CHRONOLOGY

Authorized by TVA Board of Directors	January 10, 1936
Preliminary construction, including access, started	July 15, 1936
Stripping of south abutment started	November 21, 1936
First cofferdam started	July 13, 1937
First concrete placed	April 20, 1938
Reservoir clearance started	October 24, 1938
Last (third) cofferdam unwatered	January 3, 1939
River flow diverted through sluiceways	April 22, 1939
Reservoir clearance completed	December 12, 1939
Concreting by mixer plant completed	January 31, 1940
Dam closure (ring seal gates closed)	February 8, 1940
Unit 1 in commercial operation	May 21, 1940
Unit 2 authorized by TVA Board of Directors	September 25, 1951
Unit 2 construction began	January 4, 1954
Unit 2 in commercial operation	May 24, 1956

PROJECT COST

Initial project, including 1 unit	$ 16,844,042
Addition of unit 2	6,356,211
Total, including switchyard	$ 23,200,253

STREAMFLOW

Drainage area at dam:	
Total	968 sq. miles
Uncontrolled (below Chatuge and Nottely Dams)	565 sq. miles
Gaging station discharge records (for complete records see Data Services Branch files):	
At Hiwassee Dam, September 1934 to September 1943; drainage area	968 sq. miles
Below Apalachia Dam, North Carolina, June 1941 to April 1946; drainage area	1,018 sq. miles
Near Apalachia, Tennessee, January 1914 to December 1922; drainage area	1,038 sq. miles
Near McFarland, Tennessee, October 1942 to date; drainage area	1,136 sq. miles
Gaging station discharge records (cont.)	
At Reliance, Tennessee, August 1900 to December 1913; February 1919 to September 1926; drainage area	1,181 sq. miles
Near Reliance, Tennessee, October 1926 to September 1948; drainage area	1,223 sq. miles
Maximum known flood at dam site, natural (1898)	80,000 cfs
Average unregulated flow at dam site, estimated (1901-1969)	2,040 cfs
Minimum daily natural flow at dam site (1925), approx.	145 cfs

RESERVOIR

Counties affected: State of North Carolina	Cherokee
Reservoir land at June 30, 1976:	
Fee simple	5,834 ac.
Easements	31 ac.
Total	5,865 ac.
Operating levels at dam:	
Maximum used for design (153,000 cfs)	el. 1532
Top of gates (area 6,230 ac.)	el. 1526.5
Normal maximum pool (area 6,090 ac.)	el. 1524.5
Normal minimum pool (area 2,180 ac.)	el. 1450
Backwater, length at top of gates level	22.2 miles
Shoreline, length at top of gates level:	
Main shore	161 miles
Islands	2 miles
Total	163 miles
Original river area (to el. 1526 crossing)	1,000 ac.
Storage (flat pool assumption):	
Total volume:	
At top of gates (el. 1526.5)	434,000 ac.-ft
At normal maximum pool (el. 1524.5)	422,000 ac.-ft
At normal minimum pool (el. 1450)	128,000 ac.-ft
Reservation for flood control on:	
January 1 to January 27 (el. 1526.5-1465)	270,100 ac.-ft
March 15 (el. 1526.5-1482)	216,100 ac.-ft
Useful controlled storage (el. 1526.5-1450)	306,000 ac.-ft

TAILWATER

Maximum used for design (130,000 cfs)	el. 1302.0
Maximum known flood (1936)	el. 1286.0
Full plant operation (2 units)	el. 1276.2
One unit operating at best efficiency	el. 1275.8
Minimum level	el. 1272.0

HEAD (Gross)

Maximum static (el. 1526.5-1272)	254.5 ft
Normal maximum operating (el. 1524.5-1272.5)	252.0 ft

HEAD (Gross) (Cont.)

Average operating . . . . 213.0 ft
Minimum operating (el. 1415-1278) . . . . 137.0 ft

RESERVOIR ADJUSTMENTS

Clearing below el. 1528 . . . . 3,270 ac.
Wiring down below el. 1410 . . . . 569 ac.
Drainage of isolated pools. . . . . 395 cu. yd
Highways:
Access. . . . . 11.7 miles
State. . . . . 3.4 miles
County . . . . 8.8 miles
Tertiary . . . . 3.1 miles
Total . . . . 27.0 miles
Railroads . . . . 1.7 miles
Bridges (highway 11, railroad 3). . . . . 14 bridges
Concrete box culverts. 40
Families relocated. 261
Graves. . . . . 571 agreements; 475 removals
Utilities adjusted or constructed. . . . . 3.0 miles

DAM

Material and type . . . . Concrete gravity nonoverflow dam and spillway
Lengths:
Nonoverflow dam . . . . 1,027 ft
Spillway . . . . 260 ft
Cutoff wall, right (north) bank. . . . . 89 ft
Total. . . . . 1,376 ft
Maximum height, foundation to deck level. . . . . . . 307 ft
Maximum width at base:
Spillway section only. . . . . 240 ft
Including apron. . . . . 493 ft
Deck level . . . . el. 1537.5
Outlet facilities:
Spillway clear opening (7 openings at 32 ft) . . . . . 224 ft
Spillway crest level . . . . el. 1503.5
Crest gates . . . . 7 radial gates, 32 ft wide, 23 ft high, separated by 6-ft-thick piers
Traveling crane . . . . One 120-ton gantry
Traveling hoist . . . . One 40-ton hoist
Sluices. . . . . Four 102-in.-dia. steel-lined outlets with nozzle at outlet end
Centerline sluice inlet. . . . . el. 1305.0
Sluice control:
Regulating gates . . . . . . 4 ring seal gates, screw hoist operated
Emergency gate. . . . . . . 1 roller train lift gate on face of dam, operated by gantry
Spillway discharge capacity:
HW el. 1532.0. 130,000 cfs
HW el. 1526.5 (top of gates) . . . . 90,000 cfs
Sluice discharge capacity:
HW el. 1532.0. . . . . 23,000 cfs
HW el. 1526.5. . . . . 22,000 cfs
Highway . . . . 19 ft wide on dam
Foundation . . . . Rock (graywacke)

POWER FACILITIES

INTAKES

Number 2
Gates . . . . Two 19-ft-wide by 26-ft-high structural steel gates with roller trains
Hoists . . . . Two 60-ton fixed hoists under roadway in dam
Trashrack structure . . . . 2 reinforced concrete semi-circular towers
Steel trashracks. . . . . 160 sections, 2 ft 7 in. wide by 11 ft 3-1/2 in. high
Gross area at racks (per unit). . . . . 3,050 sq. ft

PENSTOCKS

Number 2
Type . . . . Riveted steel 3/4 in. to 1-3/8 in. thick
Diameter . . . . 18 ft
Length . . . . 217 ft 5 in. for unit 1; 189 ft 9-1/2 in. for unit 2
Air vents . . . . One 30-in.-dia. for each penstock

POWERHOUSE

Generating capacity, 2-unit total . . . . 117,100 kW
Type of construction . . . . . Outdoor; reinforced concrete and structural steel
Principal outside dimensions,
including service bay . . . . 190 ft long by 89.5 ft wide by 76 ft high
Service bay . . . . 54.5 ft by 122 ft
Draft tubes:
Type . . . . Elbow, 3 openings
Horizontal length (centerline of
turbine to downstream face) . . . . 57.0 ft
Vertical distance from distributor centerline
to draft tube floor:
Unit 1. . . . . 37.0 ft
Unit 2 . . . . 32.5ft
Net area at outlet opening:
Unit 1 . . . . 661 sq. ft
Unit 2 . . . . 1,048 sq. ft
Trashrack at pump unit
(unit 2) . . . . Gross area 1,641 sq. ft; net area 1,321 sq. ft
Gates . . . . 1 set of 3 slide gates, 15 ft 4 in. wide by 13 ft high
Gate hoist . . . . 25-ton auxiliary hoist on powerhouse gantry
Erecting crane. . . . . 275-ton gantry with two 137-1/2-ton main hooks and two 25-ton auxiliary hoists

HYDRAULIC TURBINE (Unit 1)

Number 1
Manufacturer . . . . Newport News Shipbuilding and Dry Dock Co.

SUMMARY OF PRINCIPAL FEATURES

HYDRAULIC TURBINE (Unit 1) (Cont.)

Type	Vertical Francis
Rated capacity	80,000 hp at 190-ft net head
Rated speed	120 r/min
Maximum runaway speed	235 r/min
Specific speed at rating	48
Value of sigma at rating	0.141
Diameter of runner, intake	161 in.
Diameter of runner, discharge	165.187 in.
Centerline to bottom of runner	55.375 in.
Centerline to top of runner	21 in.
Diameter of guide vane circle	189 in.
Diameter of lower pit	19.6 ft
Spacing of turbines, center to center of units	62.08 ft
Governors	Woodward, cabinet actuator type
Weight of rotating parts	Approx. 142,000 lb

PUMP-TURBINE (Unit 2)

Number	1
Manufacturer	Allis-Chalmers Manufacturing Co.

	As Turbine	As Pump
Type	Vertical Francis	Centrifugal
Rated horsepower	80,000	102,000
Rated head	190 ft net	205 ft net
Rated discharge	4,180 cfs	3,900 cfs
Rated speed	105.9 r/min	105.9 r/min
Maximum runaway speed	161 r/min	121 r/min
Direction of rotation	Clockwise	Counterclockwise
Specific speed at rating	42.1	121
Value of sigma at rating	0.202	0.185

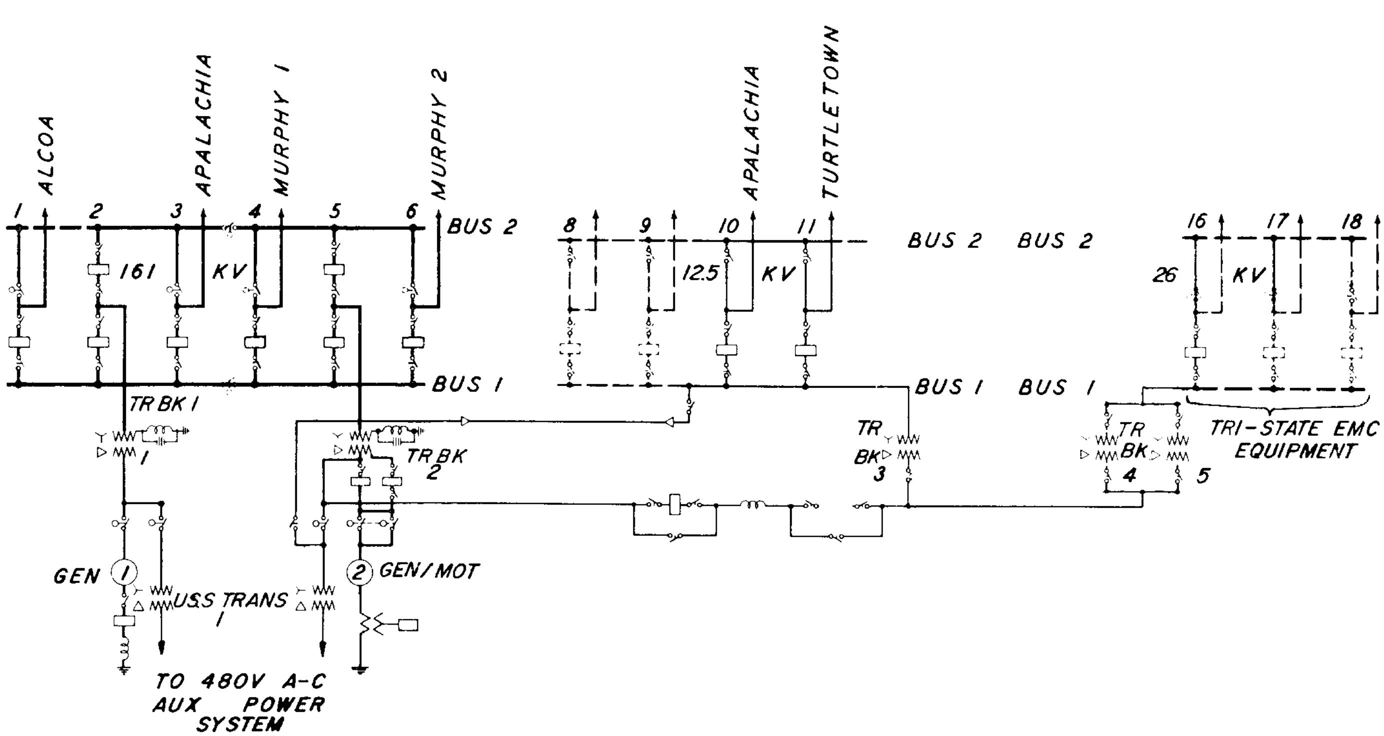
Diameter of runner, intake	266 in.
Diameter of runner, discharge	182 in.
Centerline to bottom of runner	69 in.
Centerline to top of runner	23 in.
Diameter of guide vane circle	312 in.
Diameter of lower pit	30.0 ft
Spacing of turbines, center to center of units	62.08 ft
Governors	Woodward, cabinet actuator type
Weight of rotating parts	Approx. 335,000 lb

GENERATORS

Unit 1 Generator

Manufacturer	Westinghouse Electric Corp.
Type	Enclosed, water-cooled, vertical-shaft; vertical cylindrical concrete wall of housing, and removable weather cover, furnished by TVA
Rating	64,000 kVA, 57,600 kW, 2864 A, 60 degrees C rise, 0.9 pf, 13.8 kV, 3 ph, 60 Hz
Capacity	73,600 kVA, 66,240 kW, 3086 A, 80 degrees C rise

SINGLE LINE DIAGRAM OF MAIN CONNECTIONS



GENERATORS (Cont.)

Efficiency (tested):
- At rated kVA, 1.0 pf . . . . 98.34 percent
- At 75% kVA, 0.9 pf . . . . 97.79 percent

Flywheel effect:
- Calculated . . . . .60,300,000 lb-ft ^{2}
- Tested. .62,900,000 lb-ft ^{2}

Thrust bearing . . . . Kingsbury type, dia. 76 in., max. load 540 tons

Neutral reactor. . . . . .0.97 ohm, 6000 A, 1 min

Exciters:
- Main . . . . 275 kW, 250 V
- Pilot . . . . 10 kW, 250 V

Weight of heaviest crane lift, rotor . . . . .243 tons

Diameter over air housing, less trim. . . . . .454 in.

Top of pilot exciter:
- Above stator soleplates. . . . . .153.75 in.
- Above turbine floor. . . . . .273.75 in.

Unit 2 Generator-Motor

Manufacturer . . . . Allis-Chalmers Manufacturing Co.

Type. . . . . Enclosed, water-cooled, vertical-shaft; vertical cylindrical concrete wall of housing, and removable weather cover, furnished by TVA

Rating as generator . . . . . 70,000 kVA, 59,500 kW, 2929 A, 60 degrees C rise, 0.85 pf lag, 13.8 kV, 3 ph, 60 Hz

Capacity as generator. . . . . 80,500 kVA, 68,425 kW, 3368 A, 80 degrees C rise

Rating as motor . . . . 102,000 hp, 80 degrees C rise, 0.95 pf lead, 13.5 kV

Efficiency (guaranteed):
- As generator:
  - At 70,000 kVA, 1.0 pf . . . . 97.7 percent
  - At 52,500 kVA, 0.85 pf lag. . . . . 96.9 percent
- As motor:
  - At 102,000 hp, 1.0 pf . . . . 97.6 percent
  - At 88,700 hp, 0.95 of lead . . . . 97.4 percent

Flywheel effect. . . . . .82,818,700 lb-ft²

Thrust bearing . . . . Kingsbury, dia. 87 in., max. load 683 tons

Neutral transformer . . . . 75 kVA, 14.4 kV-240 V, 1 ph

Exciters:
- Main . . . . 350 kW, 250 V
- Pilot . . . . 20 kW, 250 V

Unit 2 Generator-Motor (Cont.)

Weight of heaviest crane lift, rotor . . . . 365.8 tons

Diameter inside air housing . . . . 514 in.

Top of pilot exciter:
- Above stator soleplates. . . . . 166 in.
- Above generator floor . . . . 154 in.

TRANSMISSION PLANT

Step-up transformers:
- 1 bank of 3 single-phase, 2-winding transformers, bank 1; bank rated 13.2-161 kV, 56,250 kVA self-cooled, 75,000 kVA forced-air-cooled; Moloney
- 1 bank of 3 single-phase, 2-winding transformers, bank 2; bank rated 6.6/13.2-161 kV, 114,000 kVA forced-oil-air-cooled; 13.2-kV winding tapped at 6.6 kV for starting pump-turbine unit 2; General Electric

Intersystem transformers:
- 1 3-phase, 2-winding transformer, bank 3; rated 13.2-7.2/12.47 kV, 1500 kVA self-cooled; Westinghouse

161-kV circuit breakers:
- 3 1200-A, 2,500,000-kVA, 8/60-Hz, sol, Westinghouse
- 4 1200-A, 3,500,000-kVA, 5/20-Hz, pneu, Westinghouse

14.4-kV circuit breakers:
- 2 600-A, 50,000-kVA sol, General Electric

Structures:
- 6 161-kV switchyard bays, 36 ft wide
- 2 delta bus and transformer structures
- 1 26-kV future transformer bay, 22 ft wide
- 2 26-kV transformer bays, 18 ft wide
- 5 12-kV switchyard bays, 11 ft wide

ELECTRIC CONTROLS

From control room in powerhouse:
- Hiwassee generator No. 1 and generator-motor No. 2, transformers, switchyard, sources of auxiliary power, station auxiliaries, and starting of turbine No. 1 and pump-turbine No. 2 by direct control.
- Chatuge hydro plant and switchyard by frequency-shift powerline carrier.
- Nottely hydro plant and switchyard by frequency-shift powerline carrier.
- Murphy primary substation by frequency-shift powerline carrier.
- Apalachia hydro plant and switchyard by frequency-shift powerline carrier.

CONSTRUCTION DATA

PERSONNEL

	Dam and Reservoir Construction	Dam Construction Only	Unit 2 Addition
Peak employed	1,600	1,200	128
Total man-hours	7,682,640	5,424,683	468,114
Number of injuries	205	141	6
Days lost	16,509	15,589	2,749
Fatalities	2	2	0
Accident frequency	26.7	26.0	12.82
Accident severity	2,149	2,874	5,873

HOUSING FACILITIES
(Initial Project)

Semipermanent houses built 42
Low-cost houses built 73
Dormitories built:
Staff (48 capacity) .1
Men (416 total capacity) 4
Women (32 capacity) .1

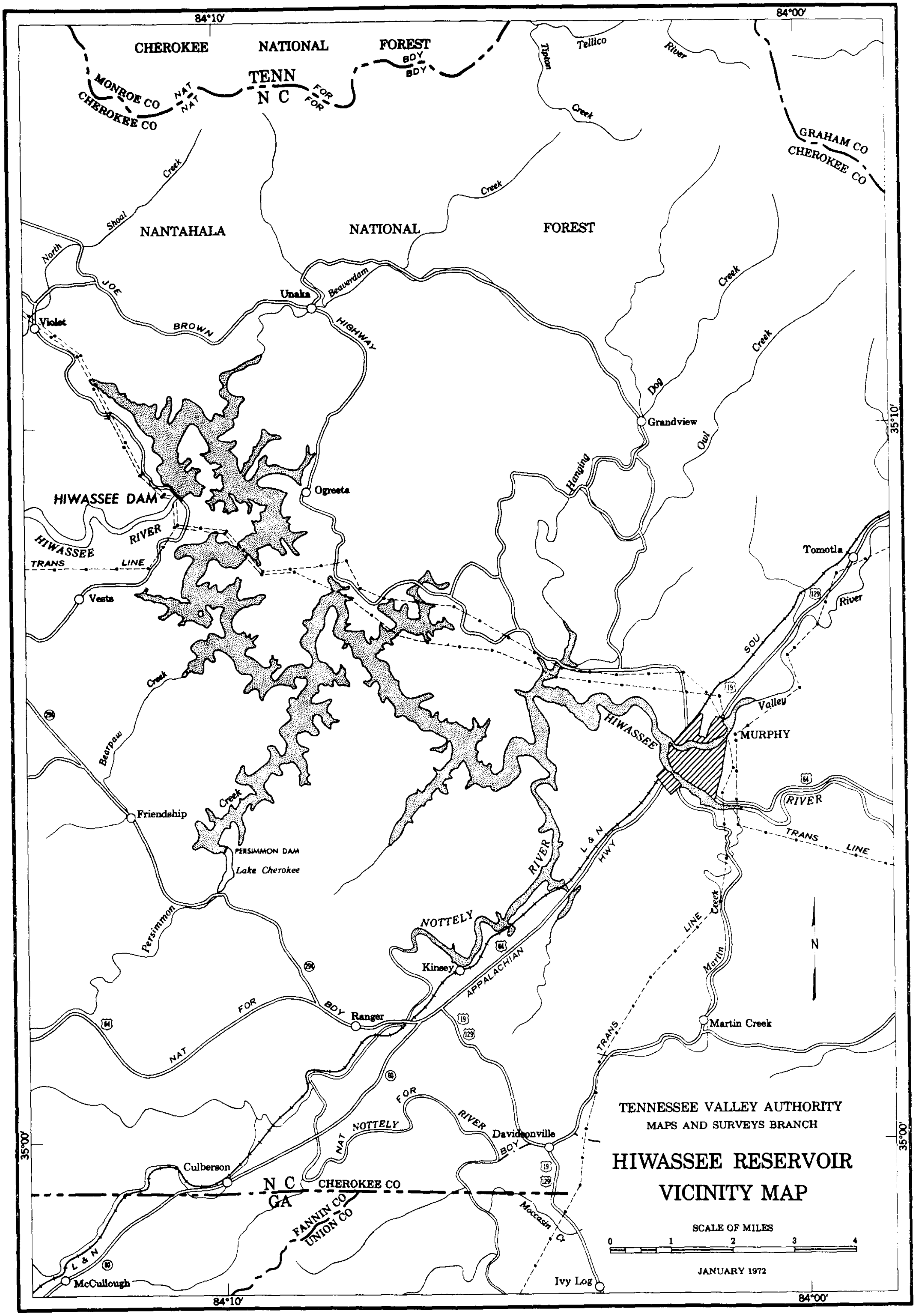
Public buildings constructed included a cafeteria (240 seats), hospital (17 beds), community and recreation building, school, gas station, and observation building.

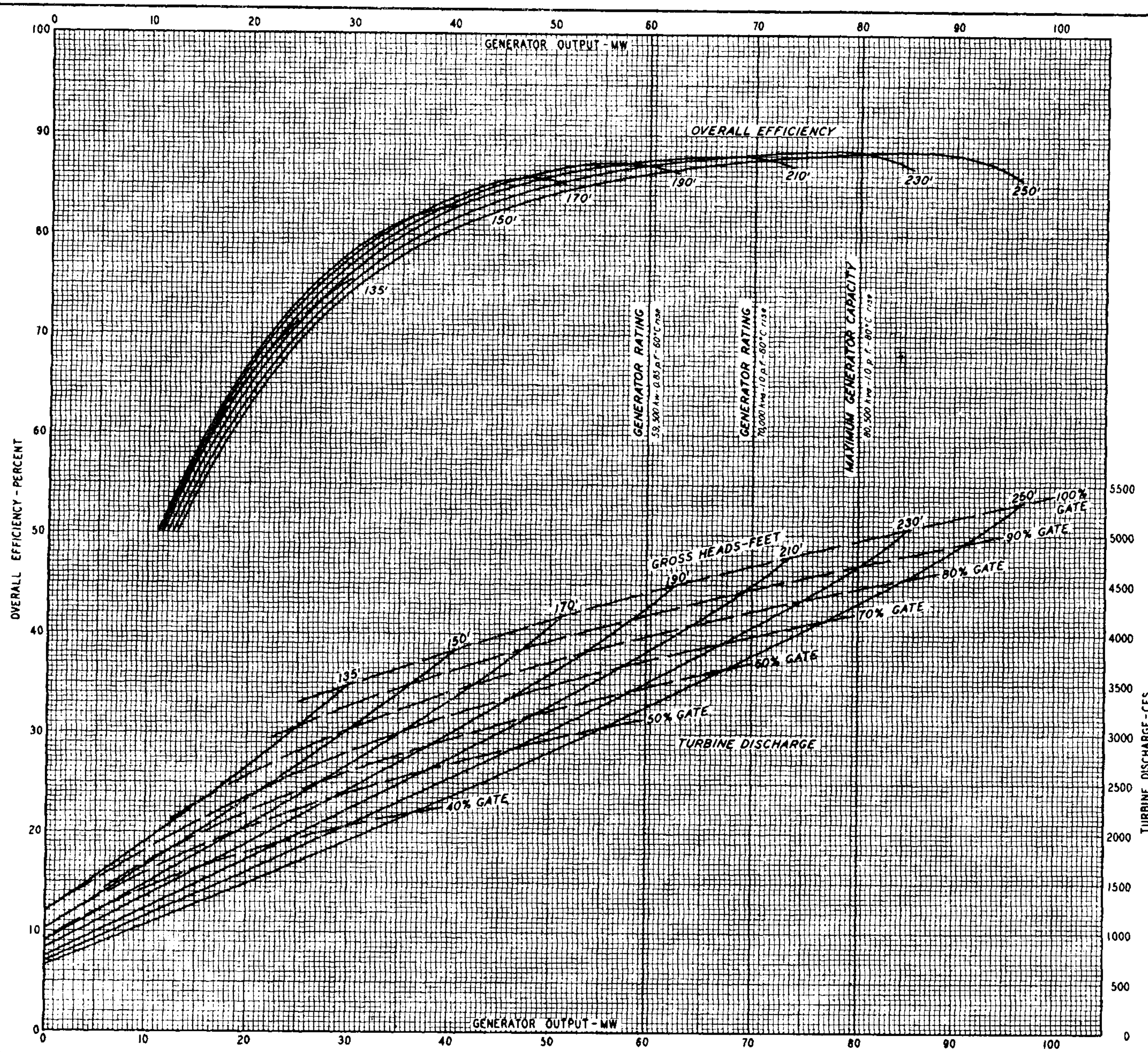
QUANTITIES

	Initial Project	Unit 2 Addition
Dam and power facilities:		
Earth excavation	64,700 cu. yd	-
Rock excavation	294,500 cu. yd	125 cu. yd
Unclassified excavation	19,500 cu. yd	-
Concrete	792,956 cu. yd	7,830 cu. yd
Structural steel	535 tons	23 tons
Reinforcing steel	1,972 tons	156 tons
Highway and railroad:		
Excavation	960,000 cu. yd	-

NOTE

Elevations are based on the U.S.C. & G.S. 1929 Preliminary Adjustment to which the dam is built. To correct to U.S.C. & G.S. 1936 Supplementary Adjustment, subtract 0.62 ft.


TENNESSEE VALLEY AUTHORITY
MAPS AND SURVEYS BRANCH
HIWASSEE RESERVOIR
VICINITY MAP
SCALE OF MILES
0 1 2 3 4
JANUARY 1972
84°10'
84°00'
35°10'
35°00'
CHEROKEE NATIONAL FOREST
TENN
N C
MONROE CO
CHEROKEE CO
GRAHAM CO
CHEROKEE CO
NANTAHALA NATIONAL FOREST
Tellico River
Tipton Creek
Shoal Creek
North
JOE BROWN HIGHWAY
Unaka
Beaverdam
Violet
Grandview
Dog Creek
Owl Creek
Hanging
Ogreeta
HIWASSEE DAM
HIWASSEE RIVER
TRANS LINE
Vests
Tomotla
River
SOU
Valley
MURPHY
HIWASSEE
RIVER
TRANS LINE
Creek
Bearpaw
Friendship
Creek
PERSIMMON DAM
Lake Cherokee
Persimmon
NOTTELY RIVER
L & N HWY
APPALACHIAN
Kinsey
Ranger
NAT FOR BDY
Martin Creek
Martin Creek
LINE
TRANS
N
NAT NOTTELY FOR RIVER BDY
Davidsonville
Culberson
N C
GA
CHEROKEE CO
FANNIN CO
UNION CO
Moccasin Cr.
L & N
McCullough
Ivy Log



This curve is based on model test No. 39112 of the Allis-Chalmers Co. and is modified in accordance with the salt-velocity test conducted on this unit on 4-2-57 at approximately 195-foot gross head Generator test efficiencies and measured penstock losses were used in the computations

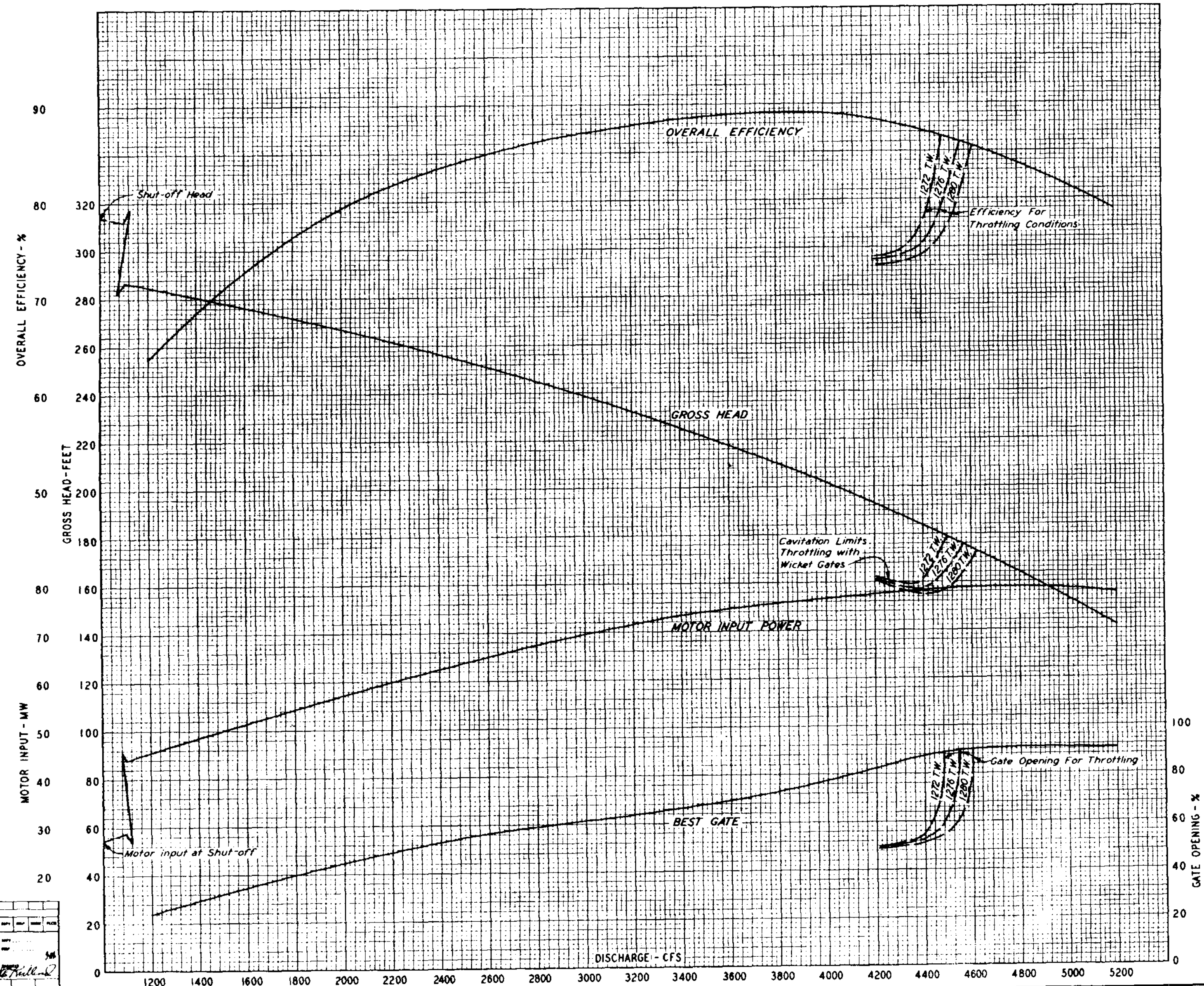
POWERHOUSE
UNIT 2

OPERATING CHARACTERISTICS OF PUMP-TURBINE UNIT GENERATING

HIWASSEE PROJECT
TENNESSEE VALLEY AUTHORITY
DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED

KNOXVILLE	4-10-58	S	M	4	47 K 2864

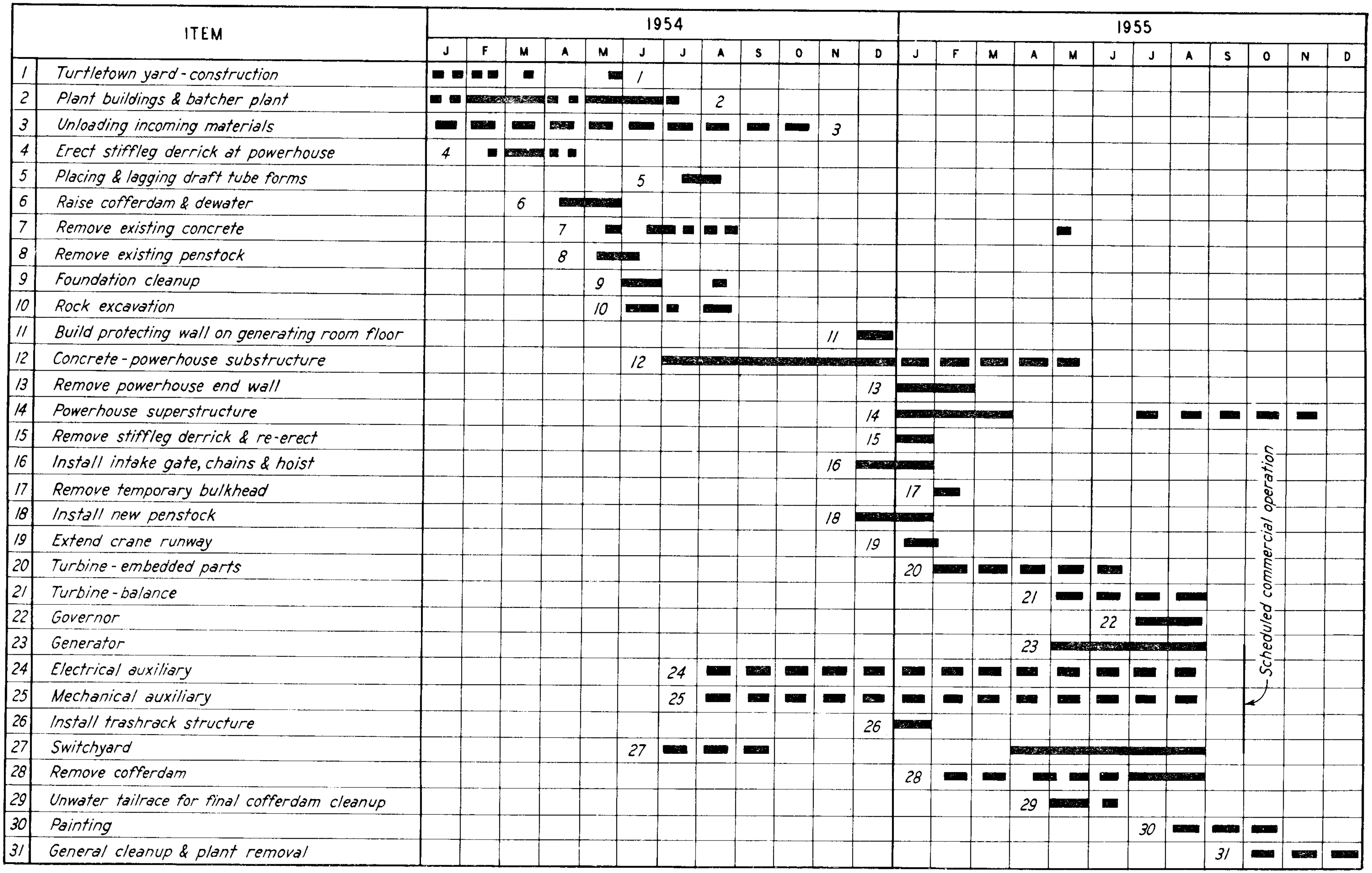


This curve is based on model test No. 39112 of the Allis-Chalmers Co., and is modified in accordance with certain data from the test conducted on this unit on 4-4-57 at approximately 195-foot head. Generator test efficiencies and measured penstock losses were used in the computations.

POWERHOUSE UNIT 2
OPERATING CHARACTERISTICS OF PUMP-TURBINE UNIT PUMPING
HIWASSEE PROJECT TENNESSEE VALLEY AUTHORITY DIVISION OF DESIGN

SUBMITTED	RECOMMENDED	APPROVED
[signature]	[signature]	[signature]

KNOXVILLE	4-17-58	5	M	4	47K2865



CONSTRUCTION SCHEDULE-UNIT 2