UNITED STATES
DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary

BUREAU OF RECLAMATION

Wilbur A. Dexheimer, Commissioner
Grant Bloodgood, Assistant Commissioner and
Chief Engineer

TECHNICAL RECORD

of

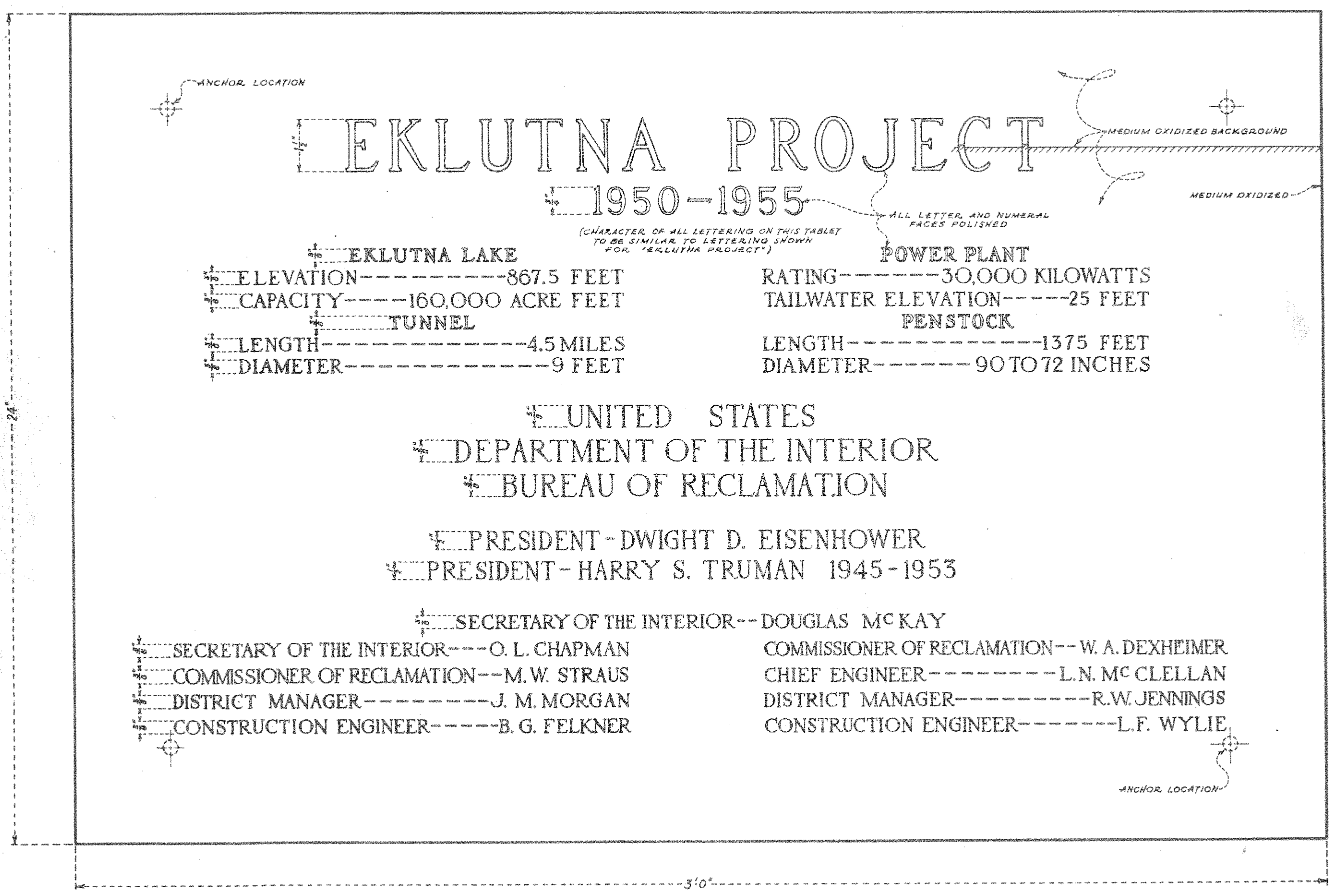
DESIGN AND CONSTRUCTION

EKLUTNA DAM, POWERPLANT AND TUNNEL

Constructed 1951-1955

Eklutna Project
Alaska

Denver, Colorado
March 1958


ANCHOR LOCATION
EKLUTNA PROJECT
1950-1955
MEDIUM OXIDIZED BACKGROUND
MEDIUM OXIDIZED
ALL LETTER AND NUMERAL FACES POLISHED
(CHARACTER OF ALL LETTERING ON THIS TABLET TO BE SIMILAR TO LETTERING SHOWN FOR "EKLUTNA PROJECT")
EKLUTNA LAKE
ELEVATION---------867.5 FEET
CAPACITY----160,000 ACRE FEET
TUNNEL
LENGTH-------------4.5 MILES
DIAMETER-------------9 FEET
POWER PLANT
RATING-------30,000 KILOWATTS
TAILWATER ELEVATION-----25 FEET
PENSTOCK
LENGTH------------1375 FEET
DIAMETER------90 TO 72 INCHES
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PRESIDENT-DWIGHT D. EISENHOWER
PRESIDENT-HARRY S. TRUMAN 1945-1953
SECRETARY OF THE INTERIOR--DOUGLAS McKAY
SECRETARY OF THE INTERIOR---O. L. CHAPMAN
COMMISSIONER OF RECLAMATION--M. W. STRAUS
DISTRICT MANAGER---------J. M. MORGAN
CONSTRUCTION ENGINEER-----B. G. FELKNER
COMMISSIONER OF RECLAMATION--W. A. DEXHEIMER
CHIEF ENGINEER--------L. N. McCLELLAN
DISTRICT MANAGER---------R. W. JENNINGS
CONSTRUCTION ENGINEER-------L. F. WYLIE
ANCHOR LOCATION
24"
3'0"

EKLUTNA DAM, POWERPLANT AND TUNNEL

Purpose

To bring urgently needed electric power to the Anchorage, Alaska, area for both civilian consumption and national defense installations

Reservoir

Name: Eklutna Lake

Location: Approximately 10 miles southeast of Eklutna Powerplant, and 30 miles northeast of Anchorage, Alaska

Reservoir statistics:

Total capacity (above trashracks)	182,100 acre-feet
Active capacity	160,000 acre-feet
Present inactive capacity	22,100 acre-feet
Surface area (at total capacity)	3,247 acres
High-water elevation	867.5
Length	7 miles
Width	0.7 mile
Depth	200 feet

Dam

Type: Earth and rockfill (base formed by natural glacier)
Foundation: Natural glacial deposits
Slope protection: Riprap on upstream face
Crest length: 555 feet
Crest width: 15 feet
Crest elevation: 875.0
Volume: 5,000 cubic yards

Spillway

Location: Right dam abutment
Crest elevation: 867.50
Length: 150 feet
Type: Overflow
Gates: Nineteen hand-operable, wooden-head gates were acquired as a part of the existing dam, but their material condition was poor due to aging and therefore the gates are to be left in the closed position at all times

Intake Structure

Location: Eklutna Lake bottom
Type: Horizontal, rectangular, concrete structure consisting of three precast units, open at the top, and protected by trashracks throughout its length
Length of structure: 133 feet 8 inches
Elevation of structure: 800 (approximately 60 feet below the lake water surface)
Inlet channel: 100 feet wide, 500 feet long

Eklutna Tunnel

Type: Circular, concrete-lined, pressure type
Inside diameter: 9 feet
Length: 23,550 feet
Hydraulic properties:
- Area: 63.62 square feet
- Velocity: 10.06 feet per second
- Capacity: 640 second-feet

Slope: 0.00341 (80-foot difference in elevation between inlet and the outlet gate at surge tank)

Surge Tank

Location: 22,805 feet downstream from bulkhead gate shaft and directly over tunnel
Height above tunnel: 176 feet
Inside diameter: 30 feet
Wall thickness: 18 inches
Type: Restricted orifice

Penstock

Location: Downstream of surge tank
Length: 1,088 feet
Variable diameters: 91-, 83-, and 75-inch outside diameters
Type: Welded and coupled steel pipe encased in concrete
Plate thickness: 5/16 inch for initial section and variable up to 1-1/2 inches at terminal section
Profile: Descends 864 feet at an angle of 53° and then a horizontal run of 501 feet

Powerplant

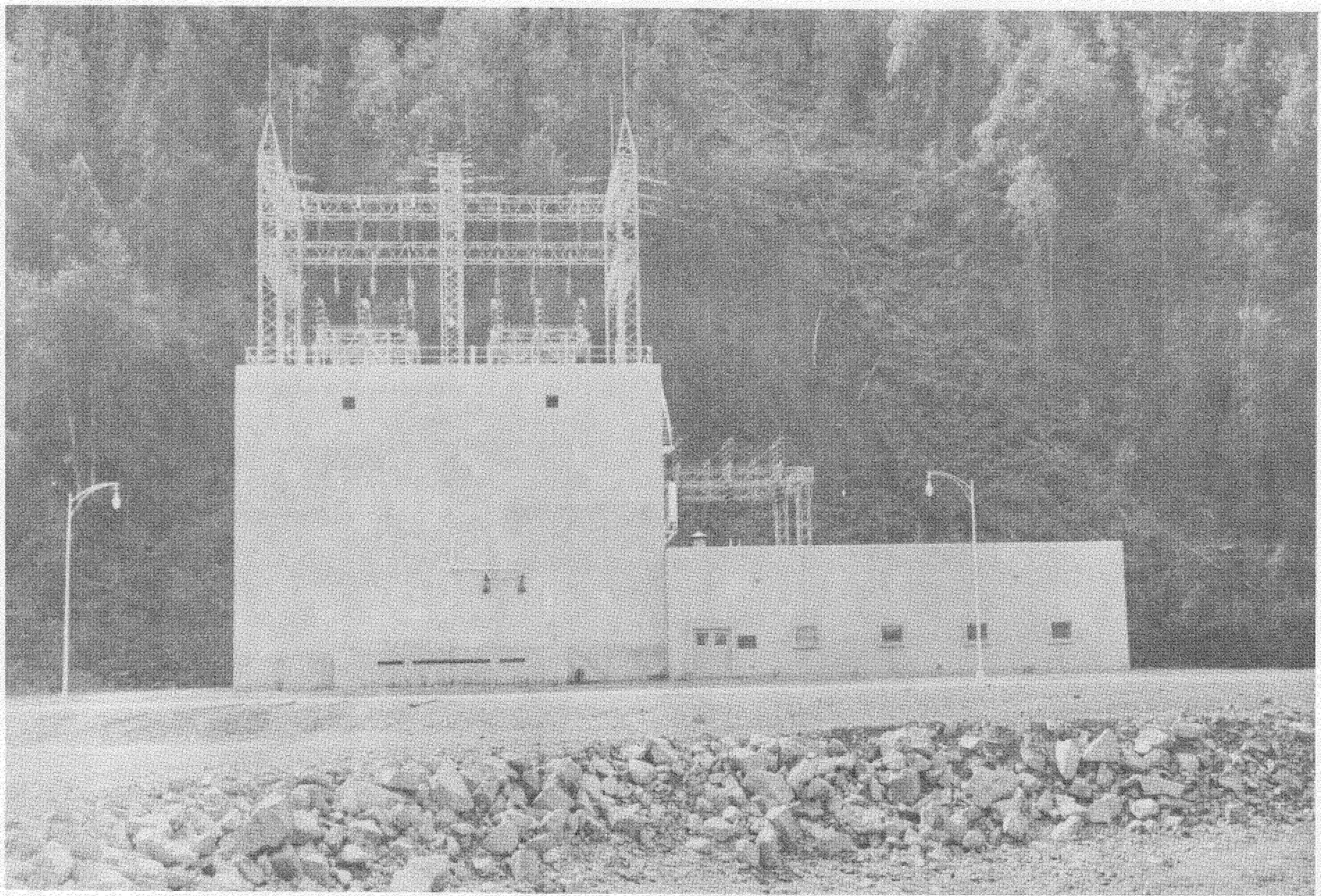
Location: Adjacent to Glenn Highway, 34 miles northeast of Anchorage, Alaska
Type: Reinforced concrete
Maximum head: 850 feet
Number of units: 2
Installed capacity: 33,334 kilovolt-amperes
Turbines: Francis type, 25,000 horsepower at a rated speed of 600 revolutions per minute and an 800-foot effective head
Generators: Vertical-shaft type, 16,667 kilovolt-amperes at 90 percent power-factor, 3 phase, 60 cycles, 6,900 volts
Transformers: Two main power transformers, 3 phase, 60 cycle, forced-air cooled, 20,000 kilovolt-amperes, 6,600 to 115,000 grounded wye-volts

Switchyard

Location: At three levels, on and adjacent to the powerplant (roof elevation 92.50, intermediate roof elevation 58.54, and ground level elevation 41.25)
Number of units: Two 115-kilovolt bays
One 12.47-kilovolt bay

Tailrace

Location: North from powerplant under the Glenn Highway and terminating in an open tailrace channel which discharges into the Knik River
Length: 209-foot-long pressure type



EKLUTNA POWERPLANT (P783-908-1896)

FOREWORD

Technical records of design and construction are a series of publications recording the planning, design, and construction of Bureau of Reclamation structures.

This technical record of design and construction of Eklutna project is divided into four main parts. Part I contains a discussion of general planning and historical data, a summary of costs, and descriptions and discussions of geology including regional and construction geology. Part II is devoted to discussions of the design of the various structures. In this part, the design of each major structure--for example, the pressure tunnel, penstock or powerplant--together with its appurtenant operating equipment, such as gates, cranes, and turbines, is made the subject of a separate chapter. Part III, Construction, comprises two chapters, one on the tunnel and the other on the powerplant.

The technical record was prepared in the Commissioner's Office, Denver, under the direction of the Assistant Commissioner and Chief Engineer. Acknowledgment is gratefully made to the designers and field construction personnel whose contributions formed the basis for this work.

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PART I--INTRODUCTION

CHAPTER I--HISTORY AND DESCRIPTION

1. Location and Purpose. - The Eklutna project (fig. 1) is a 30,000-kilowatt hydroelectric power development designed and constructed by the Bureau of Reclamation, United States Department of the Interior, to bring urgently needed electric power to the rapidly expanding area at Anchorage, Alaska. The project, the first major development by the Bureau of Reclamation outside the continental United States, was constructed during the 4-year period between 1951 and 1955.

The Eklutna Powerplant (fig. 2) is on the Glenn Highway between Anchorage and Palmer, Alaska, about 35 miles northeast of Anchorage. The Eklutna project area includes the Willow Creek mining district on the north, the Matanuska Valley on the east, and the city of Anchorage and environs to Turnagain Arm on the south. Cook Inlet, a branch of the Gulf of Alaska, lies to the west. The area is a northern reach of the Pacific Mountain system, the parallel ranges of which enter Alaska through British Columbia, Canada, and embodies two large flats--a valley floor and a coastal plain. The Cook Inlet and Chugach Mountains almost isolate these areas from each other; they are connected by a narrow strip of land bordered by a branch of the inlet--Knik Arm, a tidal estuary--and the mountains.

Anchorage lies on a low bluff overlooking Cook Inlet, and is bounded on the north, south, and west by arms of the sea. To the east is a low plain extending to the Chugach Mountains. This enclosed area comprises about 75 square miles. Matanuska Valley, through which flow the Matanuska and Knik Rivers, is roughly 50 by 16 miles, and is almost surrounded by the Alaska, Talkeetna, and Chugach Ranges.

Trending northwest from the Chugach Mountains to Knik Arm is the Eklutna Creek which descends through a steep-sided, trough-like, glaciated valley about 27 miles long. Rugged peaks up to 8,200 feet in elevation rise sharply above short valleys tributary to the creek.

The project is for power production only. Firm energy has been estimated at 143 million kilowatt-hours annually. Nonfirm energy, available only during certain hours in summer and early fall, will be more than 16 million kilowatt-hours in the average year. Transmission lines north to Palmer and south to Anchorage have been constructed, along with substation facilities. These lines operate at 115 kilovolts.

2. Description of Features (fig. 3). - (a) *Dam and Reservoir.*--The reservoir is formed by an enlargement of Eklutna Lake, a natural body of water about 10 miles southeast of the powerplant. The lake has a surface area of 3,247 acres, a length of 7 miles, and a capacity of 182,000 acre-feet at maximum water surface elevation 867.5.

The existing dam was formed by an alpine glacier about 7 miles long, which on melting and receding left a lake (Eklutna) and a natural dam. During construction the dam was raised to a crest elevation of 875 feet above sea level. The upstream and downstream slopes of the dam and other areas have been covered with riprap, underlain on the upstream slope of the dam by a sand and gravel blanket 12 inches thick. The dam has a height of 26 feet above the foundation, a length of 555 feet, and a volume of 5,000 cubic yards.

An uncontrolled overflow spillway with a crest elevation of 867.5 and length of 150 feet is located on the right abutment.

(b) *Intake Structure.*--Diversion from the lake is made through an inlet channel, 100 feet wide and about 500 feet long, excavated at the lake bottom at elevation 800 (about 60 feet below lake surface elevation). From this intake channel there extends an intake structure 133 feet 8 inches long.

The intake structure has an initial trashrack structure 112 feet long, built of rectangular precast concrete sections of varying depths. Each is 26 feet 8 inches wide

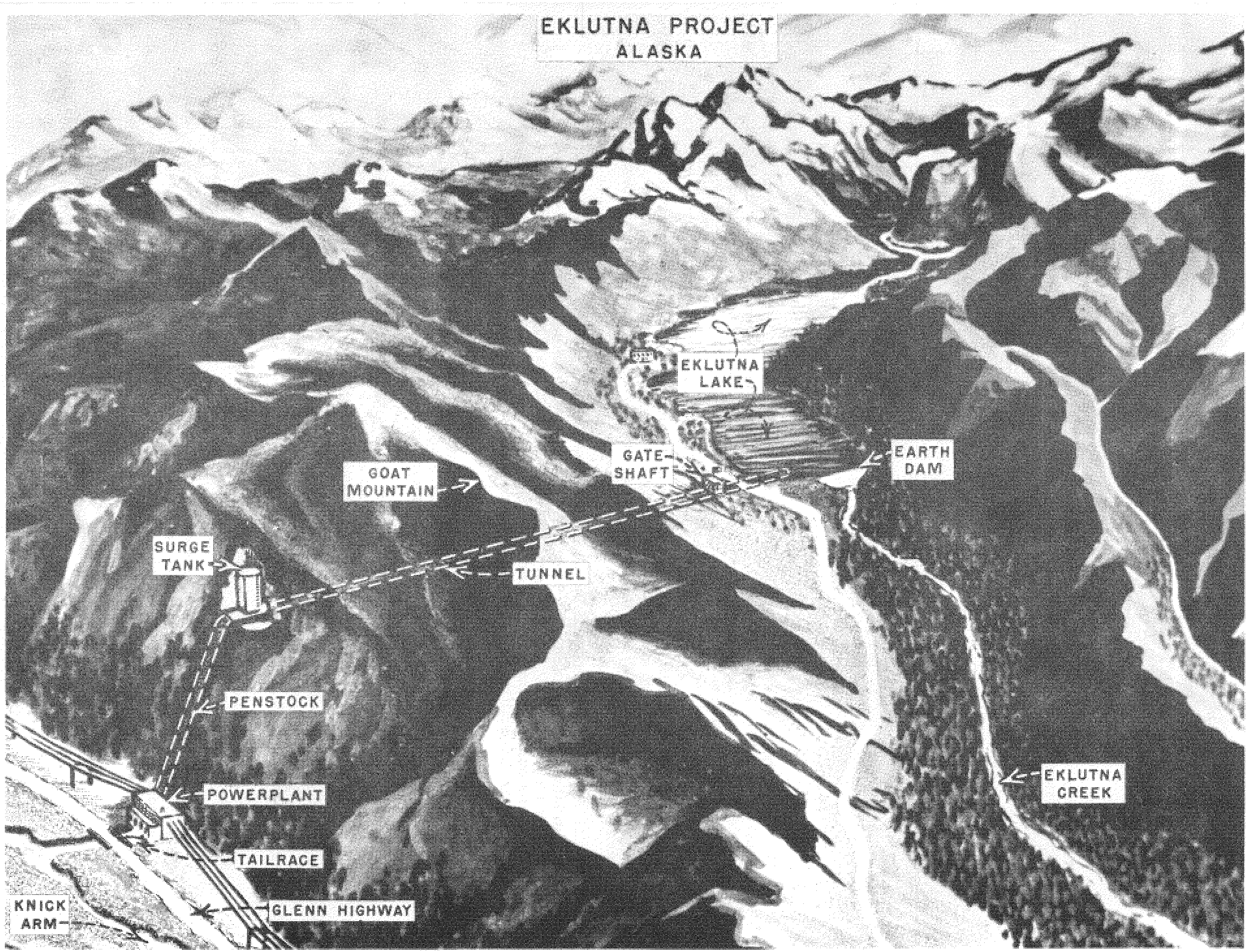


Figure 1.--Artist's conception of Eklutna project.

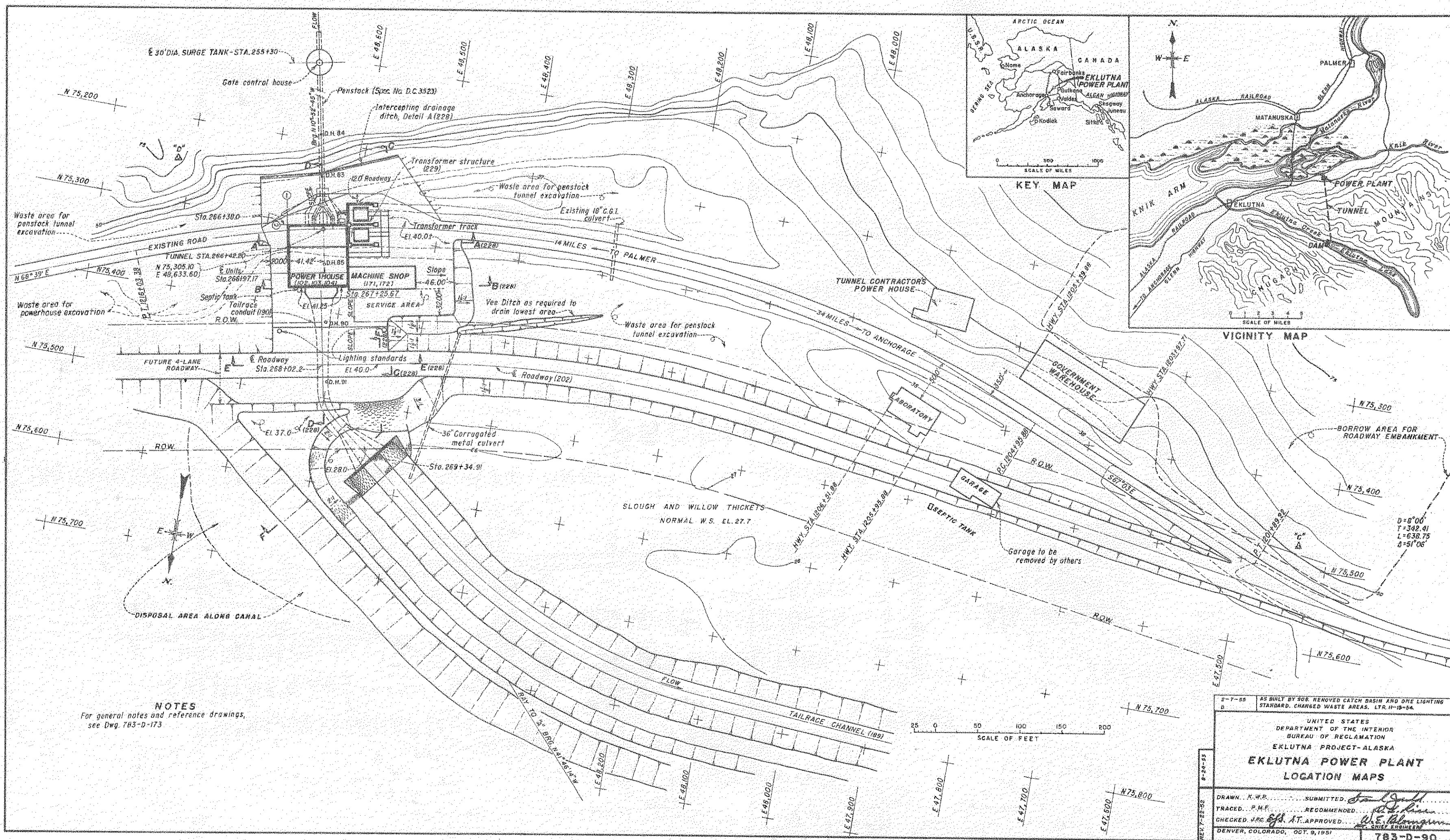


Figure 2.--Eklutna Powerplant location maps.

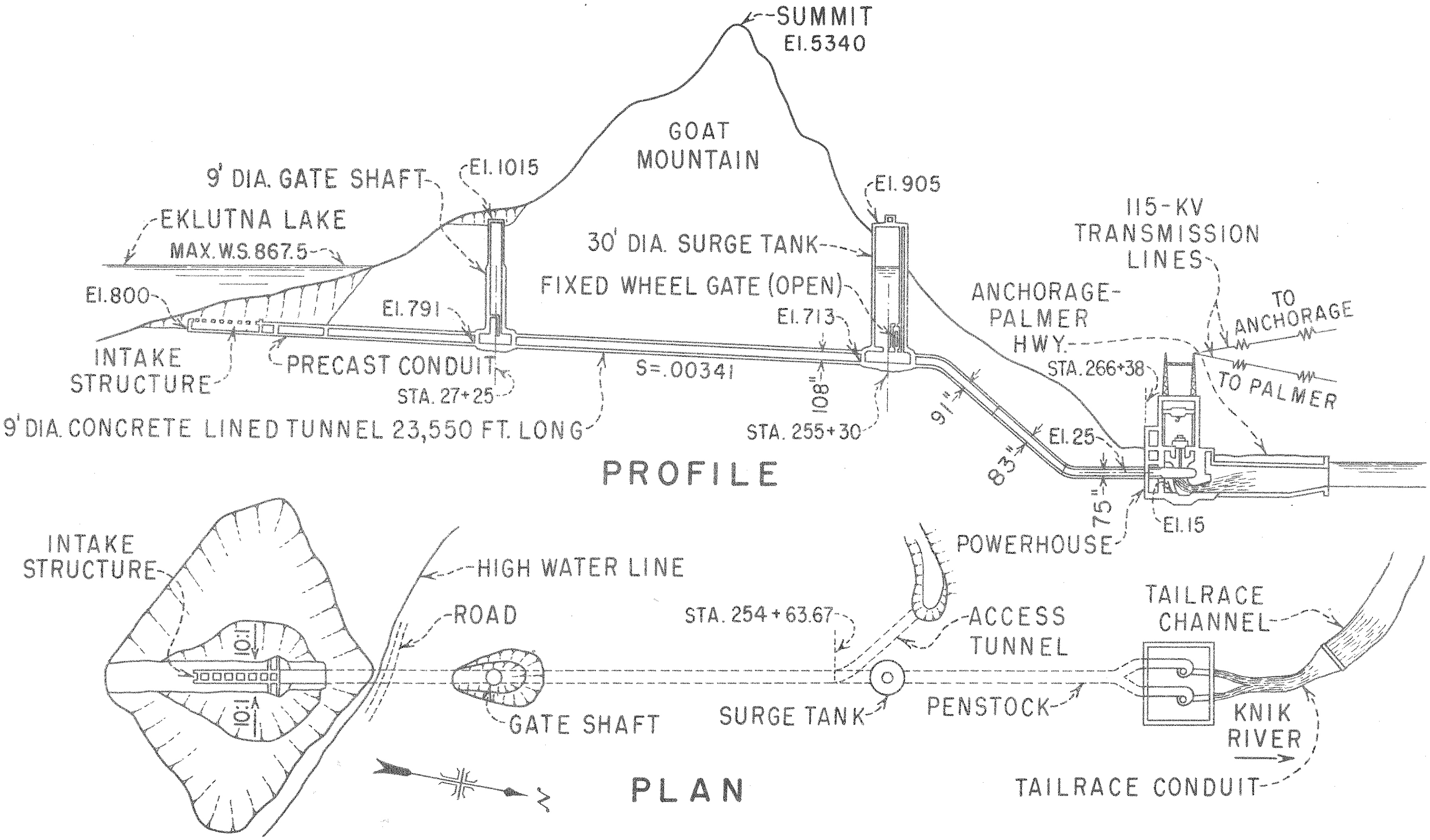


Figure 3.--Schematic plan and profile of Eklutna project features.

and 37 feet long. Immediately downstream from the trashrack structure is a precast concrete transition section, 14 feet 2 inches long. The inside of this transition section tapers from a rectangular reinforced concrete section 9 feet by 22 feet 8 inches to a circular section 9 feet in diameter. At the end of the square-to-round transition section there is a bulkhead section 7 feet 6 inches long. Slots are provided in the bulkhead section for either stop planks or a fabricated bulkhead to be used in the event of an emergency or for inspection purposes.

From the end of the bulkhead section the water is conveyed through a 9-foot inside-diameter precast concrete pipe 225 feet long extending to the entrance of Eklutna Tunnel (subsec. (c)). The pipe has a wall thickness of 12 inches. It was cast in 16-foot sections, each section weighing about 40 tons.

(c) *Tunnel.*--A circular, concrete-lined pressure tunnel 9 feet inside diameter and 23,550 feet long (4.46 miles) conveys water from Eklutna Lake to the penstocks leading to the powerplant. The capacity of the tunnel is 640 second-feet at a velocity of 10.06 feet per second, the slope of the invert being 0.00341.

The tunnel terminates in a surge tank installed directly over the tunnel 22,805 feet downstream from the bulkhead gate shaft. The surge tank, of the restricted-orifice type, has an inside diameter of 30 feet, a wall thickness of 18 inches, and extends 176 feet above the tunnel.

The tunnel section beneath the surge tank contains one 9-foot-long round-to-square transition and a similar square-to-round transition spaced 4 feet 6 inches apart along the centerline. The 4-foot 6-inch rectangular separation serves as a gate slot for the fixed-wheel gate which is used for emergency closure of the tunnel in the event of damage to the penstocks below or the turbine in the powerplant and for unwatering the penstock for inspection and maintenance.

A tunnel adit is located at the outlet end of the tunnel near the surge tank. The adit is essentially the same size as the main tunnel and is approximately 300 feet long. The purpose of the adit is to provide one means of access to the tunnel for inspection and maintenance purposes. It also acts as a free-flow conduit in conveying drainage water from the tunnel when entrance into the tunnel is necessary. Access from the adit to the tunnel is by means of a water-tight door.

(d) *Penstock.*--Extending from the surge tank at the end of the Eklutna Tunnel is the power penstock which conveys water to the powerplant turbines. The overall length of the penstock is about 1,088 feet, installed in 30-foot sections. The penstock is a variable-diameter (91-inch, 83-inch, and 75-inch outside diameter) welded and coupled steel pipe encased in concrete in a tunnel extending from the surge tank to the powerplant. Plate thickness of the penstock varies from 5/16 inch at the initial section to 1-1/2 inches at the terminal section. In profile, the penstock roughly parallels the mountainside, descending for approximately 864 feet at an angle of 53°; it then levels off and continues through a horizontal section about 501 feet long.

The penstock bifurcates into two 51-inch-diameter 23-foot-long branches at the powerplant which are connected to the spiral cases of the turbines. A 66-inch butterfly valve is installed in each penstock branch upstream from the turbines to provide means of unwatering the turbines for servicing or maintenance. These valves also serve as emergency shutoff valves in the event of damage to the turbines. Access to the penstock interior is obtained through the vent at the surge tank, through manholes in the powerplant, and through the tunnel adit.

(e) *Powerplant.*-- The powerplant is a reinforced concrete structure 149 feet long housing two vertical-shaft generating units. The turbines are of the Francis type and are rated at 25,000 horsepower at a speed of 600 revolutions per minute and an 800-foot effective head. The generators are rated at 16,667 kilovolt-amperes, 3 phase, 60 cycles, 6,900 volts. The maximum operating head is 850 feet. There are two main power transformers rated at 3 phase, 60 cycles, forced-oil and forced-air-cooled, 20,000 kilovolt-amperes, 6,600 to 115,000 grounded wye-volts.

(f) *Switchyard.*--The switching equipment for the powerplant is located at three different elevations. The switchyard equipment itself, consisting of the power circuit breakers, disconnecting switches, and main busses, is on the roof of the powerplant at elevation 92.50. The main power transformers that "step up" the generator low voltage are located in the transformer bay adjacent to and southwest of the powerplant structure at elevation 41.25. The high-voltage bushings of these main power transformers are connected to the main switching equipment located on the roof at elevation 92.50.

The 115-kilovolt bus structure on the powerplant roof consists of two bays to supply the 115-kilovolt lines to the cities of Palmer and Anchorage. In addition, there is a 12.47-kilovolt line which supplies power to the Government camp from a small transformer energized from the low-voltage generator leads. This transformer is in the transformer bay adjacent to and south of the powerplant structure at elevation 41.25.

(g) *Tailrace.*--Water discharged from the draft tubes of the turbines in the powerplant enters a 209-foot-long pressure tailrace conduit through which the water is conducted under the Glenn Highway to an open tailrace channel which discharges into the Knik River.

The tailrace conduit is made up of rectangular, reinforced concrete transition sections having varying widths and depths. The terminal section of the conduit is 50 feet long and flares outward in the downstream direction from a width of 14 feet 6 inches to a width of 46 feet 6 inches. This terminal section is also of varying depth and has five openings separated by 10-inch walls through which the water passes into the tailrace channel. Stoplog slots are provided at the outlet of the conduit. The stoplogs are available for use when it is necessary to dewater the conduit or to unwater both draft tubes at the same time.

The banks of the open tailrace channel are built on a 2 to 1 slope and are lined with riprap at its junction with the tailrace conduit. The channel has a top width of about 75 feet, a bottom width of 25 feet, and a depth of about 12 feet 6 inches.

3. Regional Development. - Cook Inlet was first explored by Russian traders in the late 18th century and by Captain James Cook, famed English navigator, about the same time. In seeking the mythical "northwest passage," the latter gave Turnagain Arm its name. First to trek over the land were fur seekers and prospectors. Commercial fishing began shortly after the United States purchased the Territory in 1867. Gold discovered there in 1880 attracted some miners, but not in stampede numbers.

Following the great gold strikes in the Klondike and later Nome and Fairbanks from 1897 to 1904, permanent settlers ranged into Cook Inlet and Knik Arm to take up homesites. Coal discovered in the Matanuska Valley led early in the century to plans for a railroad south to Seward. The Alaska Central began construction but was taken over by the Federal Government in 1914 after a coal land controversy halted work. The Government continued building north and reached Fairbanks in 1923.

Anchorage was born when the tracks came through. Main offices and shops were located there, and many construction men remained. The town has ever since expanded, its growth closely associated with farming, mining and fishing--in turn giving rise to more construction, transportation and influx of business.

A boost was given population in 1935, when 200 families from the drought-striken midwest were transported to Alaska by the Government-directed Alaska Rural Rehabilitation Corporation and settled in the Matanuska Valley. The valley has since enjoyed a steady growth and contributed greatly to Anchorage's welfare.

Prior to World War II, the only permanent military post in Alaska was a small garrison at Chilkoot Barracks near Haines, in southeast Alaska. With the war, the United States began hurriedly to arm the Territory. Thousands of workers and millions of dollars were rushed north to undertake huge defense projects, among them Fort Richardson and Elmendorf Air Field near Anchorage. Every job at the Fort was estimated to create another in town.

The wartime surge put Anchorage in no worse straits than many western cities. But later, it lagged in building and power facilities. Lack of family quarters at the nearby fort forced many soldiers to crowd into town. Electric light and power "brownouts" were frequent, despite herculean efforts to keep pace with demand.

Today the housing situation is serious, although construction of new homes and apartments goes on apace. The power shortage has eased temporarily with completion of the Eklutna project. The city counted 11,060 persons living in its corporate limits during the 1950 census, compared with a city population of 3,495 in 1939. The Anchorage district, however, numbered 31,561, the added population being contiguous with the city. This figure does not include Fort Richardson, whose military personnel, while permanent, are subject to variation. These added thousands, not considered residents of Alaska, nevertheless count definitely in the city's economic life.

The Palmer district, including the Matanuska Valley and small towns nearby, counted 2,511 persons in 1950. Anchorage in 10 years expanded 216.5 percent in population, and its district jumped 567.8 percent. The Matanuska Valley population went up 74.3 percent. And everything is still growing.

4. Preproject History, Contractual Agreement, and Water Rights Acquisition. - On September 28, 1922, Mr. Frank I. Reed, of Anchorage, Alaska, applied to the Federal Power Commission for a preliminary permit to construct a diversion dam at the lower end of the canyon on the Eklutna River about 3 miles above its mouth, in the Knik Precinct, Territory of Alaska, together with all necessary appurtenant works, including a hydroelectric generating plant, regulating dam at the outlet of Eklutna Lake and necessary transmission line to Anchorage. This application was made in order to protect the rights of priority of the applicant for a license under the Federal Water Power Act while securing the data and performing the acts necessary to perfect an application for the license. On March 8, 1923, the preliminary permit was granted by the Federal Power Commission to Mr. Reed, and on October 12, 1928, the Federal Power Commission issued to Mr. Reed, a license for a period of 50 years. This license authorized him to construct, operate, and maintain a power project, designated as Federal Power Commission licensed project No. 350 Alaska-Eklutna, and to occupy and use therefor certain lands of the United States which were necessary or useful for purposes of the project.

On October 23, 1928, the Federal Power Commission approved the transfer of the license from Frank I. Reed to the Anchorage Light and Power Company, Inc., which corporation had been organized to finance and construct the power project. The project was constructed during 1928 and 1929 according to the plans filed with the Federal Power Commission, and was operated by the Anchorage Light and Power Company until 1943.

An Act of Congress (H.R. 338) passed on June 28, 1943, stipulated that upon approval of 55 percent of the electors of the city of Anchorage, the city was authorized to increase its statutory debt limit by $1,250,000, of which $1,000,000 was to be used for the purchase of the hydroelectric properties owned by the Anchorage Light and Power Company. On July 1, 1943, the city secured an option to purchase from the Anchorage Light and Power Company its hydroelectric generating and transmission facilities. On August 17, 1943, the election was held and the measure passed, and the purchase was ultimately consumated and formal possession was taken on October 25, 1943. The purchase price of $1,100,000 covered the properties encompassed in licensed project No. 350, a small diesel generating plant in Anchorage, and a fuel oil inventory. On March 1, 1944, the Federal Power Commission approved the joint application filed November 3, 1943, by Anchorage Light and Power Company, licensee for project No. 350, and the city of Anchorage, Alaska, which application requested transfer of the license for the project from the former to the latter. This approval stipulated that the new licensee, the city of Anchorage, would be subject to all the conditions of the license and to all the provisions and conditions of the Federal Water Power Act to the same extent as though it were the original licensee.

5. Authorization. - In 1950, Public Law 628, 1st Congress, 2nd Session, H.R. 940, was passed and the Eklutna project was started. The Law reads in part as follows: "That in order to encourage and promote the economic development of the territory of Alaska, to foster the establishment of essential industries in said territory, and to further

the self-sufficiency of national defense installations located therein, the Secretary of the Interior is authorized to construct, operate and maintain the Eklutna project in the vicinity of Anchorage, Alaska---."

The selected site for the new hydroelectric powerplant was about 6 miles east of the then existing Eklutna Powerplant. In order to operate the new powerplant it was necessary to utilize Eklutna Lake as a water storage reservoir, and impound and use water theretofore utilized by the city of Anchorage in its existing hydroelectric powerplant.

On November 23, 1953, the United States, Department of Interior, Bureau of Reclamation, and the city of Anchorage, Alaska, entered into a contractual agreement, No. 14-06-906(E)-1, entitled "Contract for Plant Purchase and Electric Service with the City of Anchorage, Alaska." The contract reads in part:

> "4. WHEREAS, completion and operation of the Eklutna Project is dependent upon the United States acquiring all of the Contractor's rights to water for the operation of the Contractor's hydroelectric generating plant at Eklutna, Alaska (Federal Power Commission licensed Project No. 350), which will thereby render said generating plant useless to the Contractor; and
>
> "5. WHEREAS, the Contractor is willing to transfer and deliver all its interest in and to said water rights, said generating plant, and associated facilities and properties to the United States if in return therefor Contractor is compensated by certain adjustments in the rates and charges for the electric service furnished to it by the United States for the period of the remaining life of Contractor's Federal Power Commission licensed Project No. 350, which license for Project No. 350 expires on October 12, 1978."

The signing of the above contract removed the last remaining legal hurdle to construction of the Eklutna project.

6. Power Development. - Development of the Eklutna project is the first step in major hydroelectric development in Alaska. The project is the first part of a comprehensive plan for conservation and development of water resources in this promising railbelt which extends from Seward through Anchorage and the Matanuska Valley and over the Alaska range towards Fairbanks. Construction of the main transmission lines for the Eklutna project at 115-kilovolt capacity will permit future expansion of the power system.

7. Cost Summary. - The cost of constructing the Eklutna project features is as follows. Costs are actual costs to July 1, 1957, plus estimated costs through June 1958. See Appendix A for a detailed breakdown of costs.

Direct Costs		
Land rights	$ 12,110	
Construction by contract	23,593,728	
Materials furnished by Government	2,797,223	
Labor by Government forces	115,199	
Subtotal		$26,518,260
Construction facilities	667,130	
Government camp	589,359	
Subtotal		1,256,489
Indirect Costs		
Preliminary surveys and investigations	503,214	
Denver office	1,009,324	
Engineering and inspection	717,840	
Administration and general expense	942,805	
Subtotal		3,173,183
Calculated purchase price Old Eklutna from city of Anchorage		1,841,760
		32,789,692
Less transfers, credits and other expenditures		3,138,855
Total Project Cost		$29,650,837

CHAPTER II--GEOLOGY

8. Regional Geology. - The major part of the project geology was disclosed on the surface of the tunnel route and in the tunnel itself. The detailed tunnel logs[1/] include a section from upstream of the intake, through the tunnel, penstock, powerhouse, and to the downstream end of the tailrace channel.

The Knik River (fig. 4), Eklutna Lake, and Eklutna Creek lie in old glacial valleys covered with glacial till ranging in size from rock flour to large boulders. Where glacial and more recent streams have reworked this material, it has been sorted and somewhat bedded. In local areas, layers of nearly pure silt and clay are found interbedded with layers of coarser material. In the present stream channels and flood plain of the Knik River, well-rounded gravel and clean sand are found to a depth of at least 15 feet. Several intermittent advances of alpine glaciers have left glacial terrace remnants at high elevations along the Eklutna Creek Valley. The steep-sided valleys and flat flood plain area above the confluence of the Knik and Matanuska Rivers also are evidence of a long period of glacial erosion.

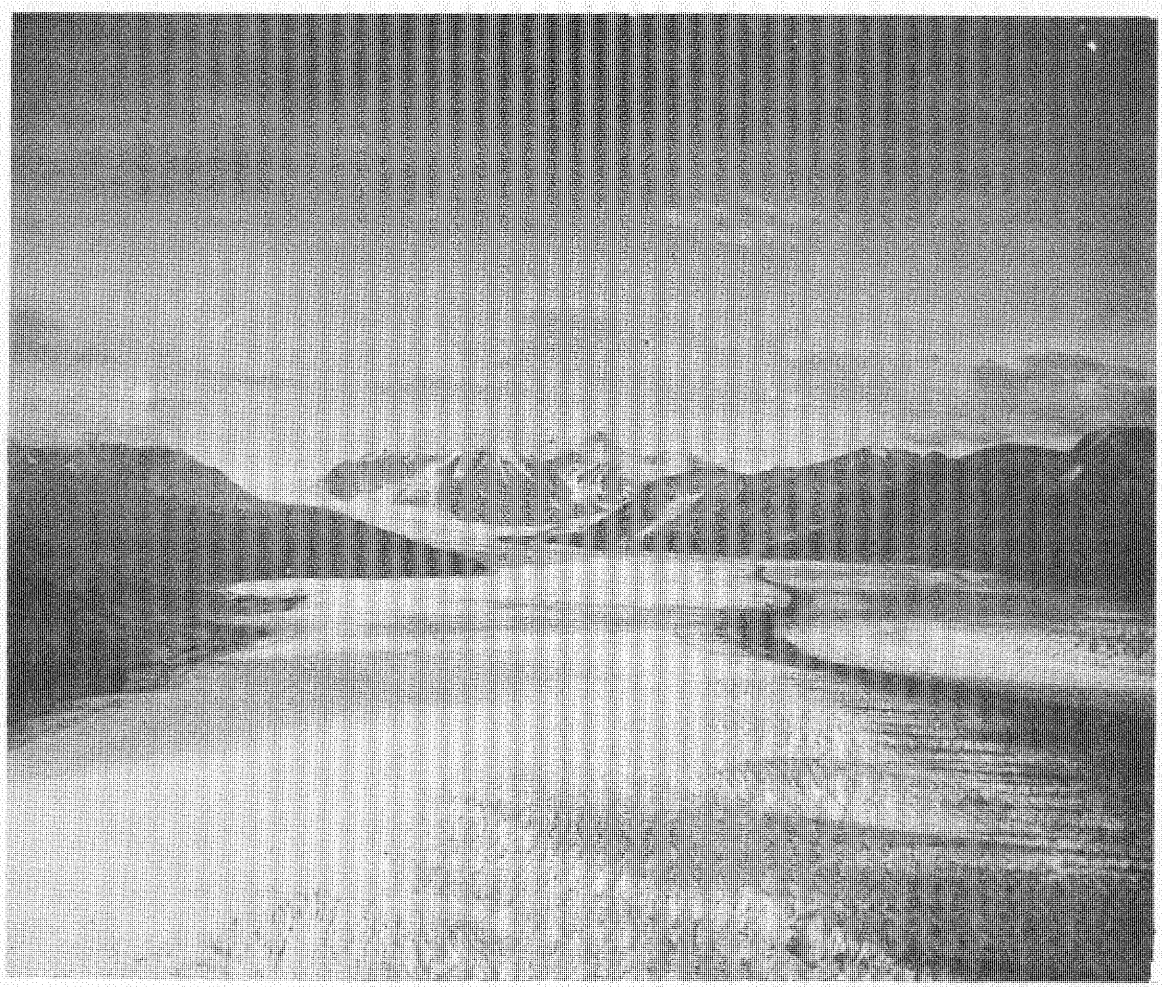


Figure 4.--The Knik Glacier--One of the many active glaciers in the Chugach Mountains. (P783-908-234)

1/ Athearn, M.J., and Judd, W.R., Final Engineering Geology Report on the Eklutna Project, January 1956.

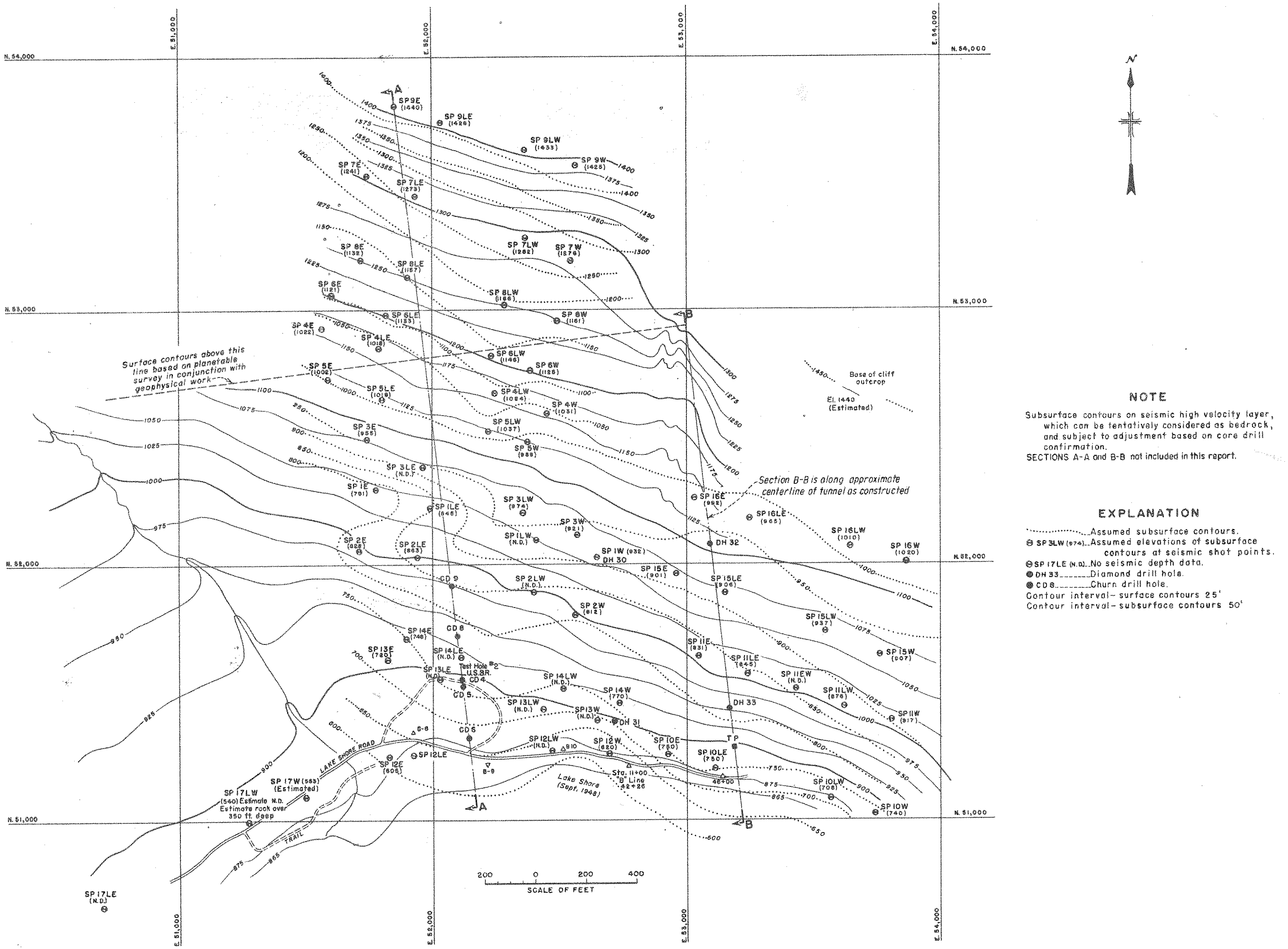


Figure 5.--Bedrock contours from seismic data for intake area. From drawing 783-908-3.

The tunnel passes through Goat Mountain, a metamorphosed series of graywackes, argillites, and slates. The first bedrock outcrops at about elevation 1350 or 1400 on the south slope of this ridge. From that elevation up to the lower limits of the jagged peaks, are low, partially covered outcrops. The approximately 1/4-mile-wide belt which makes up the jagged higher peaks consists of dark greenish-gray graywacke (previously identified as greenstone or andesite). The north slope of the mountain down to approximately the 3,000-foot contour is made up of interbedded graywacke, argillite, and slate, with the graywacke predominating. The entire lower slope, though covered by a heavy growth of vegetation, is predominantly very weathered, iron-stained, and crushed graywacke.

The structure of the entire series of rocks through which the tunnel penetrates is very complex. A determination of the forces and the direction of the forces which brought about the present conditions has not been made.

Materials for embankment, riprap, and concrete aggregate were obtained within the area of the project, except for granodiorite riprap material which was procured from the Alaska Railroad quarry some 8 miles from the powerhouse site.

9. Geology of Tunnel and Powerplant Site. - Shortly after funds were appropriated for the Eklutna project, an investigation program was initiated. Geologic investigations on the tunnel and surge tank were scheduled for completion on January 1, 1951. This provided 3 months to transfer the necessary men and equipment to Alaska and to acquire as much investigational data as possible by that date. Specifications for the tunnel were to be completed by April 15, 1951.

On October 17, 1950, the seismic exploration for bedrock began and continued for nearly 2 months. Several seismic spreads were completed in the proposed dam and tunnel inlet areas. (See fig. 5.) Drill holes were begun in November of 1950, to check the seismic data. (See figs. 6, 7, and 8.)

Geologic surface investigations were carried on in conjunction with the drilling program. The accessible areas around Eklutna Lake were studied and the proposed powerplant site was mapped in as much detail as possible. The complete tunnel line was flown by helicopter and representative photographs taken in late November of 1950. The heavy cover of vegetation in the proposed powerplant area and at lower elevations around the lake made it somewhat difficult to observe exposures of bedrock. An early snow at high elevations in the rugged terrain stopped any attempt to completely cover the tunnel line on foot.

A. Construction Geology

10. Intake Structure. - Dredging of the intake was started early in the spring of 1952, a few months after the principal construction contract was awarded, and was completed in the fall of 1952. Considerable difficulty was encountered in dredging the lower portion of the "B" material (see fig. 9 for definition) due to a few boulders that were too large for the dredge to handle.

From the top of the "B" material, or glacial till contact, to the bottom of the intake trench, it was necessary to blast the material before the dredge could cut through and pick it up. Its clay content, compact nature, and impermeability caused the material to remain very compact under water and to settle back in a compact mass on the lake bottom after blasting.

Twenty holes were drilled in the area of the tunnel intake to select the best location for the intake structure. Several holes were drilled from the surface of the ice on the lake to obtain samples for stability studies of the glacial flour and till on the lake bottom. Several methods of obtaining samples were attempted, but few samples were obtained. The uppermost portion of the glacial flour was partially in suspension in the water, and was difficult to hold in any type of sampler used. The best results were obtained from a combination of a 6-inch churn drill mud pump with a flap valve into which

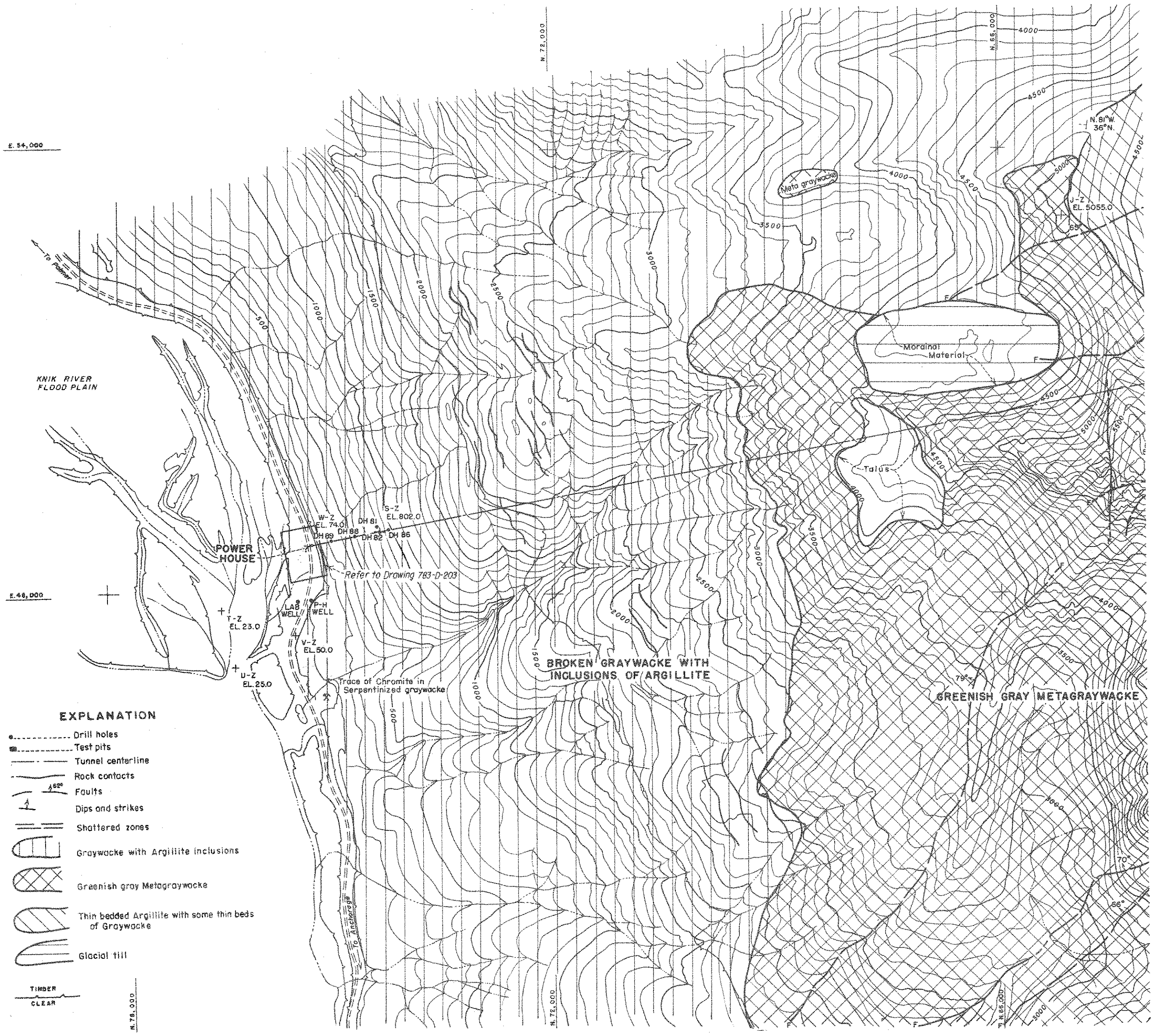


Figure 6.--Topography and surface geology of Eklutna project. (Sheet 1 of 2.) From drawing 783-908-244.

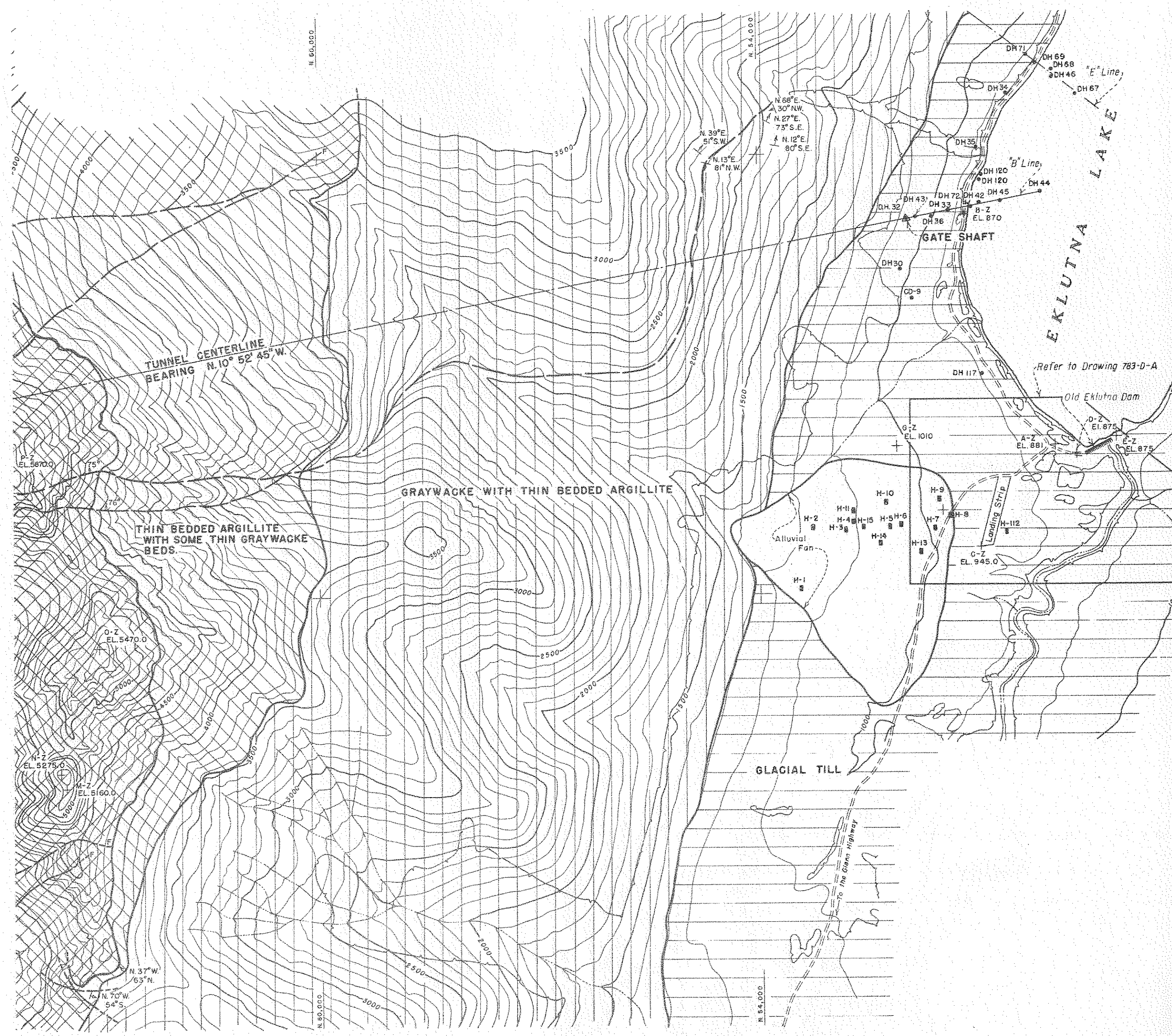


Figure 6.--Topography and surface geology of Eklutna project. (Sheet 2 of 2.) From drawing 783-908-244.

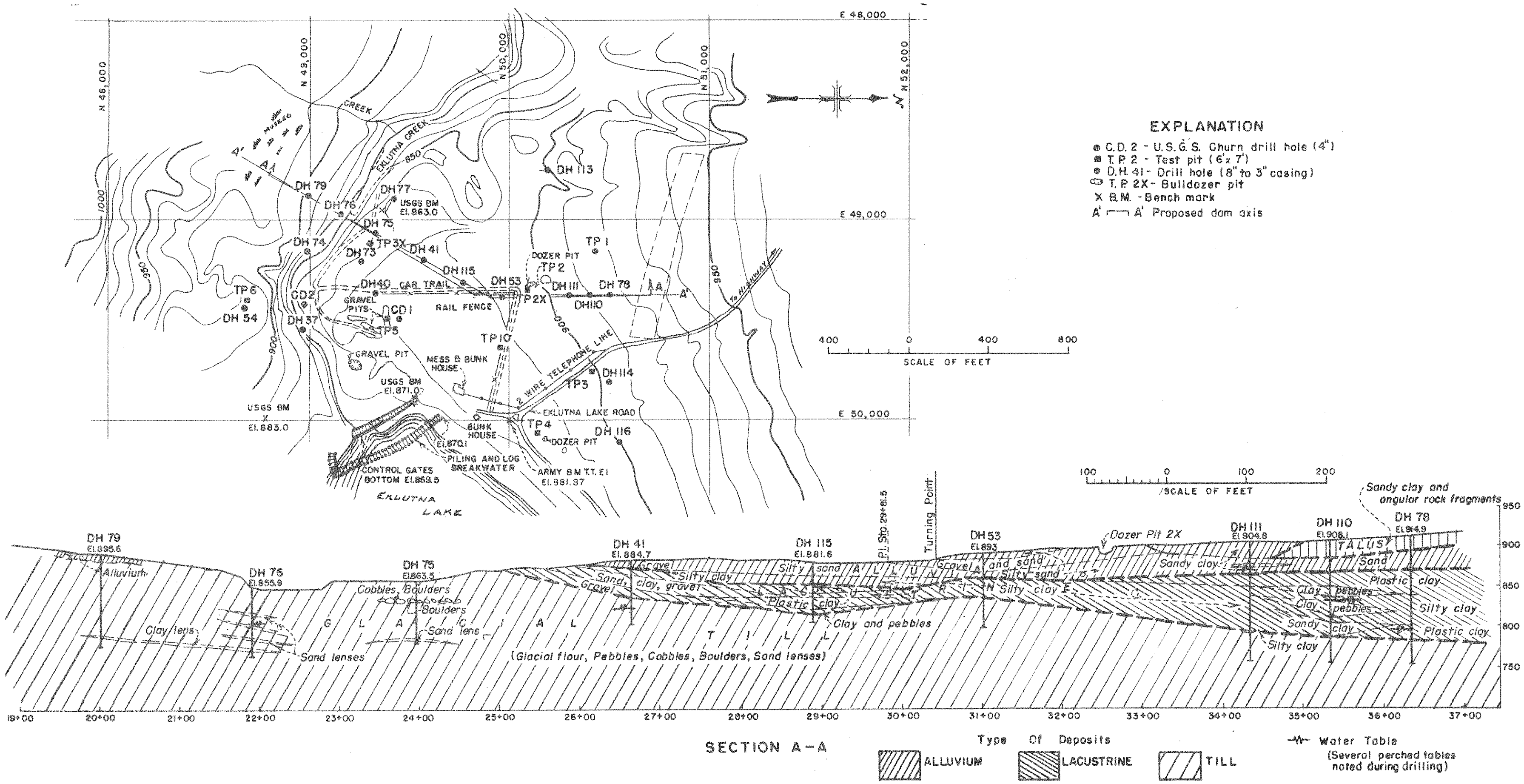


Figure 7.--Location of exploration in damsite area. From drawing 783-D-604.

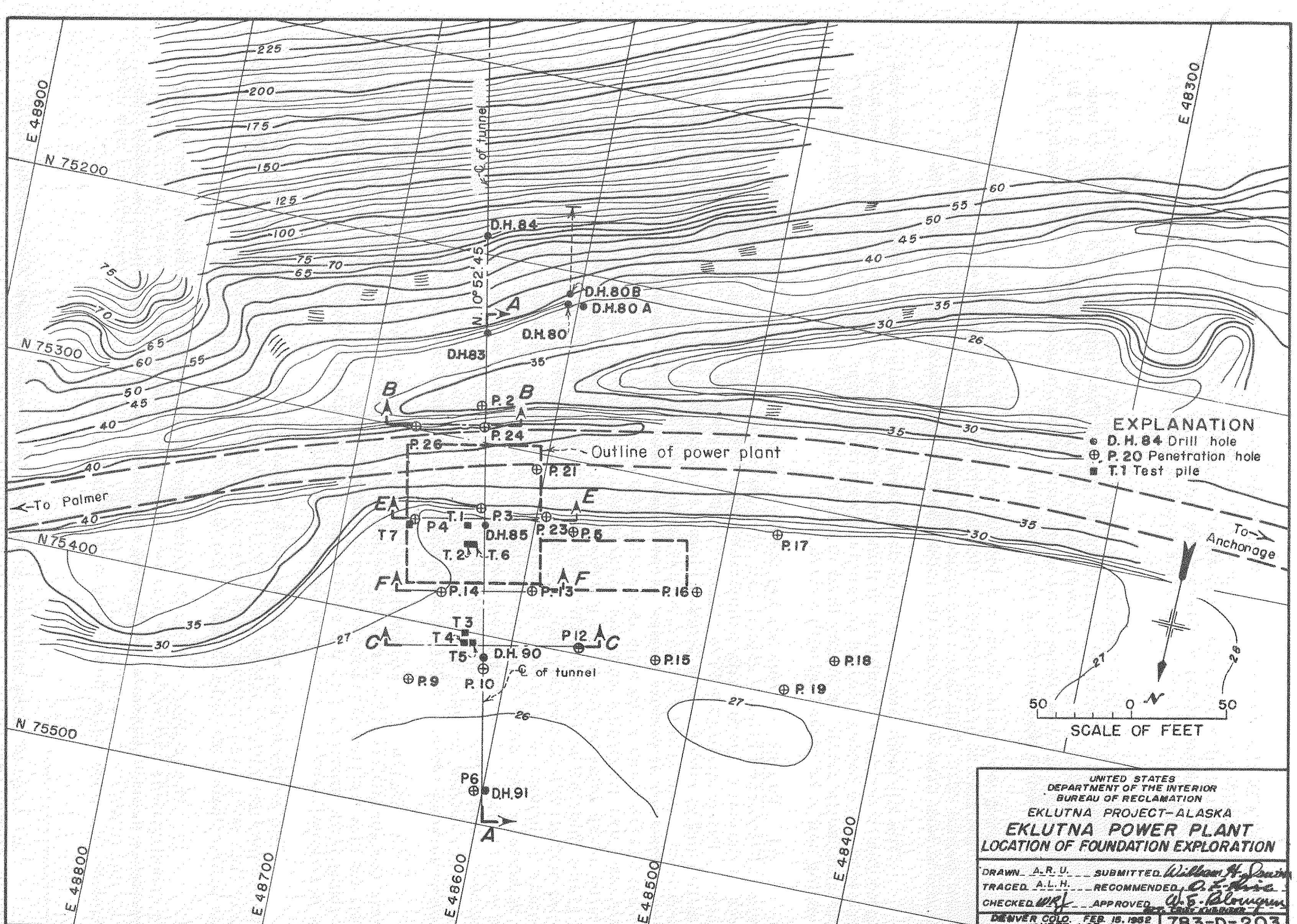


Figure 8.--Eklutna Powerplant--Location of foundation exploration.

was inserted a Denison sample tube. With this combination, several good (although disturbed) samples of the glacial flour were obtained down to the contact with the glacial till. The churn drill proved the most effective method of drilling and sampling most of the glacial till. Many of the boulders were very large and required blasting; this disturbance of the material prevented good samples from being obtained with smaller sized holes.

A geologic section of the intake area, based on notes taken while dredging, is shown on figure 10. The upper portion of the glacial flour (material "A" in fig. 9) was excavated on a 20 to 1 slope; the lower 20 feet of material "A" was excavated on a 10 to 1 slope. The very shallow slope in the upper portion was necessitated by the instability of the material, which was semifluid in consistency.

Below the glacial flour, a 3-foot layer of sandy clay with many boulders up to 3 feet in diameter was encountered. Beneath the layer of boulders was a loosely compacted glacial till. This layer was approximately 30 feet deep near the shore and thinned to less than 20 feet near the intake section (approximately station 17+00).

The till below the loose layer described previously, was extremely compact and impossible to dredge without first drilling and blasting; in some cases, it was necessary to blast it twice before it could be removed with the dredge. Many fairly large boulders were compactly set in the clayey finer material and after being loosened by blasting and dredging had to be picked up with a clam shell.

11. Tunnel. - From station 20+00 to station 25+32 (fig. 11) the material was a series of reworked beds of glacial till, clay and sand. Some ground-water was encountered in the sand layers, with a maximum total flow of approximately 300 gallons per minute. From station 25+32 to station 198+00 the rock is mostly thin-bedded, interbedded argillite and graywacke with bedding planes recognizable but very erratic in many areas. Much of the rock is very broken; innumerable minor fault planes and slippage planes cut through the rock at various angles to the tunnel axis. From station 198+00 to as far as station 234+75 most of the rock is a very metamorphosed greenish-gray graywacke. This rock was originally identified as greenstone, but petrographic examination revealed it to be of the same origin as the graywacke but more highly metamorphosed and colored by green chloritic minerals which developed during the mountain-building processes. From station 234+75 downstream, the rock is very uniformly broken graywacke with irregular inclusions of argillite. Through this area, bedding planes are entirely lacking, as apparently they were destroyed during a period of extreme faulting and folding. Also, the rock in most of this area is iron-stained and somewhat weathered; apparently there had been a fairly free flow of ground water through the more-or-less open joints. Many fault gouge seams, ranging from a fraction of an inch to several feet thick, disect the rock at varying angles. Some of the seams were the source of very small water flows.

12. Penstock. - Excavation of the penstock was initiated from the outlet end. From the steep slope adjacent to the outlet down to invert elevation the excavation was in open cut in a mixture of talus and alluvial material (fig. 12). To alleviate sloughing and washing of the material into the excavation, a sheet-pile cell was driven. From this cell, the horizontal penstock tunnel was driven upstream.

The entire section of the penstock in rock was in very broken, weathered, and iron-stained graywacke with argillite inclusions and many quartz and calcite-filled seams. Many fault gouge and breccia zones intersected the tunnel at various angles. The tunnel was in overburden for only 15 feet at the top of the arch at the outlet.

13. Powerplant. - Some 30 holes were drilled in the powerhouse area during the investigations and early construction stages. Nineteen of these were penetration resistance holes to evaluate the bearing capacity of the overburden material under the proposed powerhouse foundation.[2/] A geologic section through the powerhouse was made, based on the information from these drill holes (fig. 12).

2/ Logs of these holes are in the Eklutna Project Alaska Engineering Final Report, March 1956.

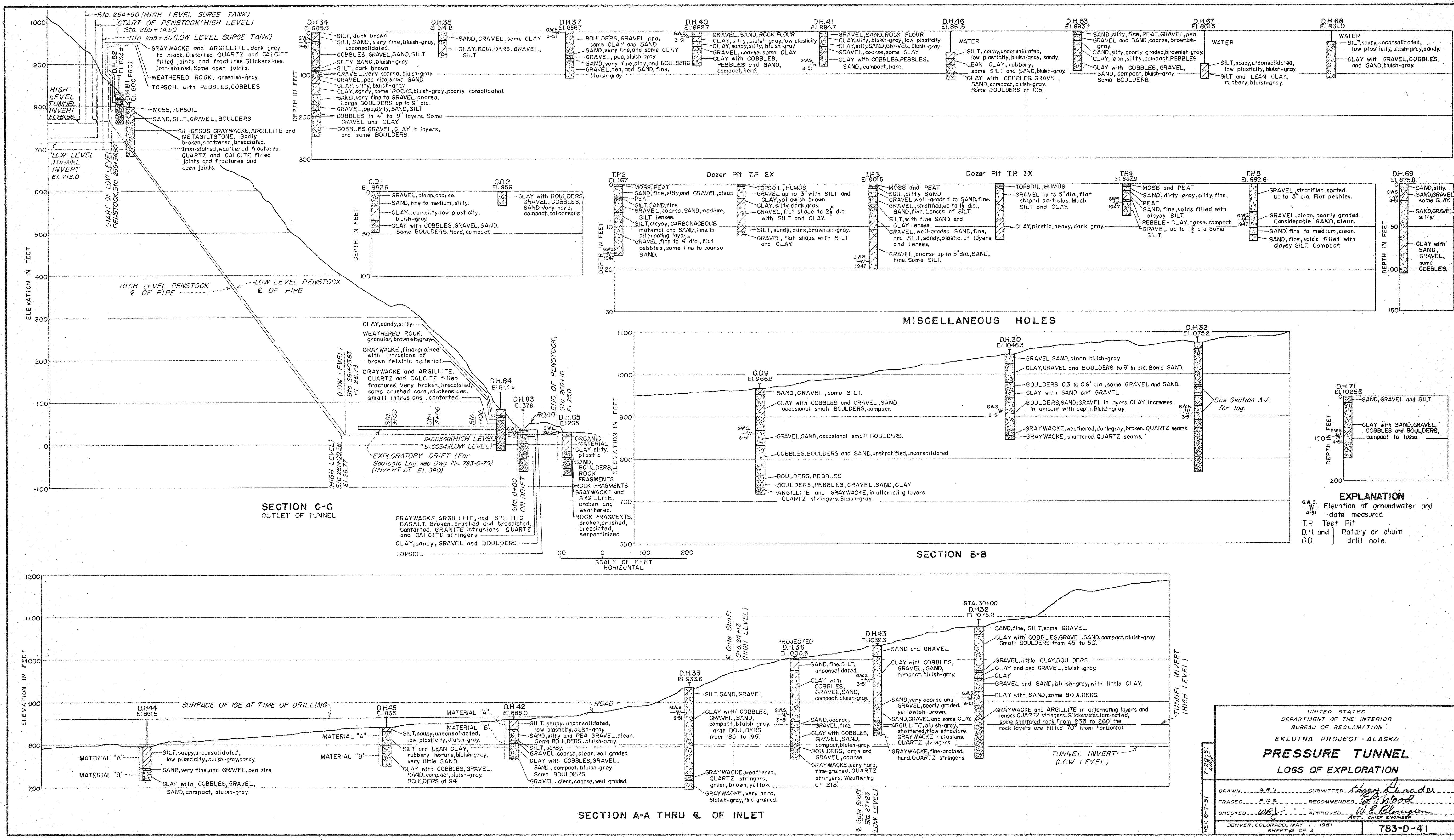


Figure 9.--Logs of exploration for pressure tunnel.

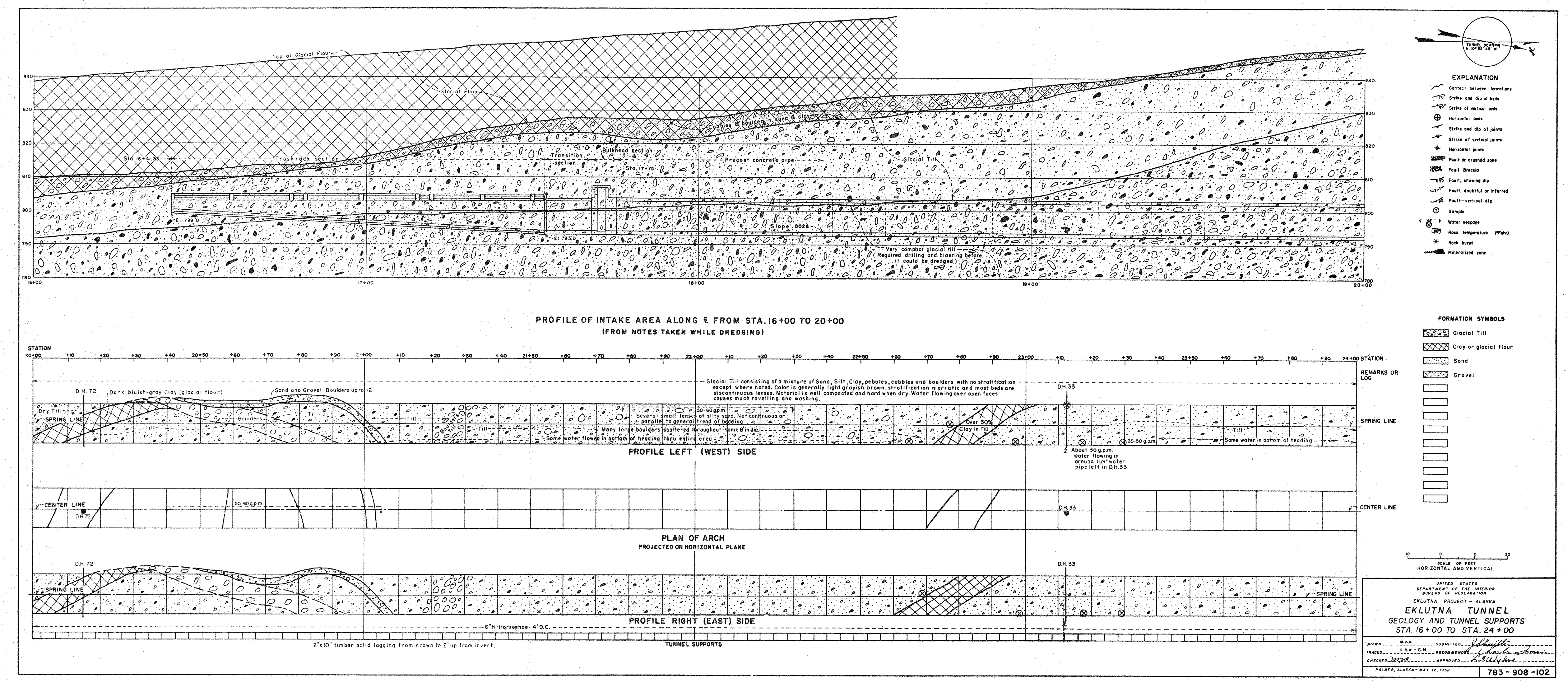


Figure 10.--Geology and tunnel supports--station 16+00 to station 24+00.

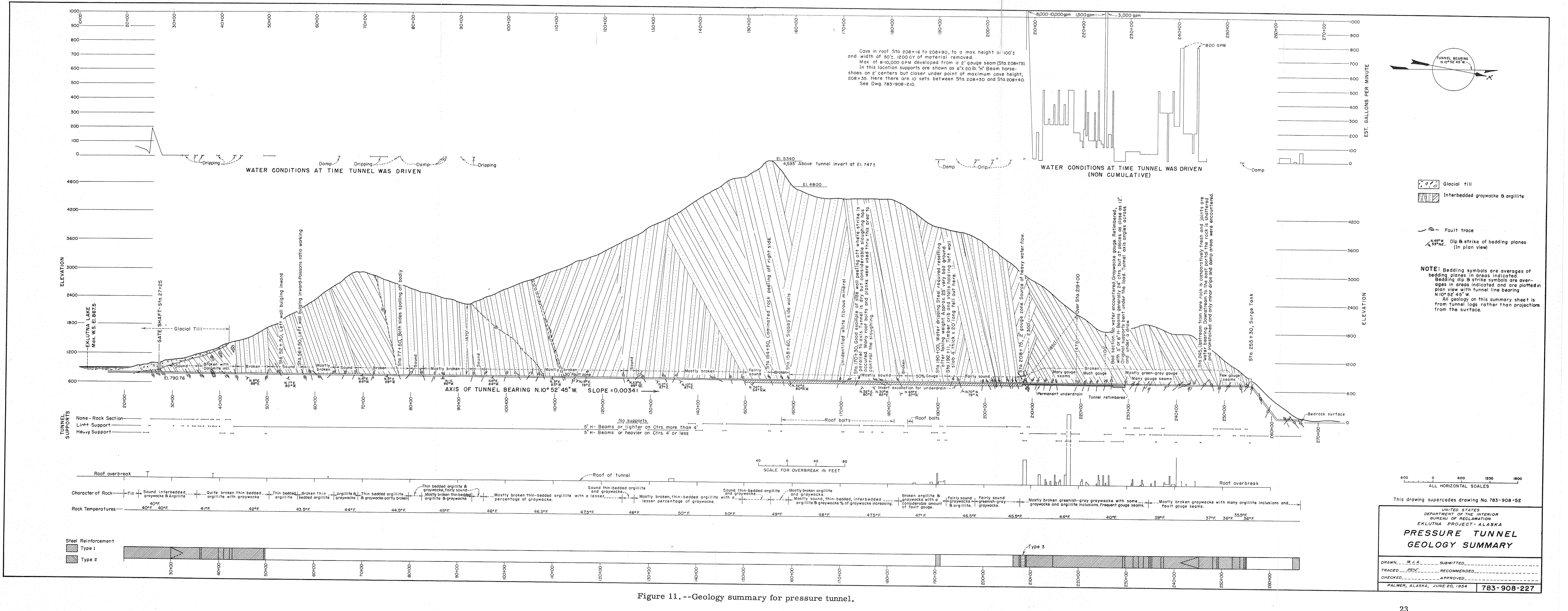


Figure 11.--Geology summary for pressure tunnel.

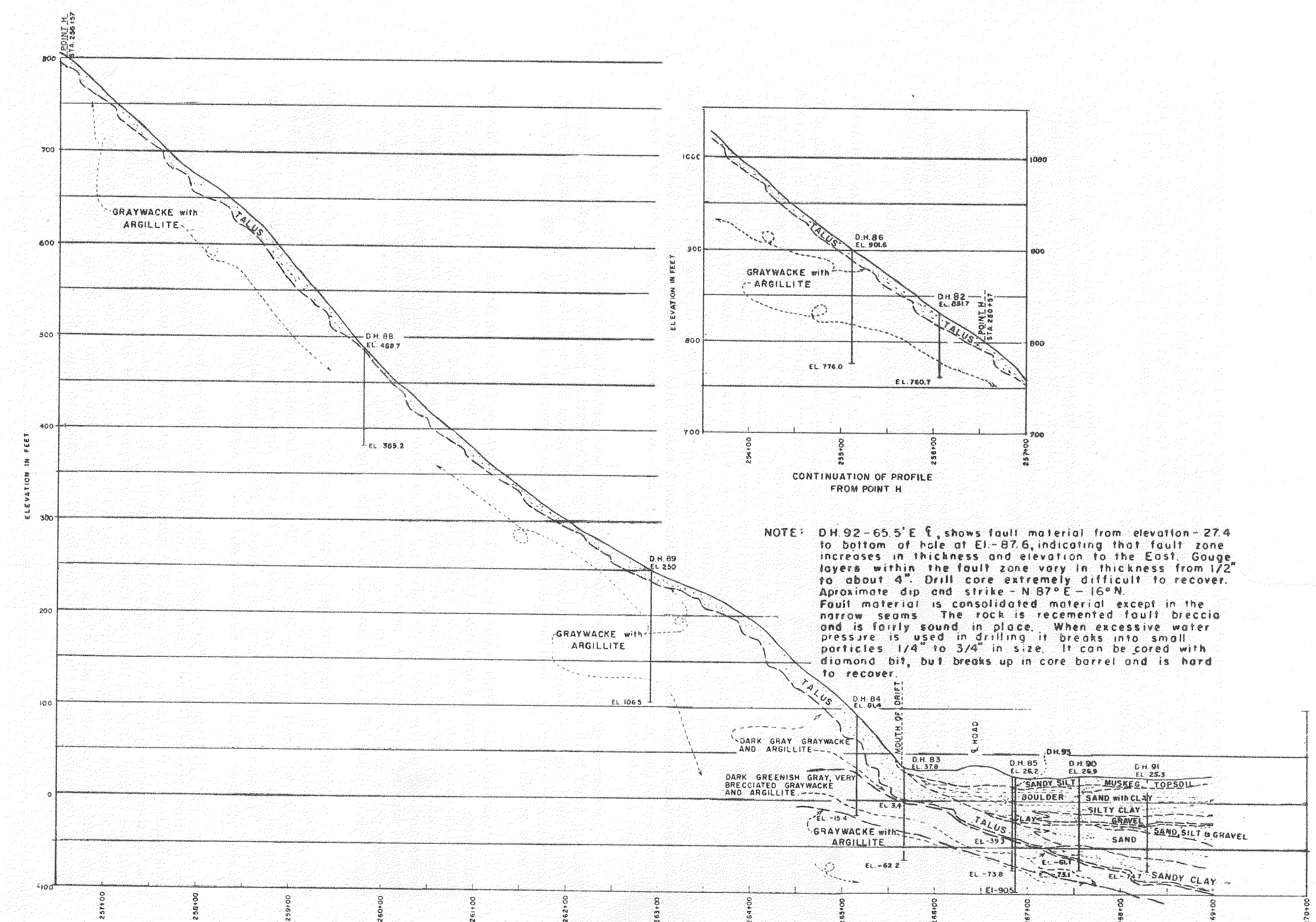


Figure 12.--Geologic profile along penstock centerline. From drawing 783-908-73.

Interstratified stream gravel, sand, silt, and clay in discontinous layers overlie the weathered bedrock surface. Extending north and west from the powerhouse site for several miles is a wide flood plain. Many changing stream channels from both the Knik and Matanuska Rivers spasmodically aggrade and degrade throughout the spring, summer, and fall seasons. These erratic sedimentation phases apparently account for the interstratified sediments in the powerhouse area.

The talus from the hillside extends only a short distance out from the toe of the slope. This is generally overlain by weakly plastic organic silts recently deposited during the annual flood stage of the Lake George breakup. At that time each year (August) the entire flood plain for several miles is completely covered with glacial water heavily laden with fine glacial silt. This silt is deposited as the water decreases in velocity.

Prior to deciding on the foundation design for the powerhouse, a pile-testing program was initiated. Five wood and two steel piles were driven and both horizontal and vertical load tests applied. Some difficulties were encountered in sustaining the required loads, and erratic settlements were recorded in some cases. A 14-inch wide-flange steel beam was driven to bedrock and load tested. No appreciable settlement occurred and with equipment available locally it was impossible to pull the pile.

Excavation in the powerhouse area was carried on at the same time as the driving of the 399 14-inch H-steel foundation piles. The upper 10 to 12 feet was organic, slightly plastic silt, containing occasional angular graywacke fragments. Below the silt a layer of talus 5 to 8 feet thick, containing angular graywacke boulders in dark brownish-gray organic sandy clay, lensed out downstream from the powerhouse foundation proper. The bottom of the powerhouse and tailrace conduit excavation was in water-bearing river sand and gravel (fig. 13). Pumping of the area was necessary during excavation and pile driving. Some sloughing of the backslope (fig. 14) in the northeast corner of the excavation occurred during the extremely high-water period of the Lake George breakup. Water seeped through the artificial earth dike and caused some caving until the slope was timbered and unwatered. The peak of the flood water was unusually high in 1953; the highest recorded in many years. Also, the high-water period was longer than has been recorded in recent years.

Prior to driving, the depth to bedrock was estimated at each pile location, based on drill hole information. The average penetration per pile was 5 feet, 2.5 feet greater than the estimated penetration. The 399 piles in the powerhouse, machine shop, transformer structure, and penstock anchor block penetrated from 30 to 56 feet below finished grade (fig. 15).

Information from several drill holes in the powerhouse area indicated a possible fault zone, with a low angle dip, lying close to the bedrock surface. The existence of faulted material was verified by holes DH 92 and 93. The core samples contained fault breccia and gouge, but the exact attitude of the fault was not determined. An assumed strike and dip of the zone is included on the penstock and powerhouse geologic section. Several feet of iron-stained, but moderately sound graywacke overlie the fault; as the bearing piles all developed the required impact loading, it is believed there will be no future settlement of the pile foundation of the powerhouse.

A study was made on the possibility of corrosion of the piling by known unfavorable pH factors in the soil and ground water. As a result, all piles were required to be coated with red lead prior to driving. The effectiveness of this coating will be checked in the future on two test piles driven at the site; one of these piles is coated and the other is not. These two piles are to be pulled in 1958 and web and flange thickness carefully measured; they then will be redriven and pulled again in 1963.

14. Tailrace. - Throughout the entire length of the tailrace, the upper 4 to 6 feet of material is silt and sandy silt, underlain by a layer of sand and fine gravel approximately 2 feet thick. Beneath the sand and fine gravel is sand and coarse gravel. During extremely high tides the water backed up in the channel and added to the water from the tunnel, during the pumping out of the powerhouse and penstock area, some sloughing of the sand and gravel layer occurred. Also during the period of extremely high water during the Lake George breakup, there was some sloughing of the banks of the channel-deposited material in the bottom of the channel (fig. 16).

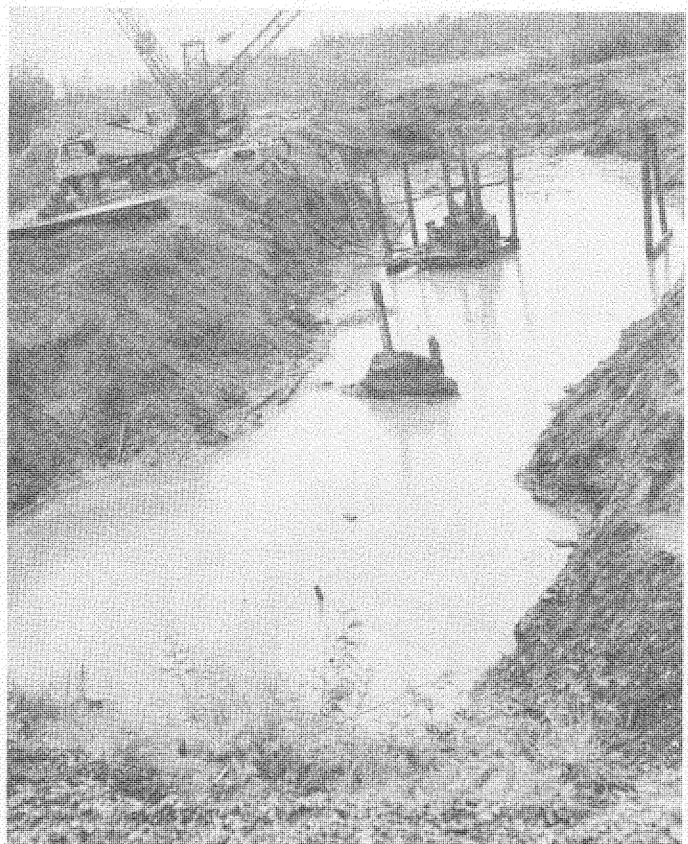


Figure 13.--Excavation operations for powerhouse and tailrace. P783-908-1007. August 2, 1952.

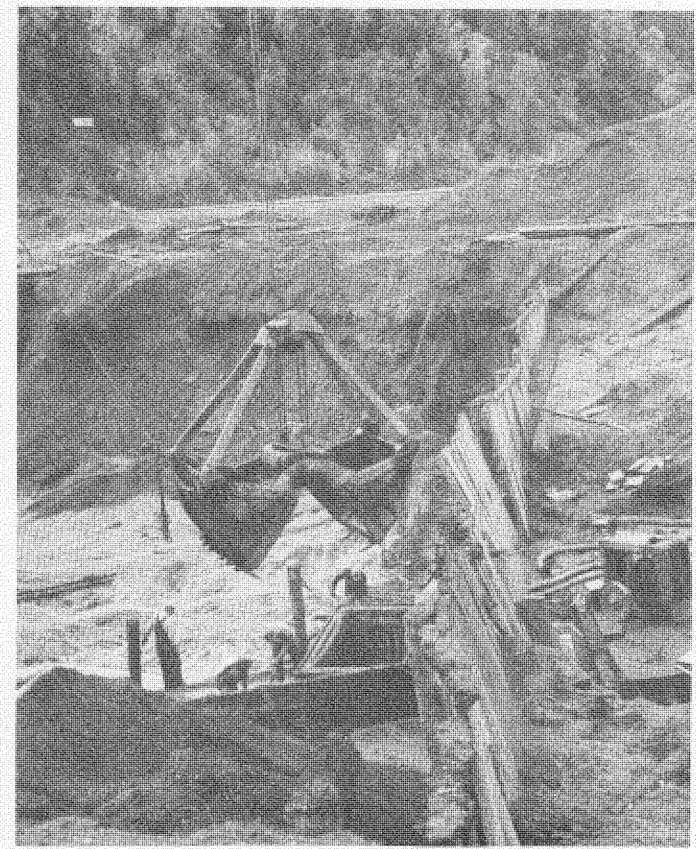


Figure 14.--Powerhouse and tailrace excavation. Note result of pressure of slough-in material against piling. P783-908-1083, September 19, 1952.

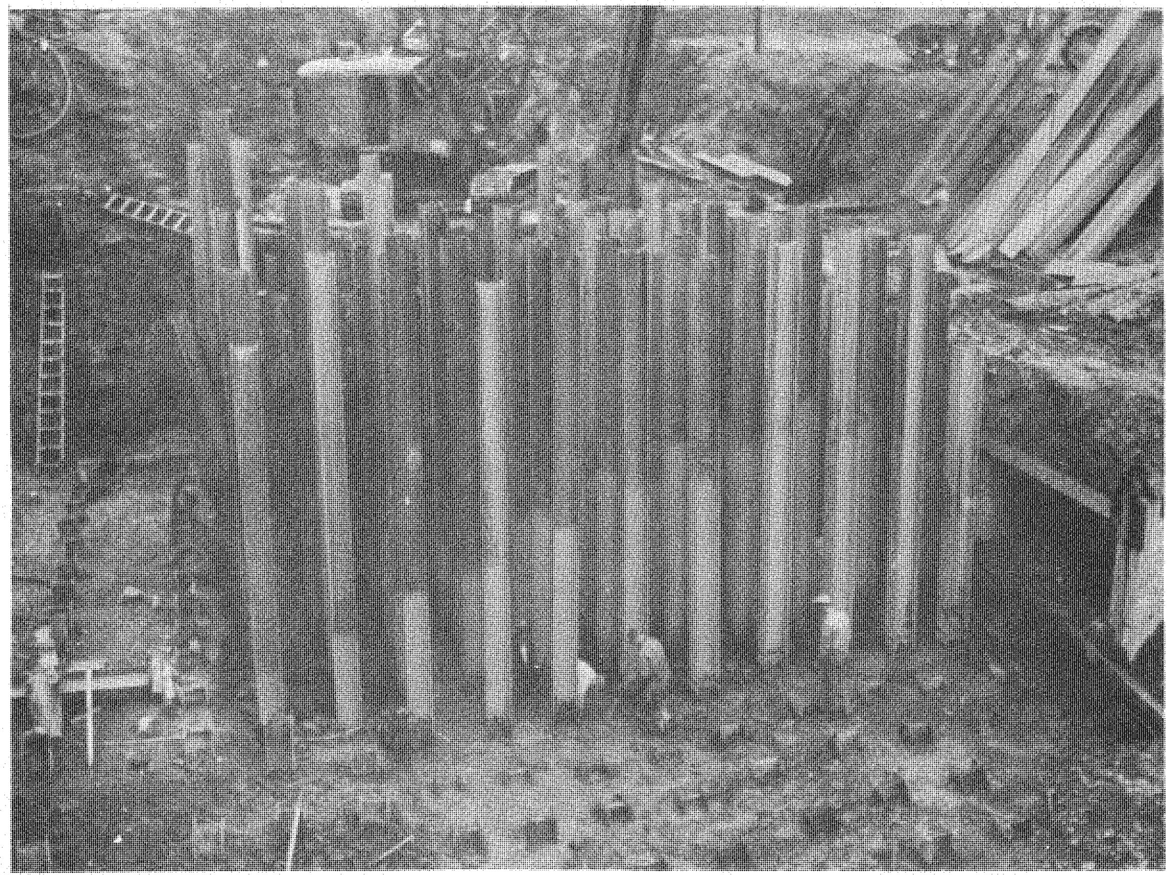


Figure 15.--A portion of piling for powerplant foundation. Piles at left have been cut off to grade prior to capping. P783-908-1441, August 13, 1953.

B. Final Geologic Status of Project

15. Minerals. - Within the authorization for the Eklutna project, Public Law No. 628, the following statements were included pertaining to minerals of economic importance which might be discovered in the construction of the project:

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled.....All minerals discovered in the course of constructing the Eklutna Project are hereby reserved to the United States and may be sold or otherwise disposed of in such manner as may be prescribed by the Secretary, if he finds and so reports to the Congress in writing that the only economically practicable method of recovering the ore so reserved is to provide for the salvage of any minerals that may be contained in the excavated materials removed from the tunnel during the normal process of construction. The net proceeds from any such sale or other disposition shall be covered into the Treasury of the United States to the credit of miscellaneous receipts....."

During the course of construction no minerals were discovered in sufficient quantities to probably ever be of economic importance. A very small kidney of cinnabar in a fault gouge zone was uncovered in the tunnel. The material was sampled and an assay made. Neither the size of the deposit nor the percentage of mercury contained were of noticeable importance.

An 800-foot section of the tunnel contained irregular masses of dolomite from an inch to approximately 10 feet in diameter. Owing to the scattered and discontinuous nature of the dolomite particles, the material would never be recoverable.

Figure 16.--General view from tunnel adit portal showing conditions at height of Knik River flood during the Lake George breakup. Note powerplant and tailrace embankment in foreground. P783-908-1665, July 26, 1954.

During the excavation of the tunnel and some of the field work, a geiger counter, on loan from the Fairbanks, Alaska, office of the Trace Elements Unit of the United States Geological Survey, was used. Nowhere in the project area was there an indication of radio-active material. A mineral-light (ultraviolet or "black" light) also was used in conjunction with tunnel logging, but no reaction was noted in the project area.

16. Weather. - A study of weather conditions at the site was made, and it was concluded that the investigations and preconstruction drilling on future projects in western Alaska not be attempted during the late fall or winter months. Difficult access, intense cold, and delays in the supply of working materials all cause very slow progress and extremely high cost.

The following weather data were accumulated at the Eklutna project station:

Month	Maximum temperature, °F.	Minimum temperature, °F.	Precipitation, inches
1951			
October	50	7	1.12
November	53	-9	0.26
December	35	-32	0.98
1952			
January	38	-36	1.78
February	40	-20	0.33
March	46	-8	0.88
April	51	-4	0.16
May	63	26	0.80
June	75	35	0.59
July	84	40	3.00
August	72	32	2.47
September	62	25	2.67
October	63	14	2.59
November	55	11	2.14
December	44	-12	1.48
1953			
January	40	-23	0.11
February	47	-23	2.32
March	45	-14	0.48
April	62	13	0.12
May	71	30	0.66
June	92	38	0.48
July	84	39	2.06
August	72	40	5.48
September	66	24	1.13
October	55	1	2.21
November	42	-6	0.09
December	48	-19	0.75

(Table continued on following page.)

(Continued from preceding page.)

Month	Maximum temperature, °F.	Minimum temperature, °F.	Precipitation, inches
1954			
January	43	-23	0.38
February	50	-33	0.45
March	45	-16	1.28
April	57	6	0.00
May	73	29	1.14
June	80	36	1.25
July	77	38	3.68
August	75	35	2.45
September	68	28	2.09
October	56	22	1.99
November	51	4	0.58
December	35	-37	1.22
1955			
January	48	-12	1.46
February	42	-22	1.86
March	53	-21	1.22
April	50	9	0.82

17. Reference. - For a complete geophysical, geological, mineralogical, petrological and economics report including drawings, pictures, and statistical data on the Eklutna project, refer to the Engineering Geology Final Report (unpublished) dated March 1956.

PART II -- DESIGN

PART II--DESIGN

CHAPTER III --*Design*-- INTRODUCTION

18. Preliminary Considerations. - Various plans of power development for the Eklutna project were investigated and discarded for various reasons. One contemplated a series of dams on Eklutna Creek; however, because of the distance to impervious material in the streambed and abutments this plan was discarded. Another plan involved enlarging and rehabilitating the existing old Eklutna hydroelectric plant, herein called Old Eklutna Powerplant. This plant (sec. 4) consists of two 1,000-kilowatt generators of the 1927 vintage. The preliminary engineering approach involved a conduit from the lake to a point near the diversion works of the Old Eklutna Powerplant. The conduit route would have been on steeply sloped unconsolidated material cut by deep side ravines. Further, climate would likely have precluded winter operation unless the conduit were deeply buried, which involved construction in highly unfavorable ground through suspected underground pockets of permafrost.

The above plans stemmed from a desire to salvage and continue operation of the Old Eklutna Powerplant. However, rehabilitation and enlargement of this plant to take full regulated flow of Eklutna Creek would be almost as costly as new construction, yet would develop only 27 percent of the power potential.

Continued generation of firm energy at the Old Eklutna Powerplant would be possible if releases for that purpose were made from the Eklutna Lake reservoir. If this were done, firm energy production at Eklutna Powerplant would be drastically curtailed.

The only time there would be sufficient water available to run the Old Eklutna Powerplant would be for the 2 or 3 months when Eklutna Lake is spilling. Since water can be used much more efficiently at Eklutna Powerplant there appears to be no reason for operating the old plant until such time as the summer peak loads exceed the capacity of the new plant. Since the old plant would be of help for only 2 or 3 months of the year and this during the light-load period and to the extent of 2,000 kilowatts (less than 1 year's load growth), there appeared to be no justification to use the existing plant; therefore, the old plant has been put out of "standby" service and no attempt will be made to maintain it.

19. Alternate Design Schemes. - Basically two final plans were proposed for the transportation of water to the new hydroelectric plant. Plan No. 1 was issued as schedule No. 1, specifications No. DC-3523, and plan No. 2 as schedule No. 2 of the same specifications. The main difference in the two plans was the elevation of the tunnel intake in the Lake bottom. Plan No. 1 proposed an intake elevation of 794.00 and alterations to an existing earthen dam, whereas plan No. 2 proposed an intake elevation of 842.68 which would have necessitated materially raising the height and structure of the existing dam at some later date and under a future contract.

When the bids were opened it was found that plan No. 2 was approximately 95 percent as costly as plan No. 1 and, therefore, plan No. 1 was adopted as it was more advantageous to the interest of the Government.

A. General Design of Features

20. Eklutna Lake and Dam. - Eklutna Lake and Dam are both the results of a retreating glacier. In 1941, the natural dam was reconstructed. The present dam, which is located at the outlet of Eklutna Lake into Eklutna River, is an earth and rockfill structure with wood and steel piling core walls, and is riprapped on the upstream face. The headgate section is a reinforced concrete and steel structure, provided with 19 hand-operated headgates. These gates are in poor material condition due to age and as a result are being left in the closed position. Specifications No. DC-3523 contained provisions for alterations to the existing dam, including earthwork, riprap, sheet piling, and repairing existing timber trestle. A plan and section of the dam as designed is shown on figure 22.

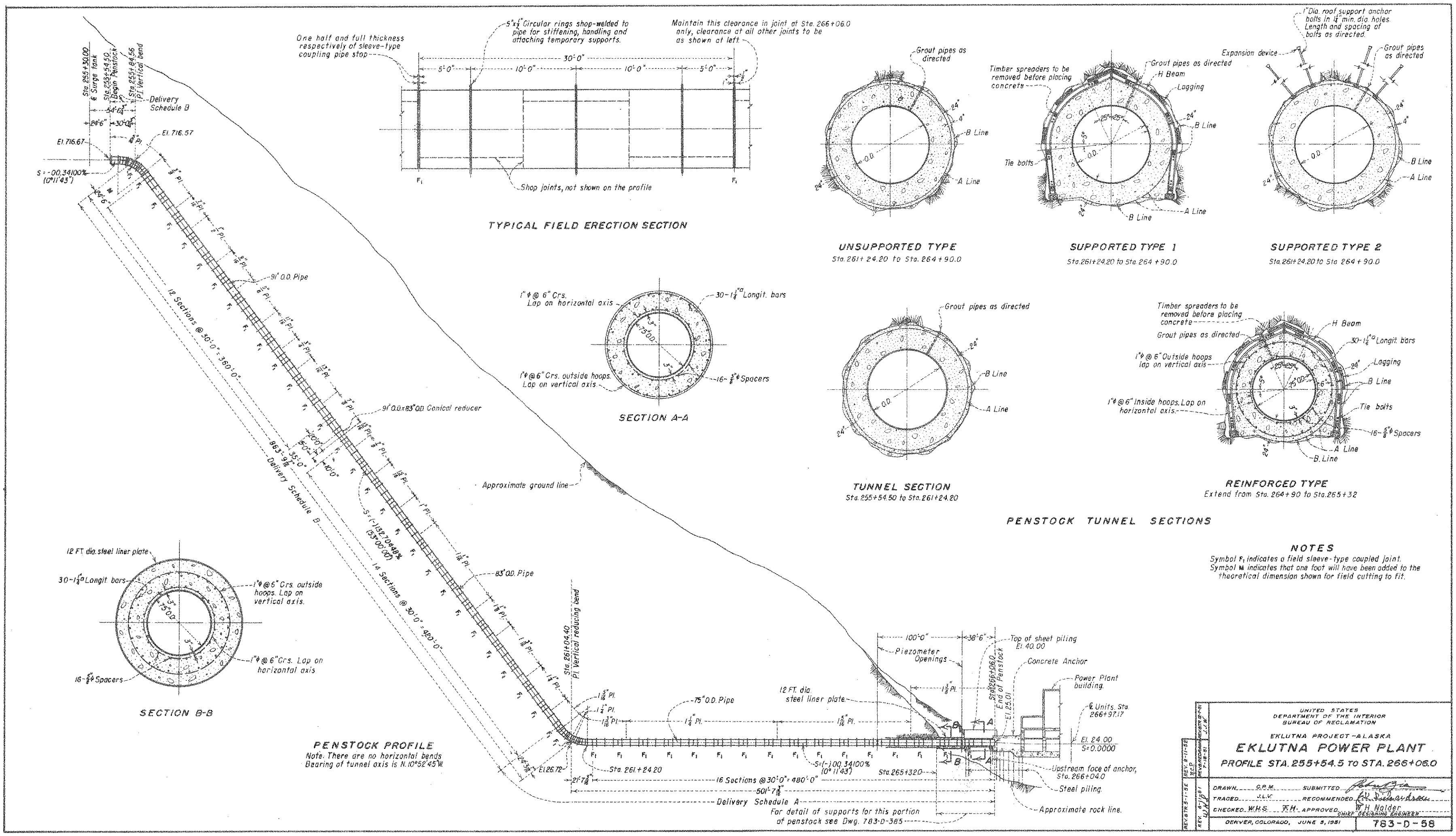


Figure 17.--Penstock profile from station 255+45 to station 266+06.0.

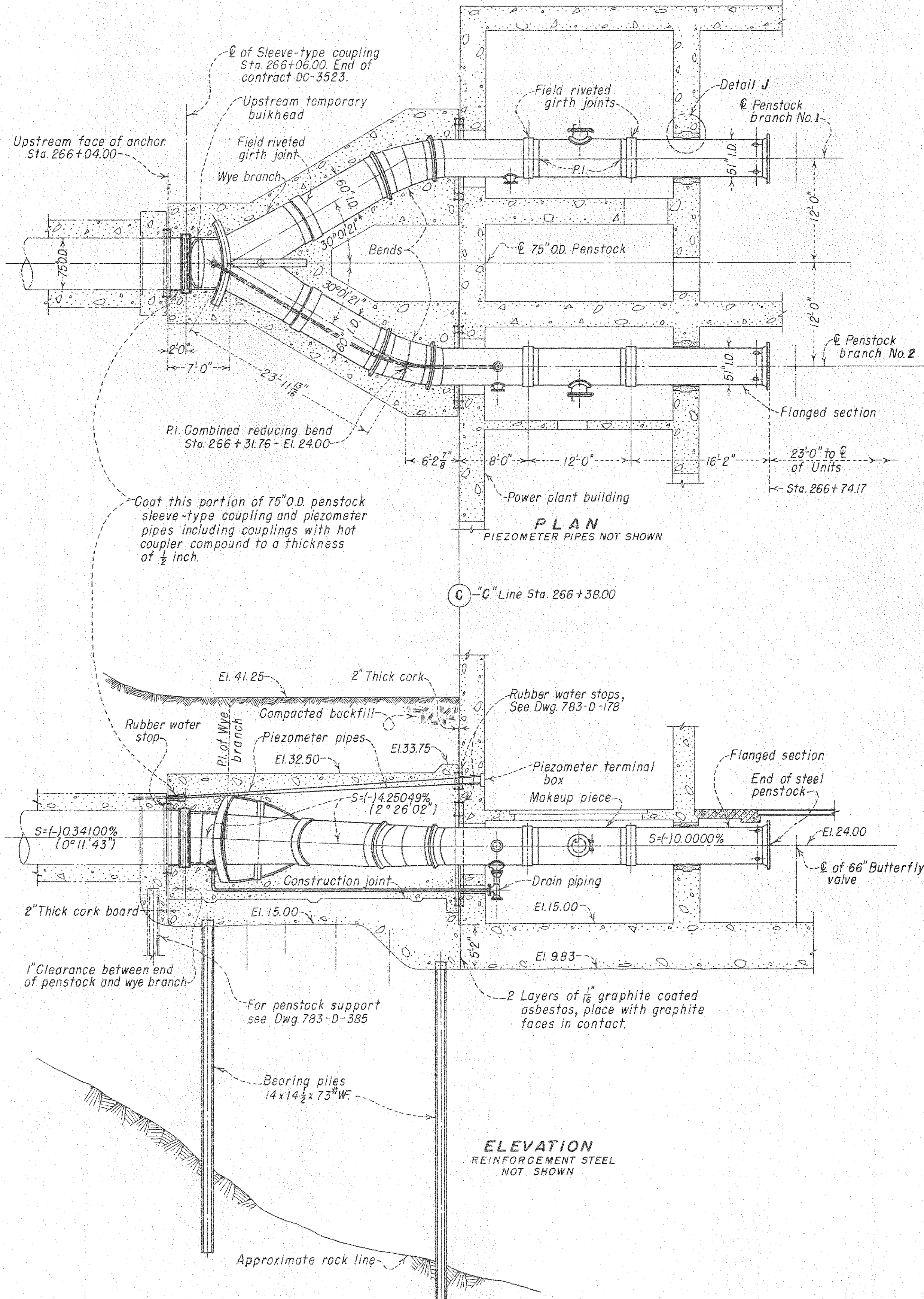


Figure 18.--Plan and elevation of penstock wye-branch. From drawing 783-D-232.

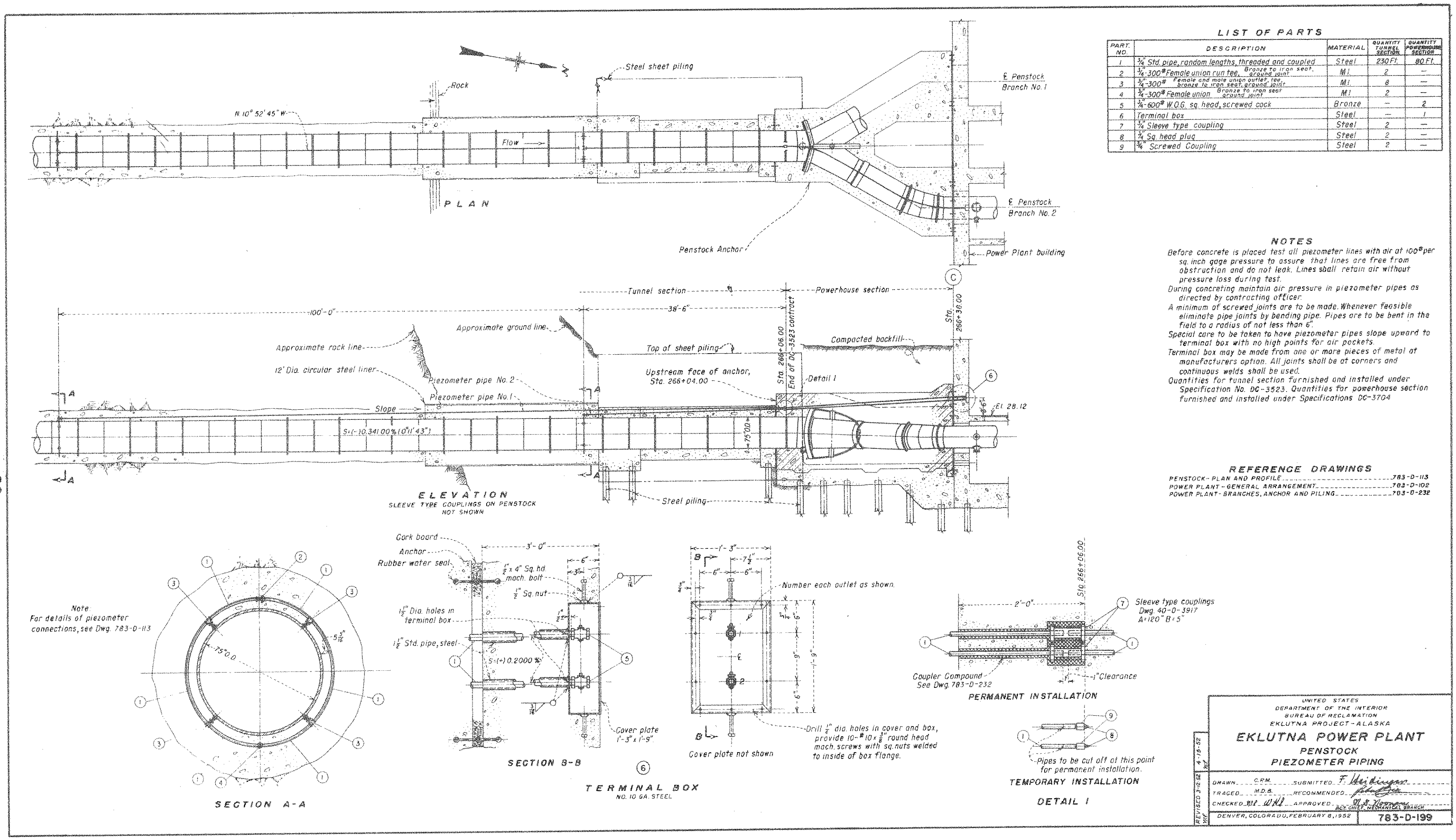


Figure 19.--Penstock piezometer piping.

21. Intake Structure. - The location of the intake for the tunnel with invert set at elevation 794.00 required an underwater excavation of approximately 400,000 cubic yards of material. Disposal of the material excavated was permitted to be made in Eklutna Lake below elevation 785. Considering the expense and difficulty of unwatering the above site, the intake structure and associated equipment were designed as precast units to be set on a prepared sand and gravel bedding. Because of the severity of earthquake effects, it appeared desirable to found the gate shaft on solid rock.

A watertight concrete bonnet was provided around the gate in the lower part of the shaft so that access to the tunnel could be had with the bulkhead gate in the closed position and the tunnel drained.

A plan and section of the inlet is shown on figure 24.

22. Tunnel. - Operation studies indicated that the tunnel should be designed to transport a mean total annual release of 244,800 acre-feet of water. Based on this release, a value for power of 7.8 mills per kilowatt-hour, an interest rate of 3 percent, and a recovery period of 50 years, the present worth of 1 foot of head was determined to be $40,000. By considering the hydraulic losses for various average rates of flow over a range of tunnel diameters, and based upon the $40,000 figure and estimated construction costs, it was concluded that a 9-foot finished diameter tunnel would be optimum. The circular tunnel section was selected for its more advantageous properties in resisting both internal bursting loads and external loads.

A profile and sections of the tunnel are shown on figures 23 and 31.

23. Surge Tank. - The surge tank (fig. 36) is situated at the upstream end of the penstock. The tank is 30 feet in inside diameter with a throttling restriction at the base. An emergency guard gate is installed in the downstream end of the tank so as to be able to shut off tunnel flow at the upper end of the penstock. Original design studies considered two diameters for the tank, one of 20 feet and the other of 30 feet. An economic comparison indicated that it would be slightly more advantageous to construct a 30-foot-diameter tank.

24. Penstock Tunnel. - Tunnel sections for the underground penstock were fixed at diameters 4 feet greater than the inside diameter of the steel penstock in order to facilitate construction work. The slope of the inclined portion of the penstock tunnel was fixed so as to facilitate mucking out of material during construction.

25. Penstock. - A profile of the penstock and a cross section of the tunnel are shown on figure 17. A concrete surge tank is located at the junction of the tunnel and the inlet end of the penstock. A fixed-wheel gate is provided to guard the penstock inlet. At the downstream end the penstock is bifurcated in two 51-inch-diameter branches (figs. 18 and 20) and each branch is provided with a butterfly valve. The exposed portions of the branches in the powerhouse are supported in openings through the B-line wall with provision for free longitudinal temperature movements. Expansion joints are provided in the connecting sections between the butterfly valves and the turbine spiral cases. The butterfly valves are free to slide on their supporting pedestals when temperature movement occurs. If the tunnel is unwatered, the penstock can also be entered through the fixed-wheel gate opening. In the powerhouse a manhole is provided in each 51-inch branch pipe. The arrangement of piezometer piping used for flow measurement is shown on figure 19.

26. Powerplant. - The powerplant is divided into three main structures: the powerhouse containing the generating units and accessories, the machine shop located at the northwest corner of the powerhouse, and the transformer structure located at the southwest corner of the powerhouse. The powerplant is of reinforced concrete throughout except for the superstructures of the powerhouse and machine shop which are of structural steel framing with reinforced concrete slabs, walls and roofs. Views of the powerplant are shown in chapter VI.

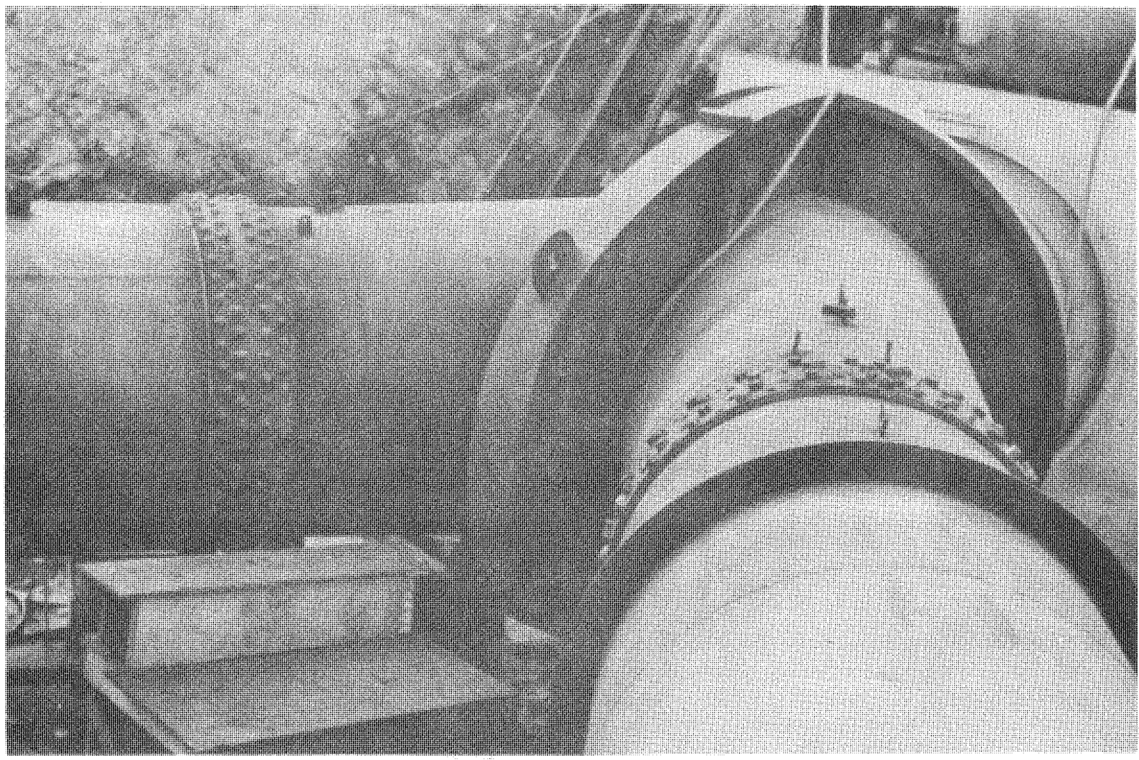


Figure 20.--Penstock wye-branch after resizing buttstraps. Strap at left completely riveted and seal welded. Strap at right bolted up prior to welding. P783-908-1612, June 8, 1953.

The exterior of the powerplant structure was designed quite simply architecturally. Generally, the exterior walls were formed to expose plain concrete surfaces which are devoid of window openings. Owing to extremely cold weather conditions, windows were installed only in the machine shop portion of the plant, and there, sparingly. Fixed metal windows were used, and were glazed with glass insulating units. During the preliminary switchyard location studies, it was first contemplated to locate the switchyard as a conventional structure on the ground. However, later it was decided because of poor foundation conditions and possibility of snow slides, that the switchyard be located on the roof of the powerhouse.

27. Tailrace. - Water leaving the draft tubes of the plant enters a pressure tailrace conduit (fig. 21) somewhat over 200 feet in length. A small surge chamber is provided at the entrance to the conduit so as to accommodate surging which will occur with load changes.

Consideration was given to supporting the tailrace conduit on piling, but, because of extra expense involved, as well as the favorable indications derived from a settlement study, it was decided to place the structure on a 24-inch compacted gravel blanket and articulate it longitudinally at approximately 25-foot intervals with 9-inch rubber water-stopped joints.

Because of the annual floods in the Knik River, it was necessary to give special attention to the protection of the outlet end of the tailrace conduit. Stability studies for the tailrace channel indicated that the banks would be stable on 2 to 1 slopes, with the top of bank elevation of 37.0, which is 2 feet above the maximum flood level noted in the Knik River at this location.

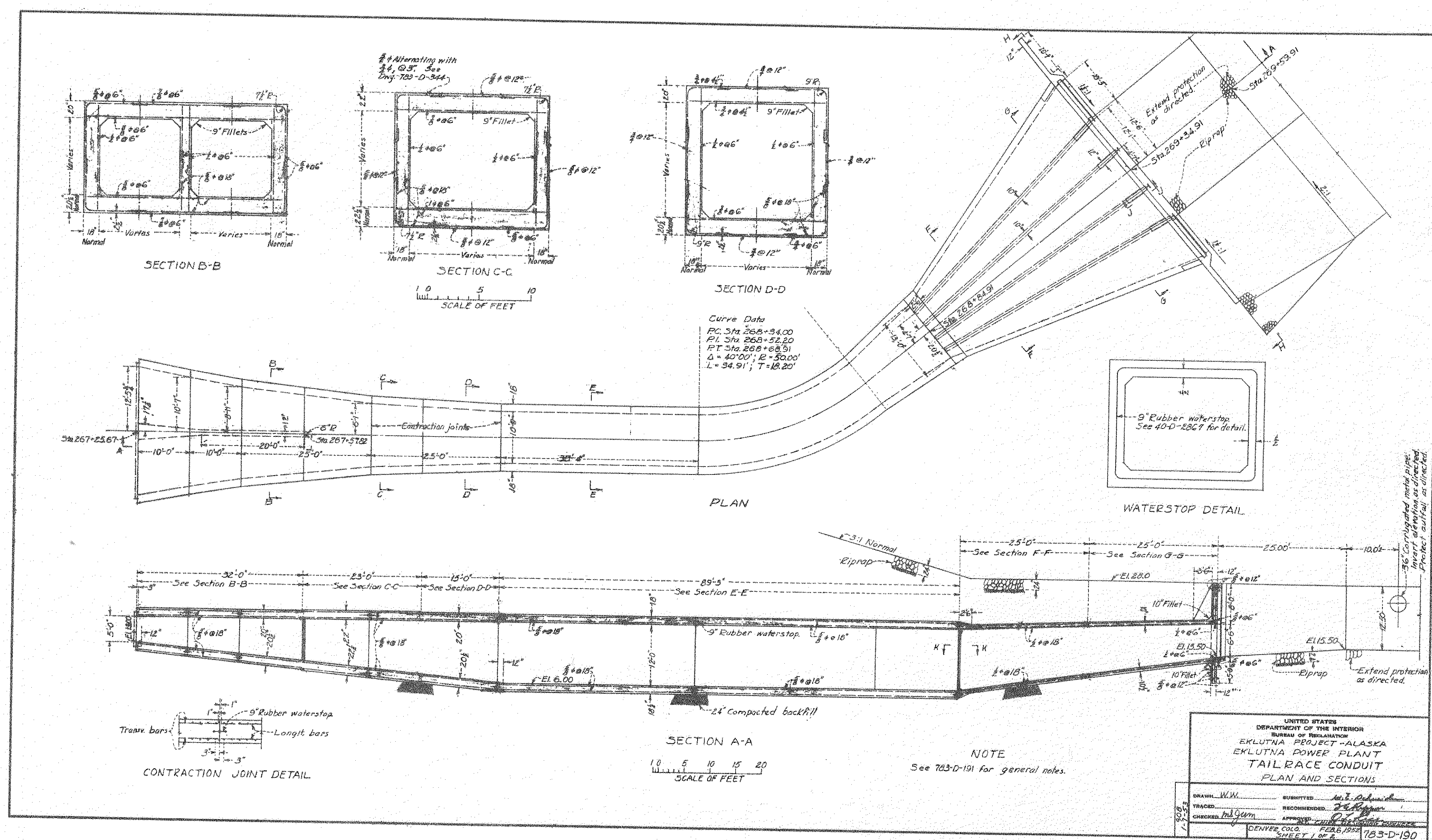


Figure 21. --Plan and sections of powerplant tailrace conduit.

CHAPTER IV --*Design*-- EARTH DAM

28. Design. - Additional earthfill embankment material was placed on the existing embankment of Eklutna Lake Dam to lines and grades established by the contracting officer, which in general were the lines and grades shown on figure 22. The embankment material was secured from borrow areas adjacent to the abutments of the existing dam. The combined excavation in borrow pits and placing operations on the embankment were such that the materials when compacted in the embankment blended sufficiently to secure the best practicable degree of compaction and stability. Cobbles or rocks more than 6 inches in diameter were not placed in the embankment. No material was placed in the embankment when either the embankment or the surface on which it would be placed was frozen. The embankment was placed in continuous, horizontal layers of not more than 12 inches in thickness after being compacted. The layers were carried across the entire width of the embankment. The contractor's hauling equipment was routed over the layers already in place in order to obtain the maximum amount of compaction possible.

A sand and gravel blanket, 12 inches in thickness, was placed beneath the riprap on the upstream slope of the dam. Processing of this material was not required; however, pieces larger than 3 inches in size were removed from the blanket before final placement.

For riprap material on the upstream face and crest of the dam, the specifications required that not more than 25 percent of the riprap materials shall consist of pieces of rock smaller than one-half-cubic-foot size, and at least 30 percent shall consist of pieces larger than 3-cubic-foot size with a maximum size of one-half cubic yard. The riprap on the downstream face of the dam was reasonably well graded in size from a maximum of one-eighth of a cubic yard to one-tenth of a cubic foot.

A concrete anchor, complete with reinforcement, embedded metal anchors and tie-rod connections, was constructed. In addition, 5 additional feet of height of sheet-steel piling were added to the existing sheet-steel piling.

Round timber piles were driven for the existing trestle as shown on figure 22.

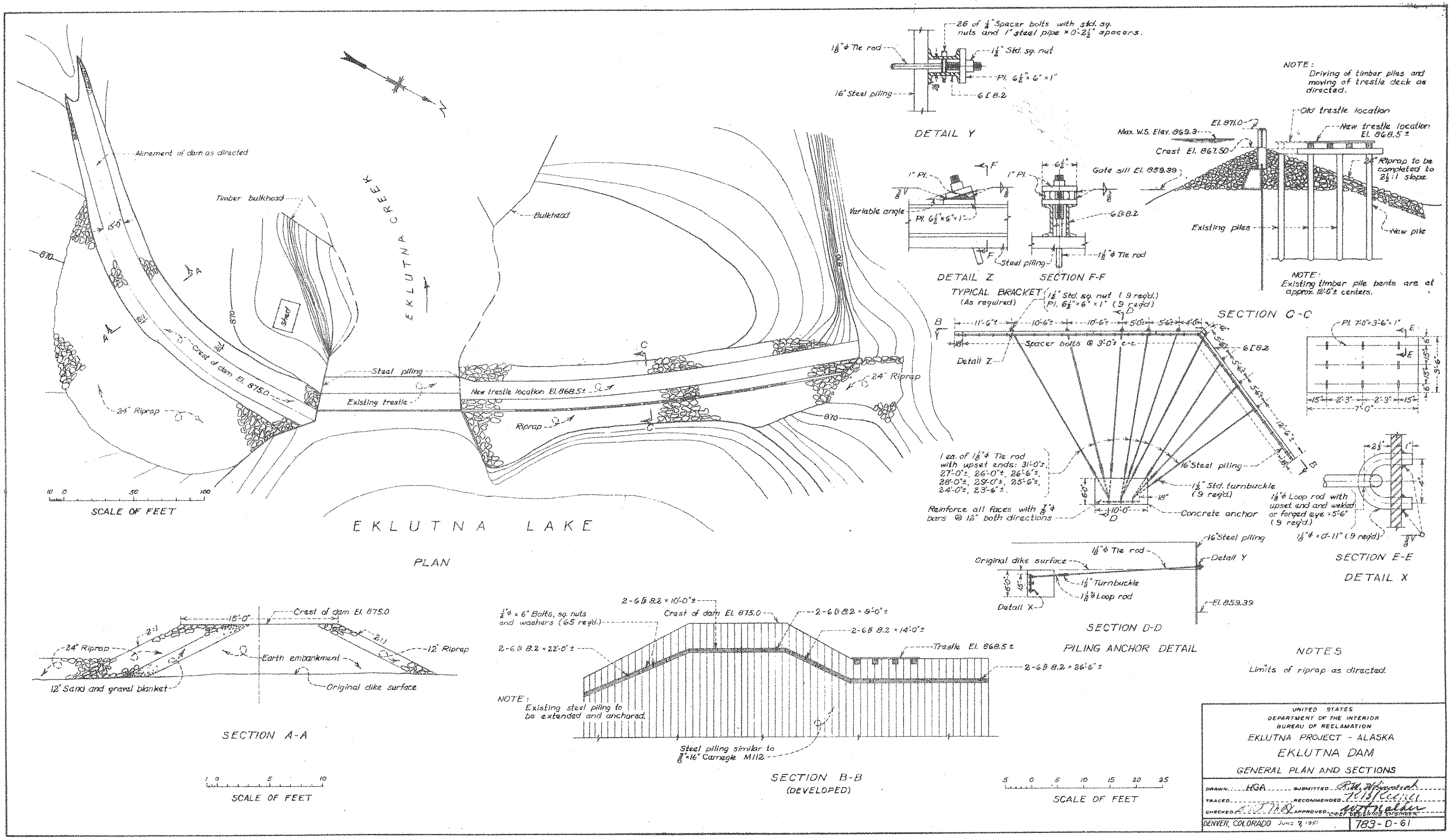


Figure 22.--Eklutna Dam--General plan and sections.

29. Hydraulic Requirements. - The Eklutna Tunnel is 23,550 feet long and was designed to satisfy the following hydraulic requirements (see also sec. 22):

Maximum static head	850 feet
Water-hammer head (gate closure time of 5 seconds from full open)	291 feet
Maximum design head (at turbine inlet)	1,141 feet
Rated flow of turbine	640 second-feet
Maximum water velocity (75-inch outside-diameter portion of penstock)	22.4 feet per second

30. Intake Structure. - The intake, transition, and bulkhead sections are located in the bottom of Eklutna Lake (fig. 23). The precast intake structure (figs. 24 and 25) is rectangular and the average design velocity through the trashracks is 0.5 foot per second. The trashracks are 2- by 8-inch timbers set on edge with a clear spacing of 2 inches between timbers. The timbers span from wall to wall and are designed for a load of 60 pounds per square foot. As the trashrack is to be cleaned regularly and the foundation is very pervious in nature, the relatively light unbalanced load was considered adequate. The trashrack is built of preconstructed sections (fig. 26) approximately 17 feet wide to facilitate placing under water. The ends of the trashrack timbers have been encased in a concrete beam of sufficient weight to prevent flotation.

The concrete end and side walls are designed for lateral earth pressures, and the concrete frames transfer the earth pressures from one side to the other. In the original design, two precast units were proposed for the intake structure, but upon request of the contractor, three precast units were used so that the weight of each unit would be within the 45-ton capacity of the contractor's equipment. The joints between the precast units are similar to bell-and-spigot joints with the space between the bell and spigot filled with tremie concrete.

The transition and bulkhead sections (figs. 27 and 28) are precast units and were placed on a prepared sand and gravel base. The joints between the transition section and the bulkhead section and between the bulkhead section and the precast conduit section were provided with metal joint rings and a clamp type assembly to facilitate pulling the joints together underwater by divers.

The head wall of the transition section was curved, as flownet studies made with the electric analogy tray apparatus showed that such a head wall would produce a more uniform flow through the trashracks at low lake water surface.

The bulkhead section was provided with a removable precast concrete cover over the bulkhead gate slot.

31. Precast Conduit. - Tunneling under the lake bottom adjacent to the bulkhead section was considered infeasible. Owing to the light cover of "A" material and the water in the lake, it was necessary to resort to a type of construction which could be accomplished from the lake surface. Accordingly, designs were prepared for 225 feet of conduit between the bulkhead section (station 17+75) and the tunnel (station 20+00) to be constructed of precast pipe sections (fig. 29).

The precast sections were designed with special pull-up clamp assemblies to facilitate placing by underwater divers. The sections were bedded on a 2-foot minimum thickness of gravel and were backfilled to a minimum depth of 3 feet above the top of the pipe. The sections were designed to withstand external loading due to backfill and water, as this load could develop when the conduit is dewatered.

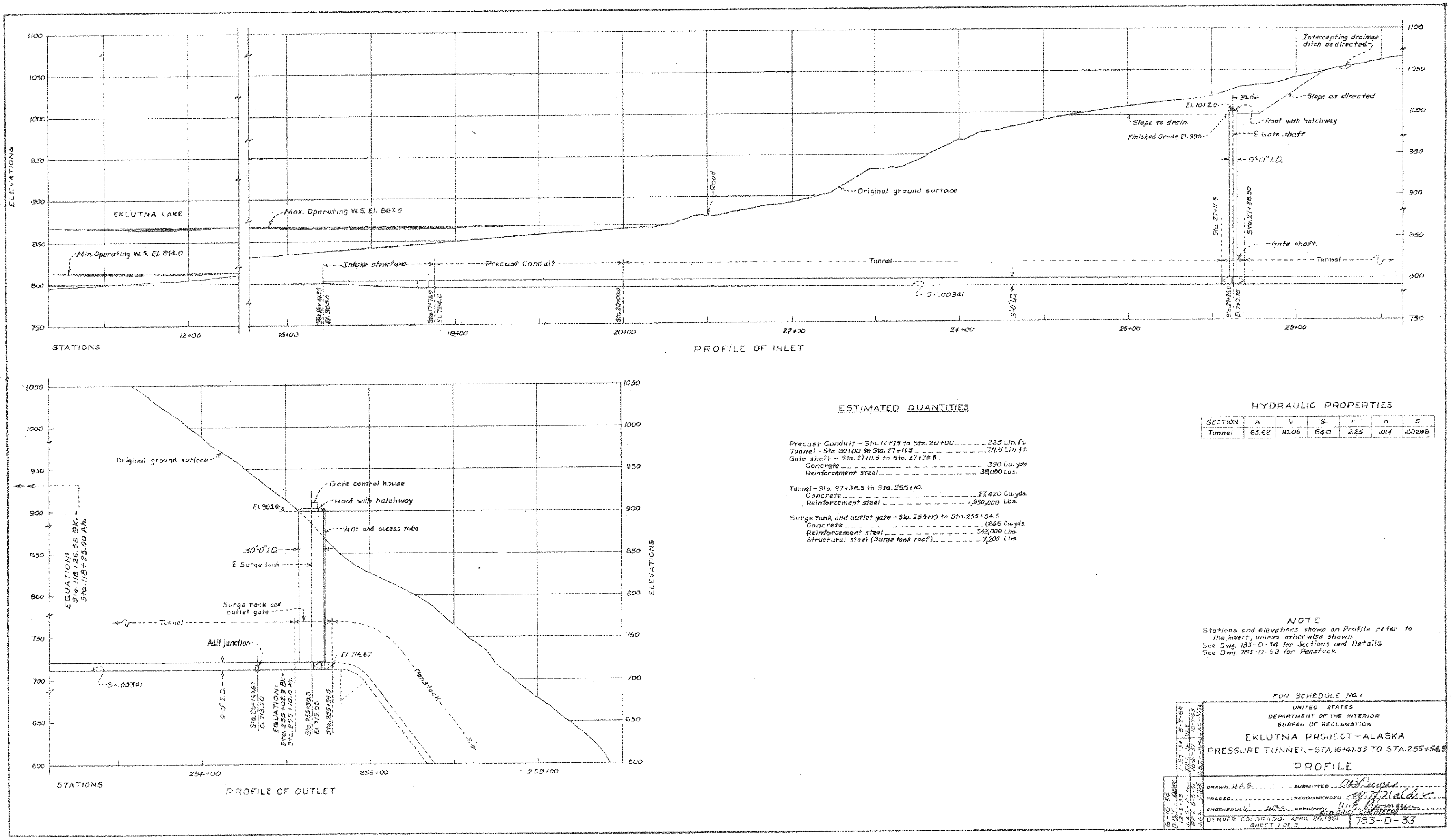


Figure 23.--Profile of pressure tunnel from station 16+41.33 to station 255+54.5.

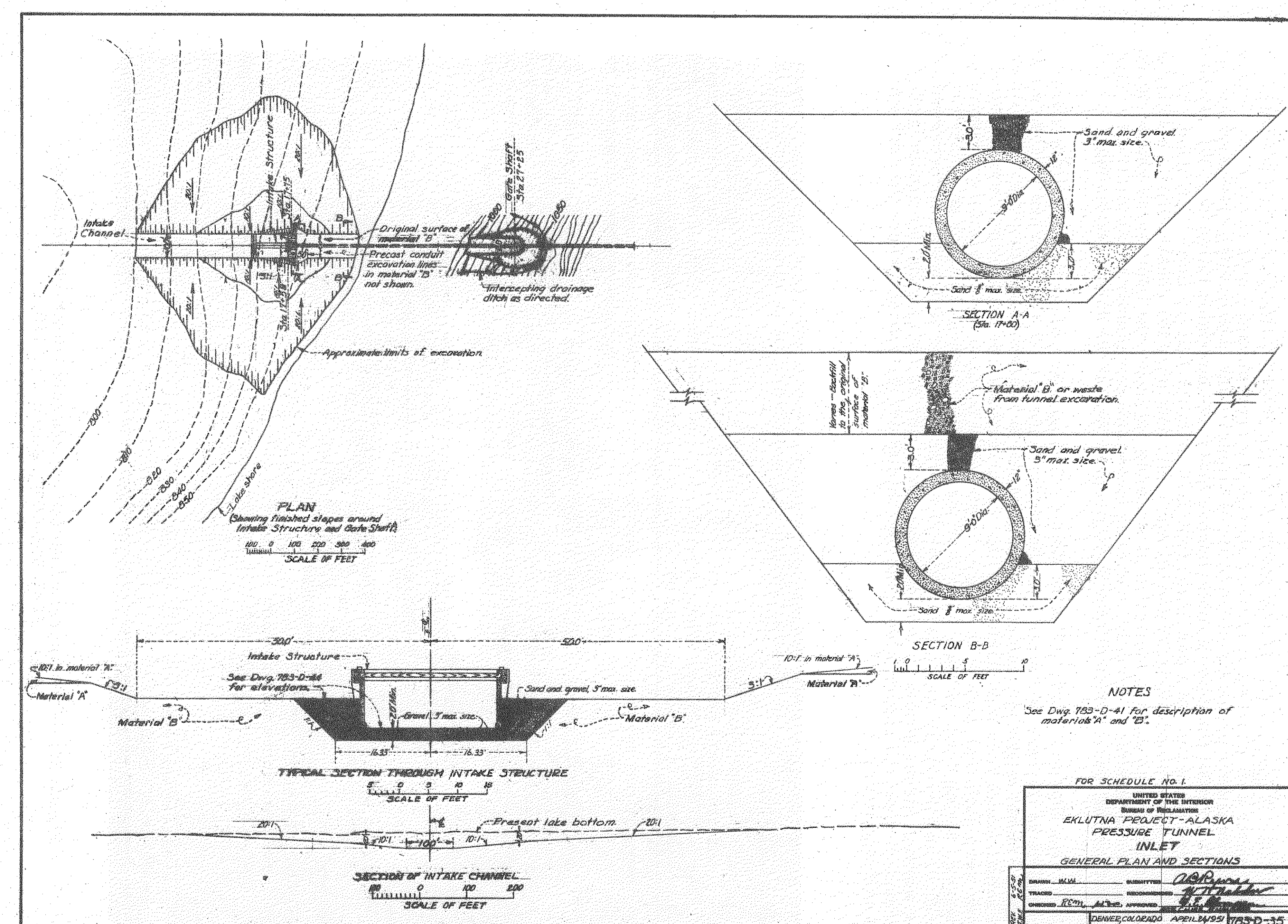


Figure 24.--General plan and sections for pressure tunnel inlet.

32. Tunnel. - (a) *Station 20+00 to Station 27+11.5.*-- Because of the unknown ground-water and tunneling conditions through the predominantly glacial till of this reach, specifications were prepared on the basis of requiring the constructing between these stations of a 9-foot finished-diameter tunnel with a 12-inch-thick lining (fig. 30). Proposals were requested on a per linear foot cost basis for this portion of the tunnel, the contractor being required to furnish all materials and labor for construction. In addition, the contractor was allowed the option of tunneling out under the lake beyond station 20+00 if considered feasible. Actually, tunneling operations terminated at station 19+06. The precast conduit was connected later through operations at the surface of the lake.

(b) *Station 27+11.5 to Station 255+10.*--Geologic data along the tunnel line were incomplete at the time of issuing specifications; therefore, it was provided that the entire length of tunnel might be reinforced with steel hoops to prevent bursting (fig. 31). After the actual tunnel bore was started, it was discovered that the rock properties and tunnel cover were such that most of the tunnel length could be lined with unreinforced concrete. However, during construction, some portions of tunnel between the gate shaft (station 27+25.0) and the surge tank (station 255+30.0) were provided with hoop reinforcement. The working stress generally used in these areas was 24,000 pounds per square inch. Permanent steel rib supports were utilized throughout the reaches where the rock was not self-supporting.

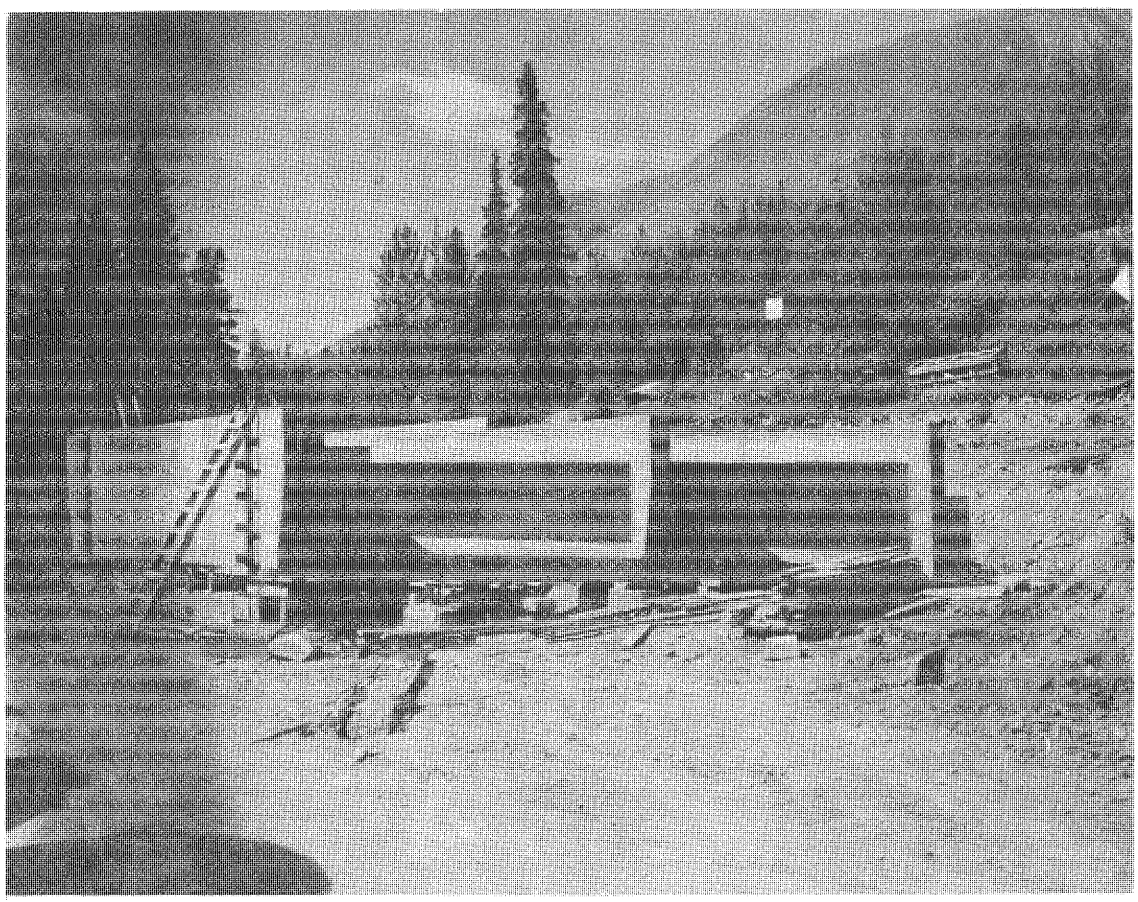


Figure 25.--One completed section of concrete trashrack for intake area. P783-908-1030, August 16, 1952.

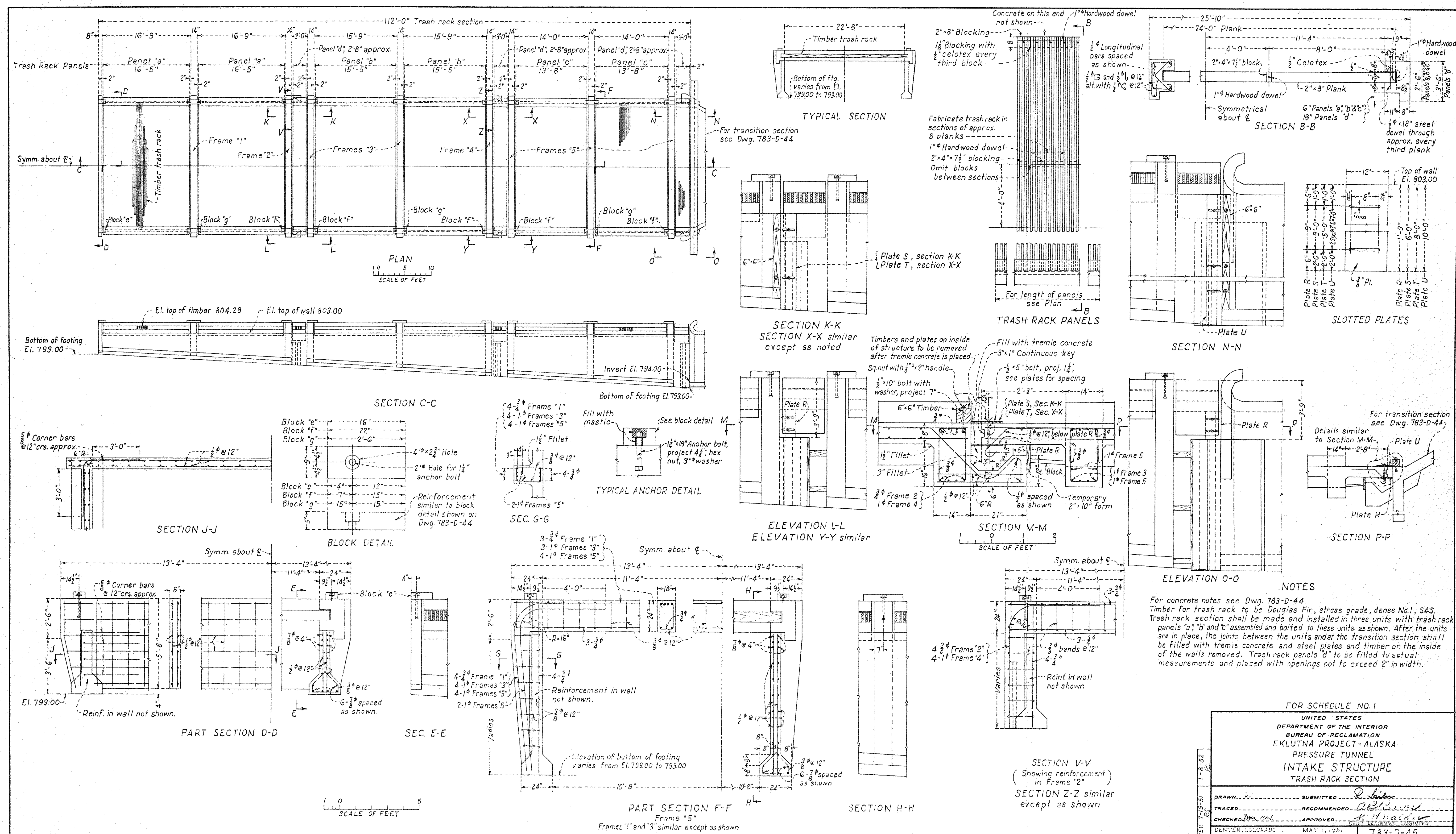


Figure 26.--Trachrack section of pressure tunnel intake structure.

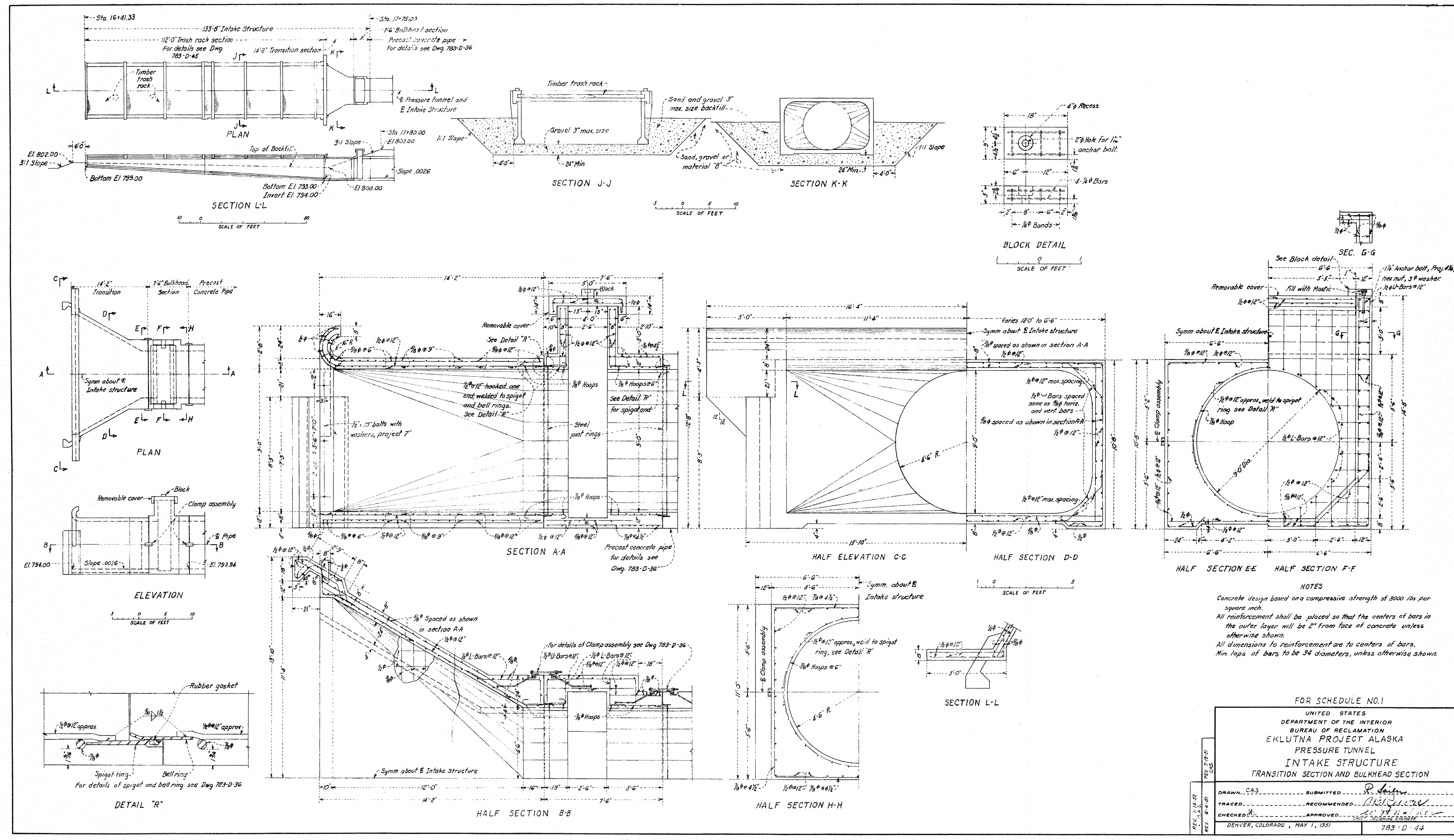


Figure 27.--Transition section and bulkhead section for pressure tunnel intake structure.

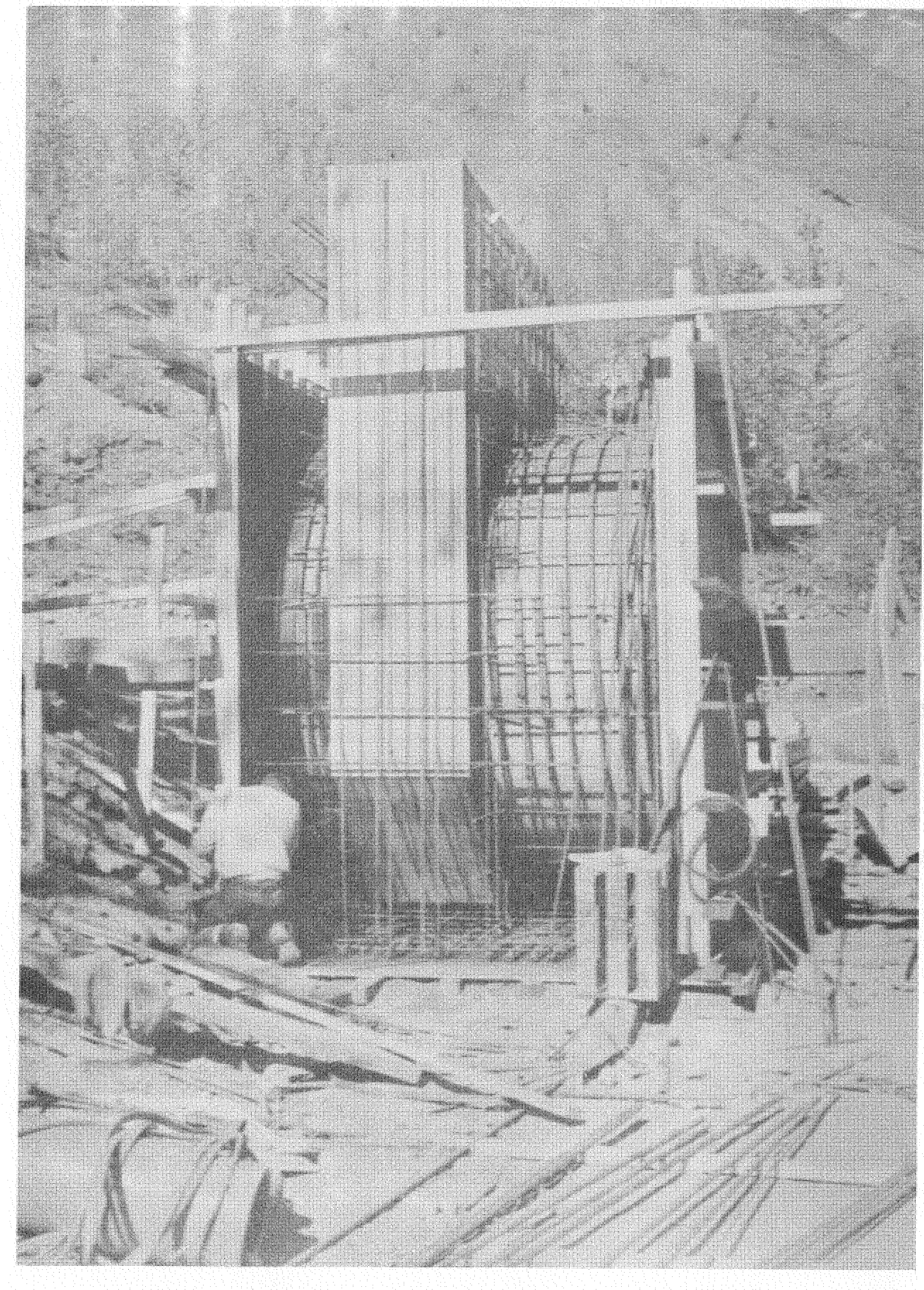


Figure 28.--Bulkhead section of intake structure--Reinforcement steel being placed prior to concrete placement. P783-908-914, June 18, 1952.

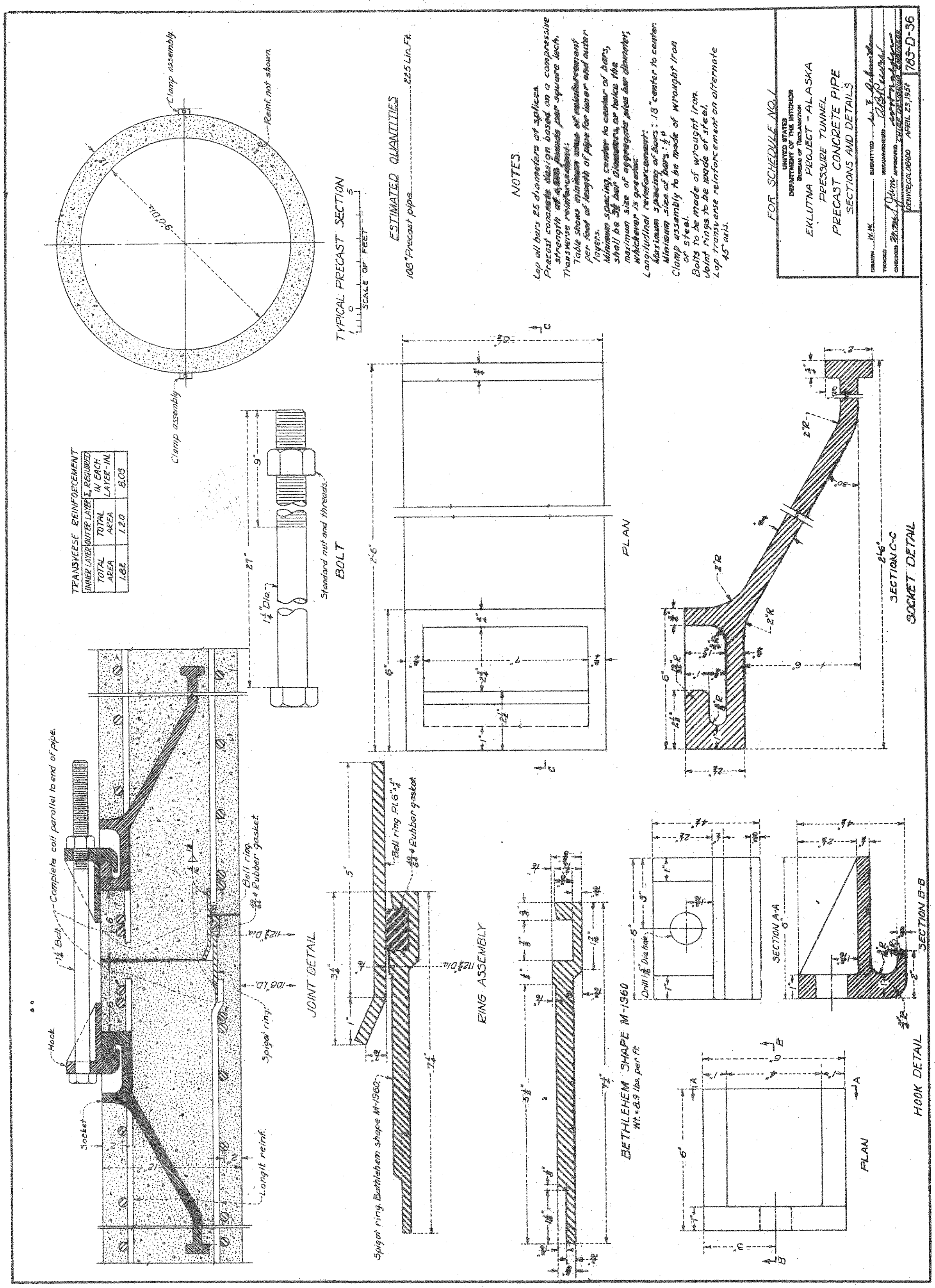
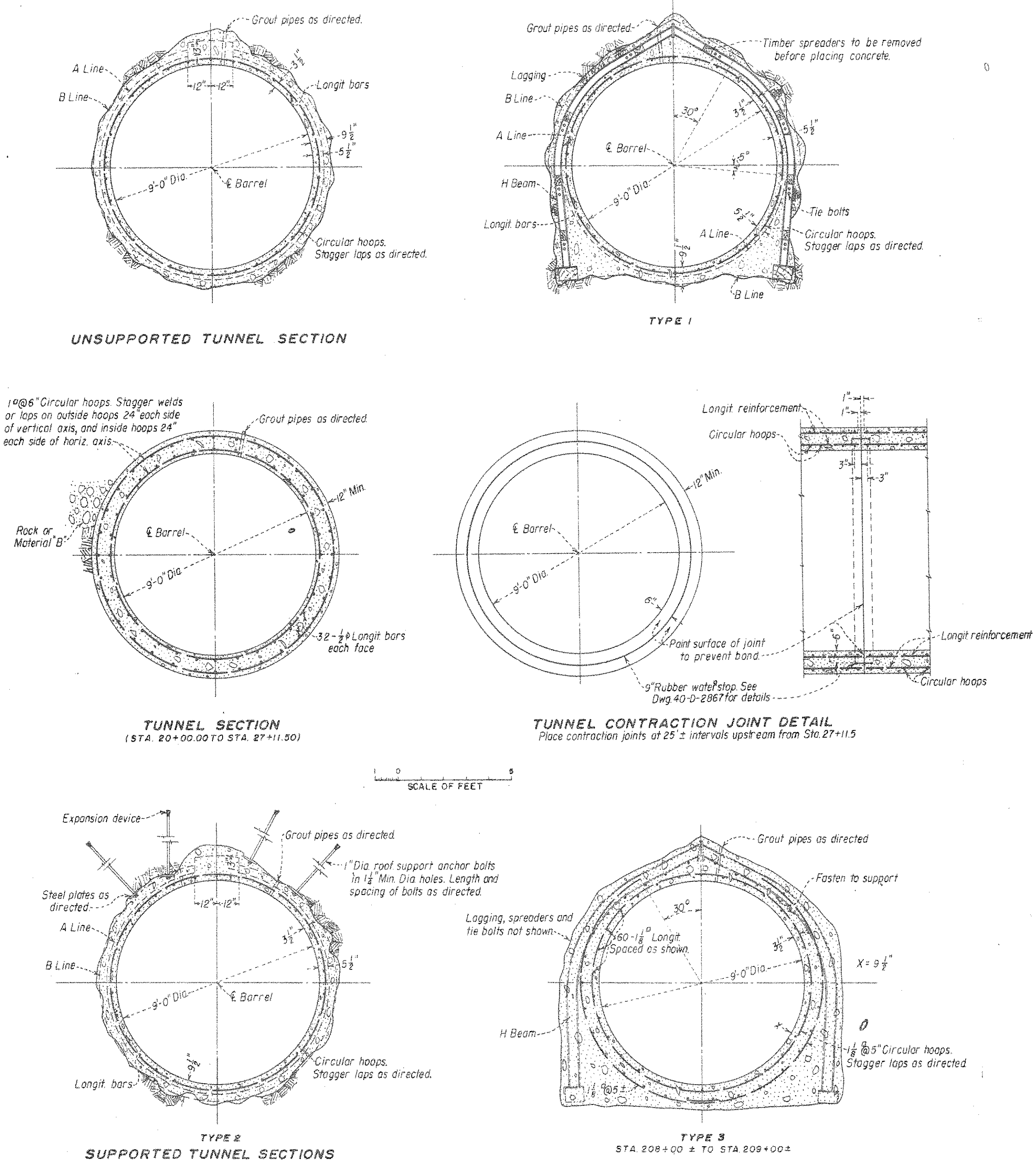


Figure 29.--Sections and details for precast concrete pipe in inlet portion of pressure tunnel.

Figure 30.--Reinforcement steel in tunnel section at station 20+50. Steel forms are in background. P783-908-926, June 25, 1952.



TUNNEL REINFORCEMENT

FROM STATION	TO STATION	LONGIT.	HOOPS	REMARKS
27+38.5	44+00.0	30-$\frac{5}{8}\phi$	1 φ @ 10"	
44+00.0	51+00.0	30-$\frac{5}{8}\phi$	1 φ @ 9"	
51+00.0	190+25.0	-	-	Unreinforced
190+25.0	193+25.0	30-$\frac{5}{8}\phi$	1$\frac{1}{8}$□ @ 8"	
193+25.0	206+50.0	-	-	Unreinforced
206+50.0	208+00±	30-$\frac{5}{8}\phi$	1$\frac{1}{8}$□ @ 8"	
208+00±	209+00±	-	-	See Section-Type 3
209+00±	215+00.0	30-$\frac{5}{8}\phi$	1$\frac{1}{8}$□ @ 8"	
215+00.0	254+15.0	30-$\frac{5}{8}\phi$	1$\frac{1}{8}$□ @ 7"	

NOTES

Place all reinforcement so that the centers of bars in the outer layers will be 2½" from face of concrete unless otherwise shown.
Lap all bars 34 diameters at splices.
Concrete design based on a compressive strength of 3,000 pounds per square inch.
See Dwg. 783-D-33 for Tunnel Profile.
See Dwg. 783-D-41 for description of material "B."
See Dwg. 783-D-480 for reinforcement from Sta. 254+15.0 to Sta. 255+02.9 Bk. (255+10.0 AH) and details of adit junction.

Figure 31.--Sections and details of pressure tunnel from station 20+00 to station 255+10. From drawing 783-D-34.

In the vicinity of station 208, considerable water was encountered (fig. 32) and as a result much material was washed into the tunnel, leaving a large chimney above and to one side of the tunnel. Special reinforcement and relieving drains were placed throughout this chimney reach (fig. 33). The relieving drains were fitted with bronze-mounted flaps to prevent any return flow of tunnel water into the rock.

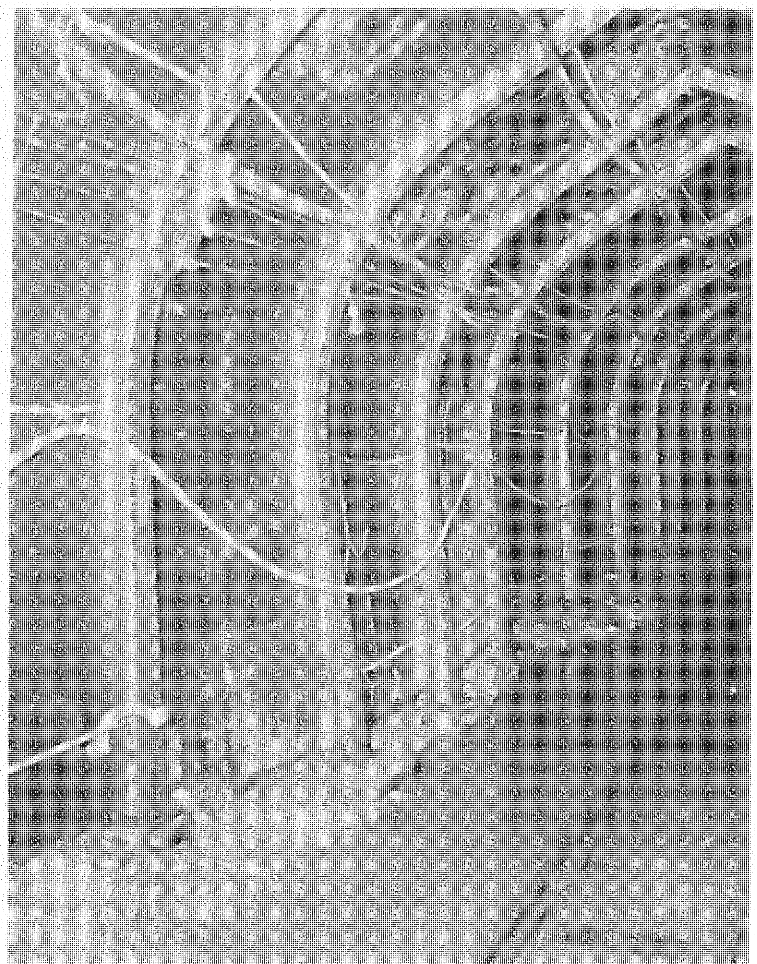


Figure 32.--View of tunnel section showing typcial sheet metal panning used through wet sections. P783-908-1662, July 15, 1954.

In order to construct the tunnel, an adit was driven which intersected the tunnel at about station 254. Upon completion of tunnel construction, this adit was sealed with a heavy concrete bulkhead grouted to close contact with the rock. An access was provided through the bulkhead and sealed adjacent to the tunnel with a swinging steel door (fig. 34).

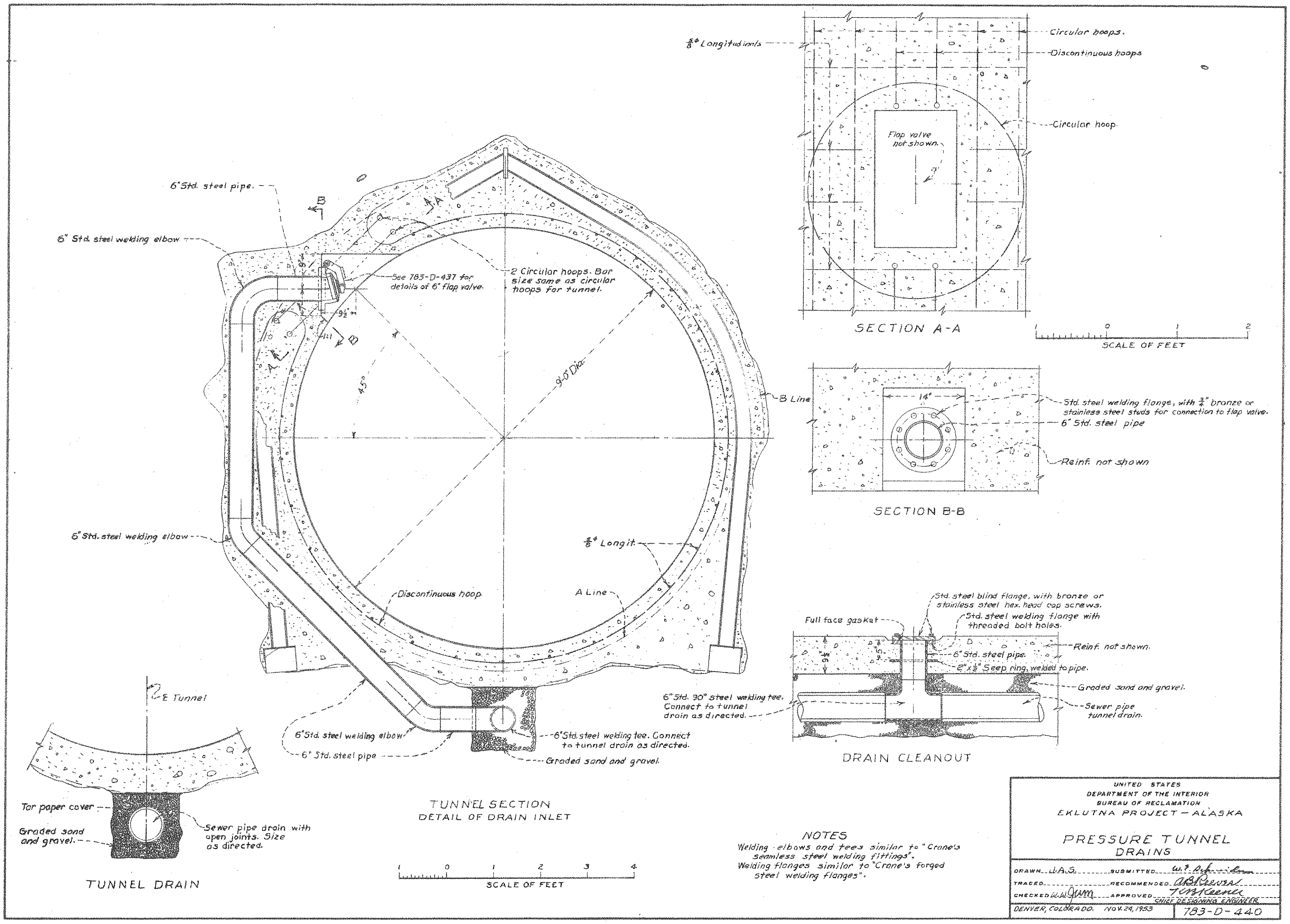


Figure 33.--Drains for pressure tunnel.

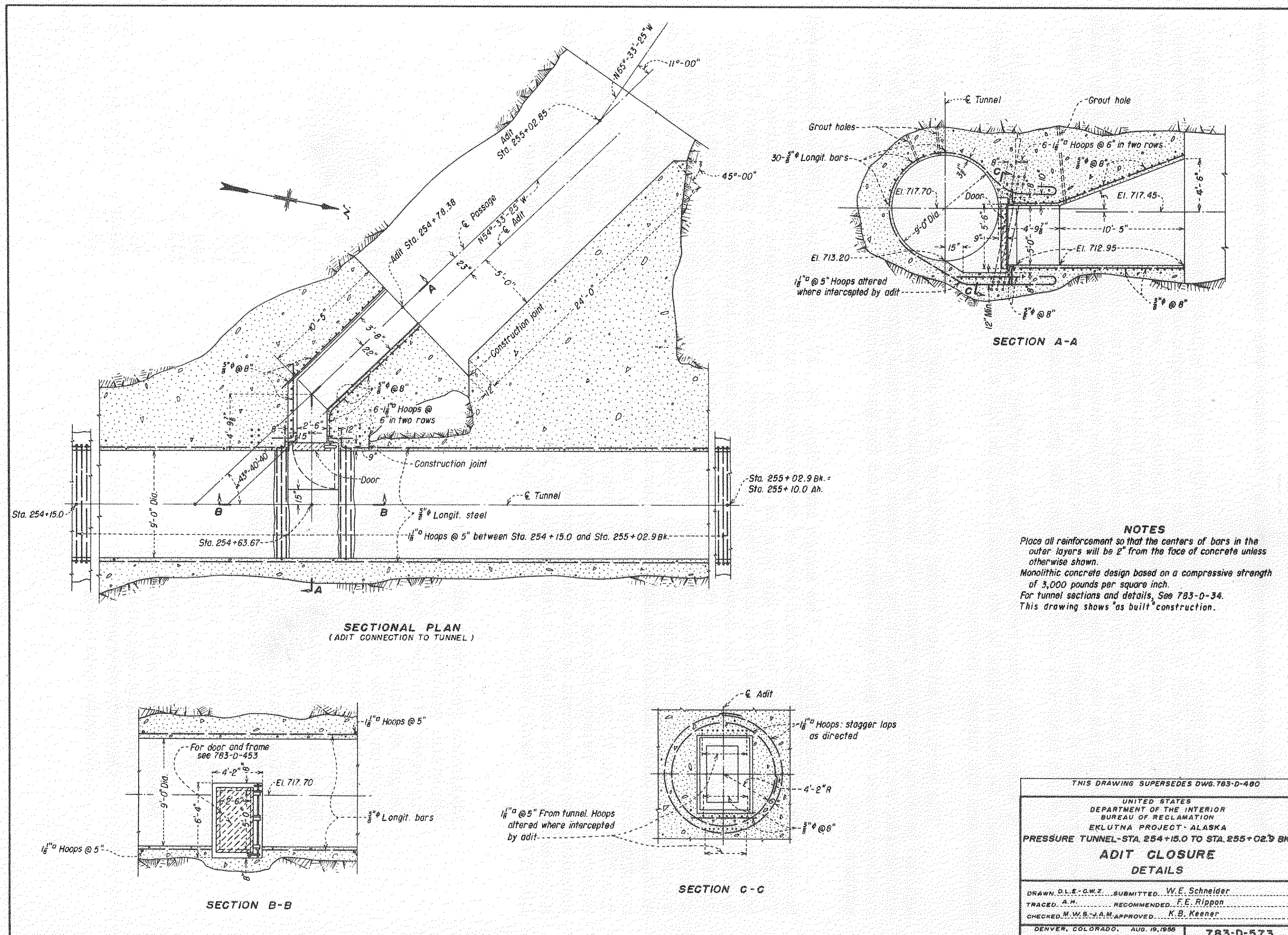


Figure 34.--Pressure tunnel adit closure details.

In areas not provided with drains, the tunnel was completed with backfill grouting.

33. Gate Shaft. - Earthquake design made it appear desirable to found the 9-foot-diameter gate shaft (fig. 35) in solid rock. Geologic data indicated that the bottom of the shaft would be safely in bedrock at station 27+25, and the design proceeded accordingly. The termination of the top of the shaft was determined by an economic study in which the cost of shaft construction was compared with the construction and maintenance of an open cut at the top of the shaft. From this study the position for the top of the shaft was determined at elevation 1000.00; however, it was later fixed at elevation 1012 when sloughing of the open-cut material around the shaft became a problem.

A watertight, concrete bonnet was provided around the gate in the lower part of the shaft so that access to the tunnel could be had with the bulkhead gate in the closed position and the tunnel dewatered.

The vertical and horizontal portions of the shaft structure were reinforced against internal bursting pressures, and possible vertical deflections of the shaft due to earthquake were provided for by a number of horizontal joints. Design stresses for reinforcement of the gate shaft structure and the gate bonnet were 20,000 pounds per square inch.

34. Surge Tank. - The surge tank (figs. 36, 37, and 38) is 1,108 feet measured horizontally from the upstream side of the powerplant and 23,765 feet from the intake. The invert of the tunnel below the tank is 689 feet in elevation above the turbines, while the top of the tank is 192 feet above the tunnel invert. An emergency guard gate (7.08 by 9 feet) is installed in the downstream end of the tank so as to permit shutting off the tunnel flow at the upper end of the penstock. The gate control, complete with position indicator, piping, and heating elements, is provided to operate the hoist for the fixed-wheel gate. A control cabinet housed in a weatherproof shelter has been provided on top of the surge tank, and the position indicator is mounted in the surge tank adjacent to the hoist cylinder. The gate is both manually and electrically operable at the surge tank and, in addition, electrical gate control has been provided in the powerplant for emergency closure only. Temperatures in the shaft range from 0° F. to 70° F. and the air surrounding the equipment is relatively humid. The surge tank, fixed-wheel gate hoist, and accessories were furnished under invitation No. DS-4022, item 2, and invitation No. DS-3673. The basic data used in making final design studies are as follows:

Maximum reservoir elevation	869.0
Minimum reservoir elevation	814.0
Diameter of tunnel, feet	9.0
Length of tunnel, feet	23,755
Friction factor for tunnel (Kutter's)	$0.011 < n < 0.014$
Diameter of surge tank, feet	30.0
Diameter of throttling ring, feet	4.0
Head loss in penstock system (estimated)	$H = 32.0 \times 10^{-6} Q^2$
Number of units in powerplant	2
Minimum gate closure time, seconds	3
Full discharge through each unit, second-feet:	
At 700 feet net head	325
At 750 feet net head	337.5
At 800 feet net head	350
At 850 feet net head	362.5
Minimum tailwater elevation:	
Two units operating	21.0
One unit operating	20.0
No units operating	18.0

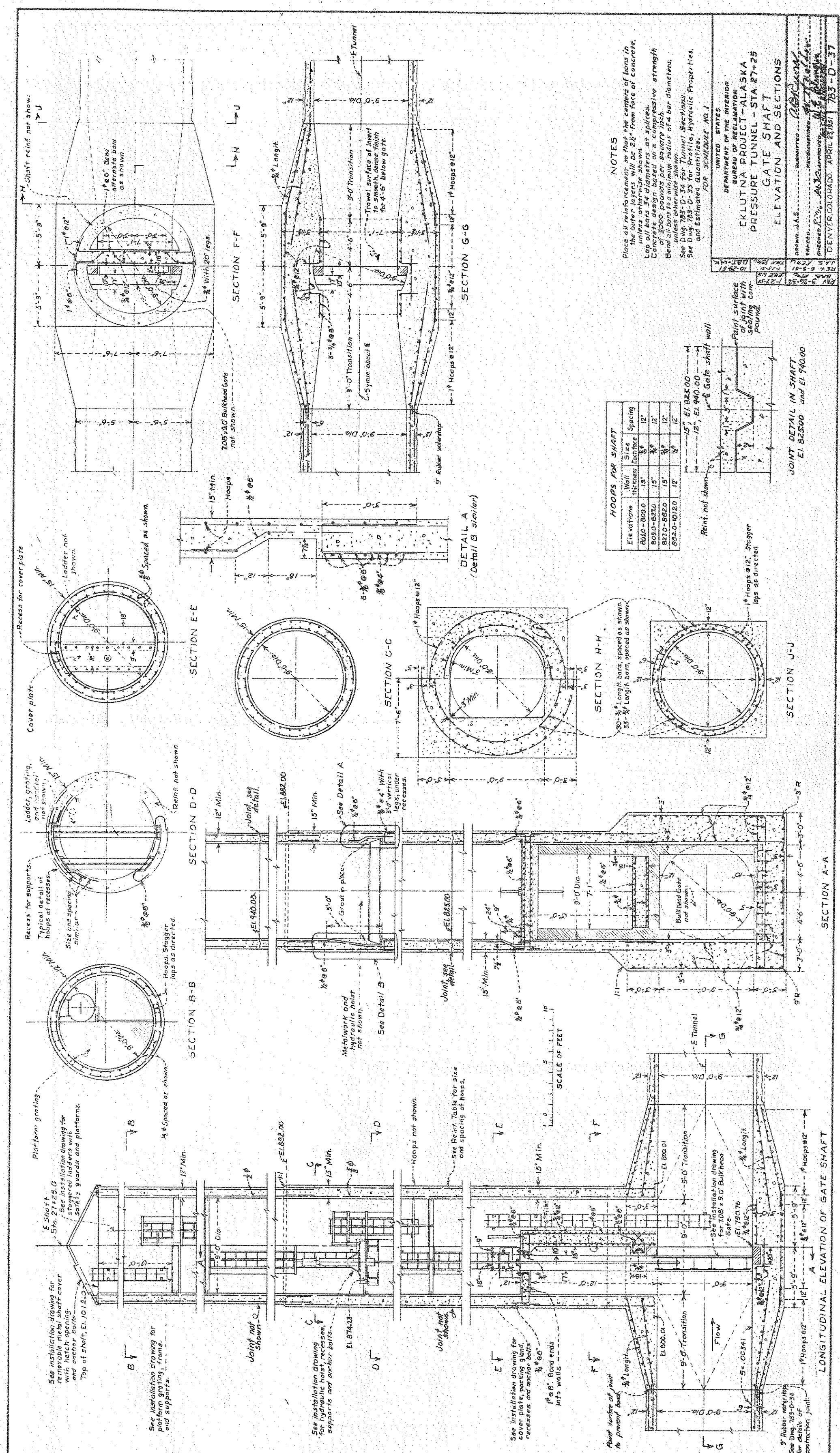


Figure 35.--Elevations and sections of pressure tunnel gate shaft.

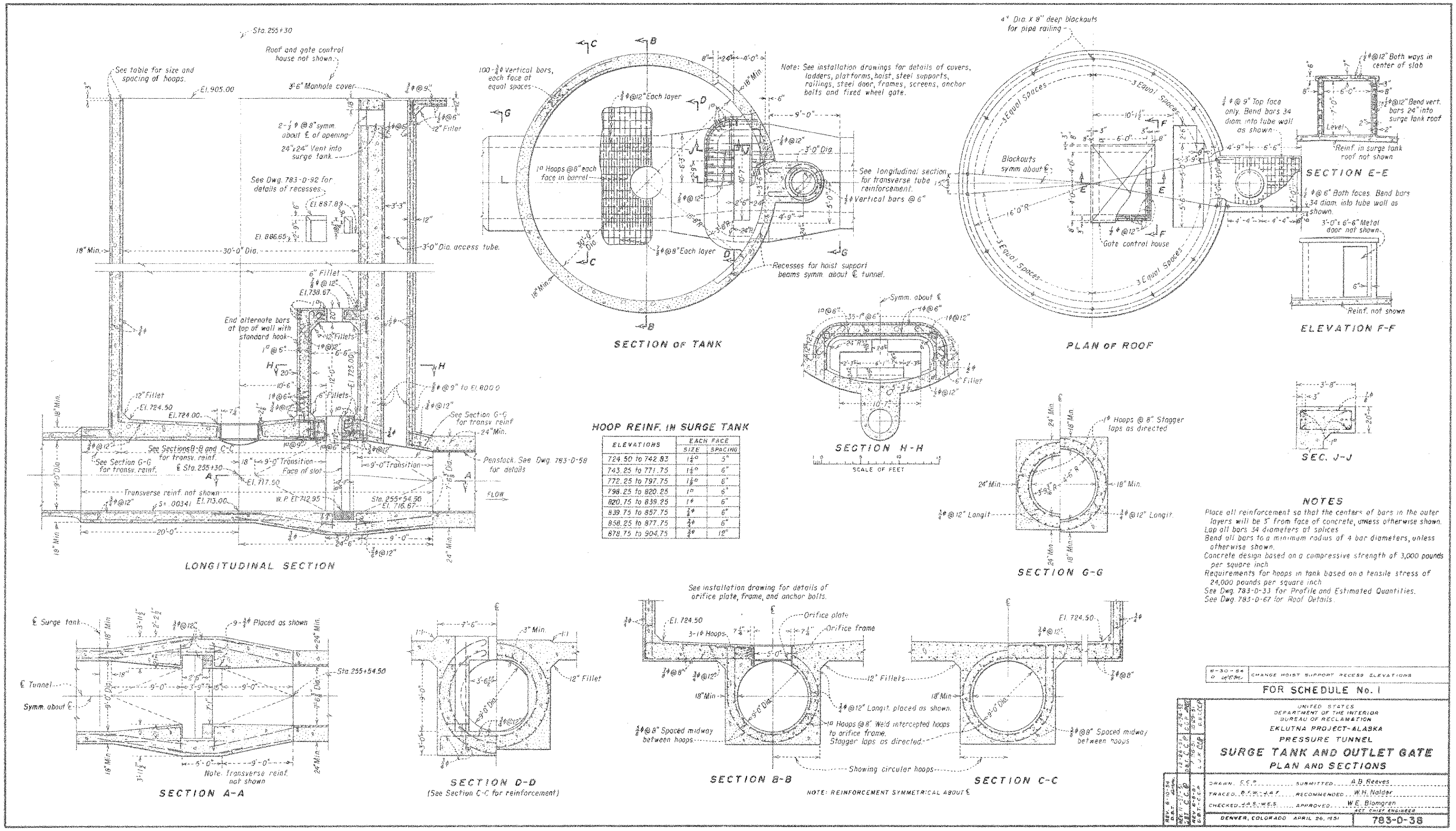


Figure 36. --Plan and sections of surge tank and outlet gate for pressure tunnel.

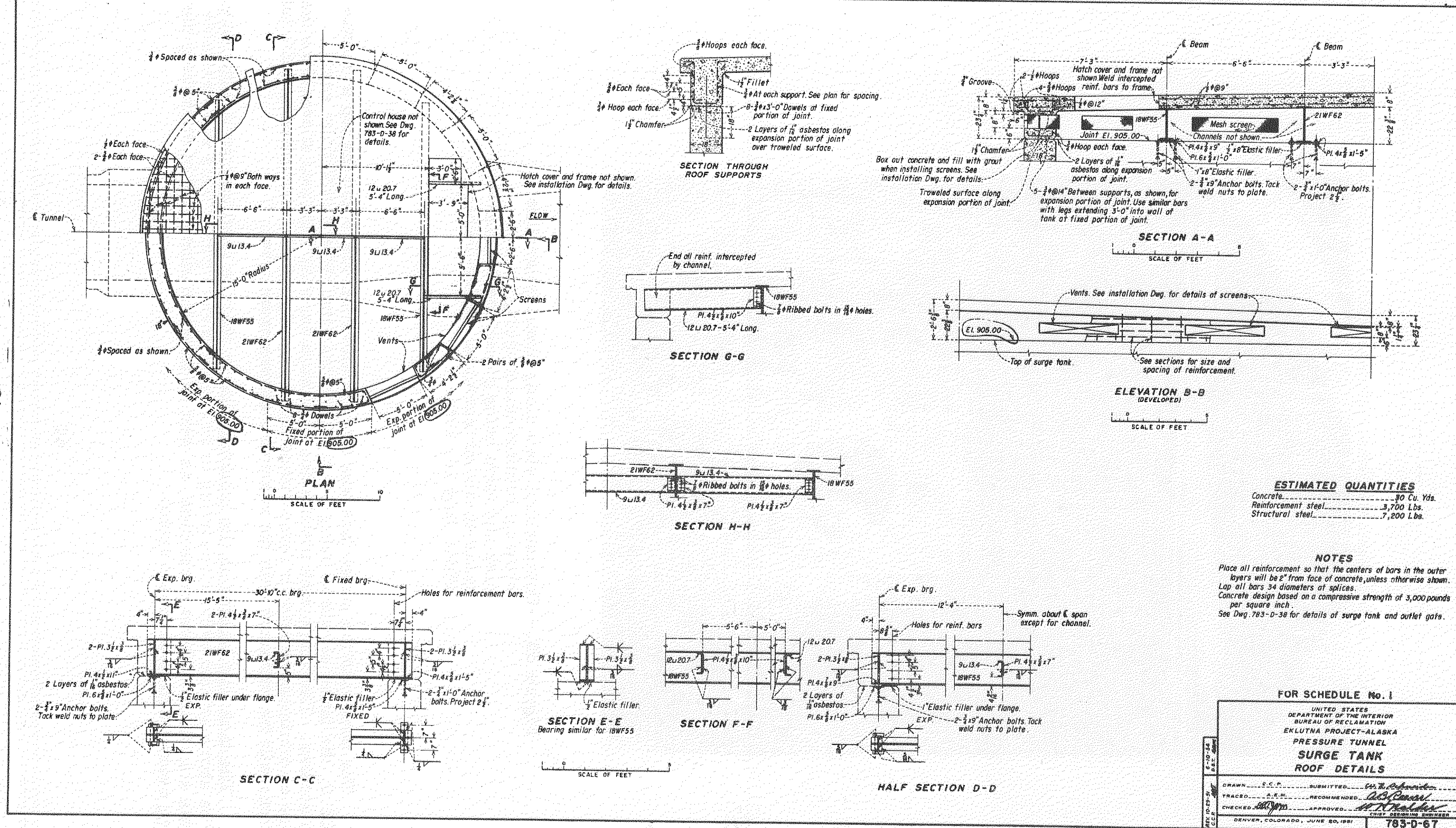


Figure 37.--Roof details for surge tank.

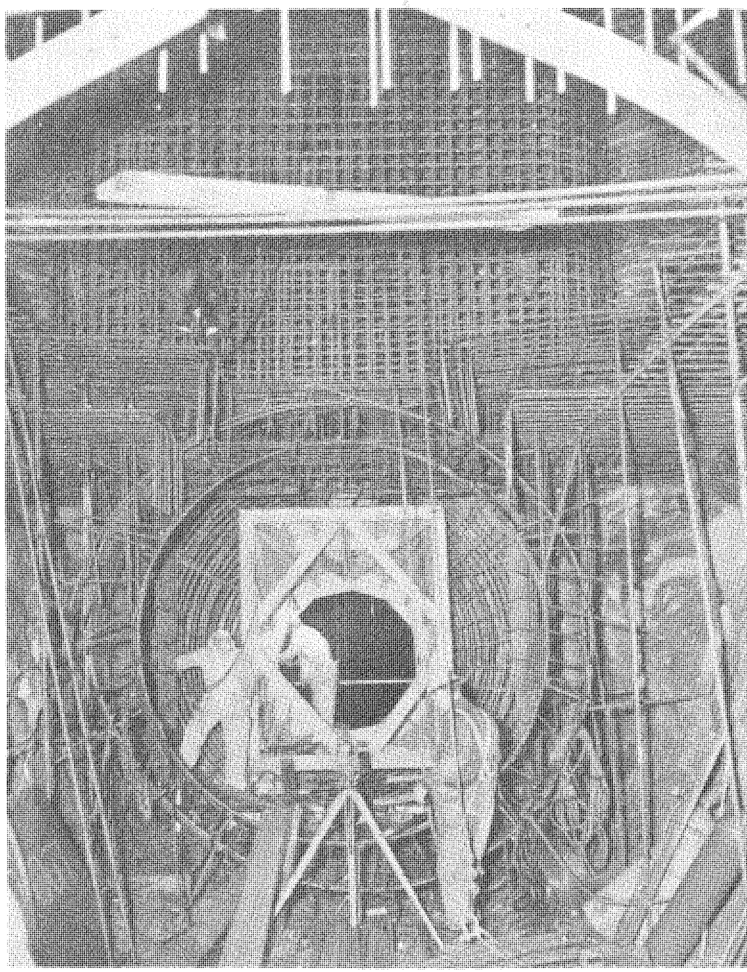


Figure 38.--Downstream view along tunnel centerline showing reinforcement steel in surge tank and form being placed for rectangular-to-round transition. P783-908-1664, July 20, 1954.

The bottom of the surge tank was fixed at elevation 724.0 and the top at elevation 905.0, the latter elevation being 5 feet higher than that determined from early design studies. The surge tank installation is of such capacity that load annexations may be made at minimum reservoir level without imposing any special limitations, while load rejections will be contained with the reservoir at maximum level.

The tank was located on the mountainside so that the least amount of structure would be above ground without resorting to extensive open cutting. This was desirable from the standpoint of frost protection, as well as from the standpoint of disturbing the existing overburden to the least extent.

The minimum thickness for the vertical walls of the tank was fixed at 18 inches, and reinforcement was provided in the form of circular hoops. In determining the reinforcement, it was assumed that the rock surrounding the tank would not be effective in resisting deflections in the tank. The amount of hooping reinforcement required was then determined by using the maximum surge head and a working stress of 24,000 pounds per square inch for the steel. Even though the walls are monolithic with the base, no allowance was made for this in the computation for the tank bursting stresses.

The floor of the tank and the concrete bonnet around the gate are reinforced to carry the load resulting from a 75-foot differential head between tank and tunnel. The working stress for reinforcement in the bonnet was 16,000 pounds per square inch.

Steel roof support beams were used for the surge tank roof in order to simplify framing. The roof was designed for dead load plus 100 pounds per square foot live load. Support for the gate hoist was provided by steel beams recessed into the sides of the tank.

35. Gates. - (a) *Purpose and General Description.*-- One fixed-wheel gate is required at the surge tank in the pressure tunnel. Normally, this gate is closed after the flow of water through the penstock has been stopped by either closing the turbine wicket gates or the 66-inch butterfly valves for the purpose of unwatering, inspection, and maintenance of the penstock and turbine. In case of damage to the turbine or penstock, the gate may be used for emergency closure under full reservoir head.

One bulkhead gate is required in the pressure tunnel at the gate shaft. The gate can only be closed with no flow in the tunnel. It serves as a bulkhead to allow unwatering, inspection and maintenance of the pressure tunnel and surge tank, and is to be raised a maximum of 18 inches during tunnel refilling. After the tunnel has been refilled, the gate may be fully raised. The gate is opened and closed by a hand-operated hydraulic hoist.

The general arrangement and details of the fixed-wheel and bulkhead gates are shown on figures 39 through 42. Both gates are 7.08 by 9 feet nominal size, which dimensions represent the net opening of the pressure tunnel at the surge tank and the gate shaft. The gates operate in slots formed in the lower portion of the surge tank and gate shaft concrete.

The gates are flat structural steel units of welded construction consisting of a framework of horizontal members connected at the ends to vertical members. A skinplate is welded to the downstream face of the gate framework.

(b) *Fixed-Wheel Gate.*-- The overall gate leaf of the fixed-wheel gate is 10 feet 2-1/2 inches wide by 9 feet 5-1/2 inches high. Four 24-inch-tread-diameter flanged wheels are installed on each side of the gate between the two vertical end members. The wheels transfer the hydraulic load from the gate to tracks that are attached to bases embedded in the concrete at the downstream face of the gate slot. When the gate is on the tracks, lateral movement is controlled by the wheel flanges. Semielliptic springs, which bear against angles embedded in the concrete at the upstream face of the gate slot, hold the wheels against the track.

Solid rubber, double-stem, brass-clad seals are fastened across the top and on each side of the downstream face of the skinplate, and a flat rubber seal is fastened across the bottom of the gate. The seals contact steel seats which are attached to bases embedded in the concrete at the downstream face of the gate slot.

(c) *Bulkhead Gate.*-- The overall gate leaf of the bulkhead gate is 8 feet 1 inch wide by 9 feet 6 inches high. A gate seat on the downstream face of the skinplate and over the vertical end members, transfers the hydraulic load from the gate to seats that are attached to bases embedded in the concrete at the downstream face of the gate slot. Lateral movement of the gate is controlled by means of a gate slot in the concrete gate shaft, and when the gate is closed, the gate seat is positioned against the embedded seat by means of a beveled guide placed in the upstream face of the gate slot near the tunnel floor.

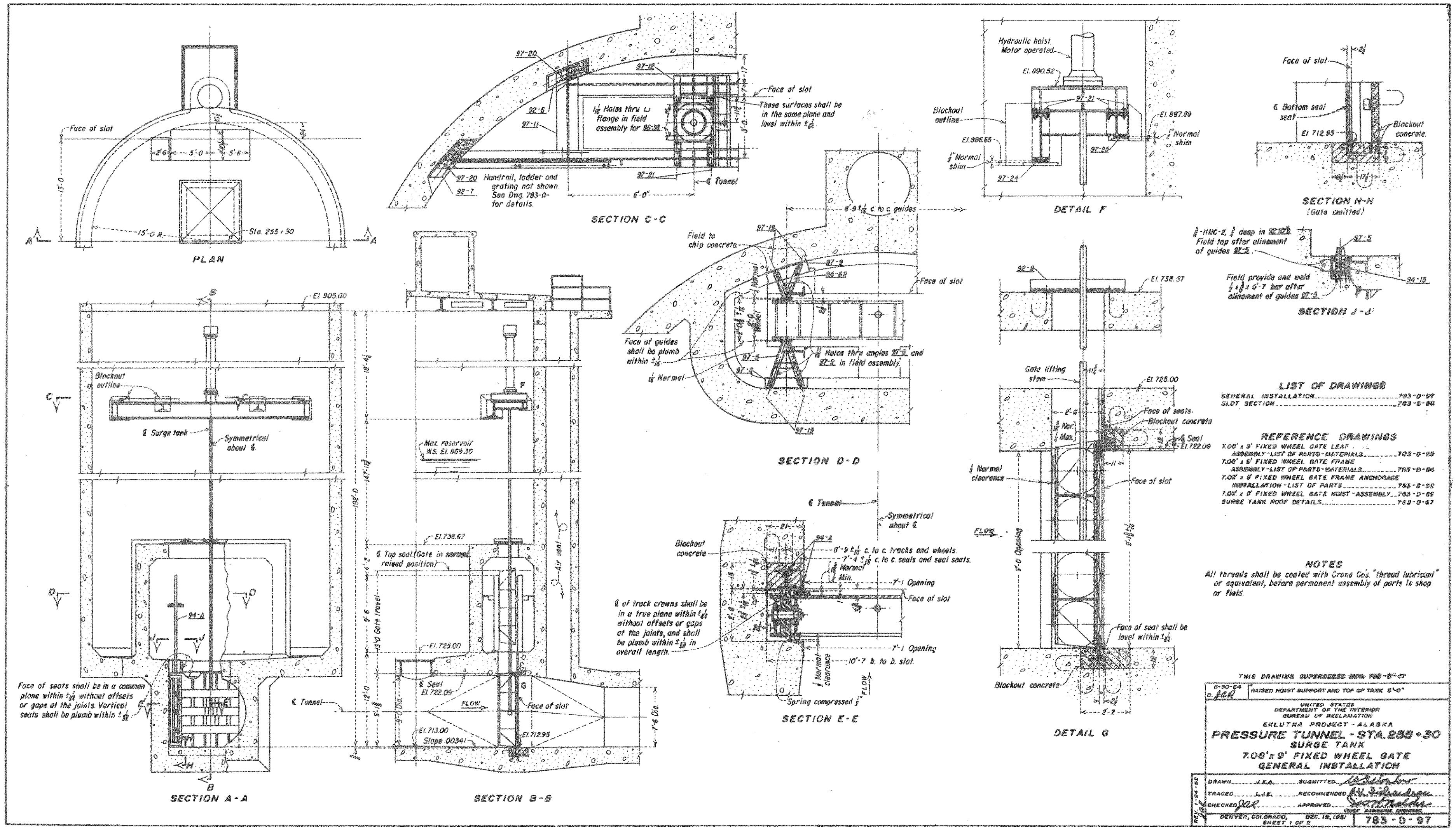
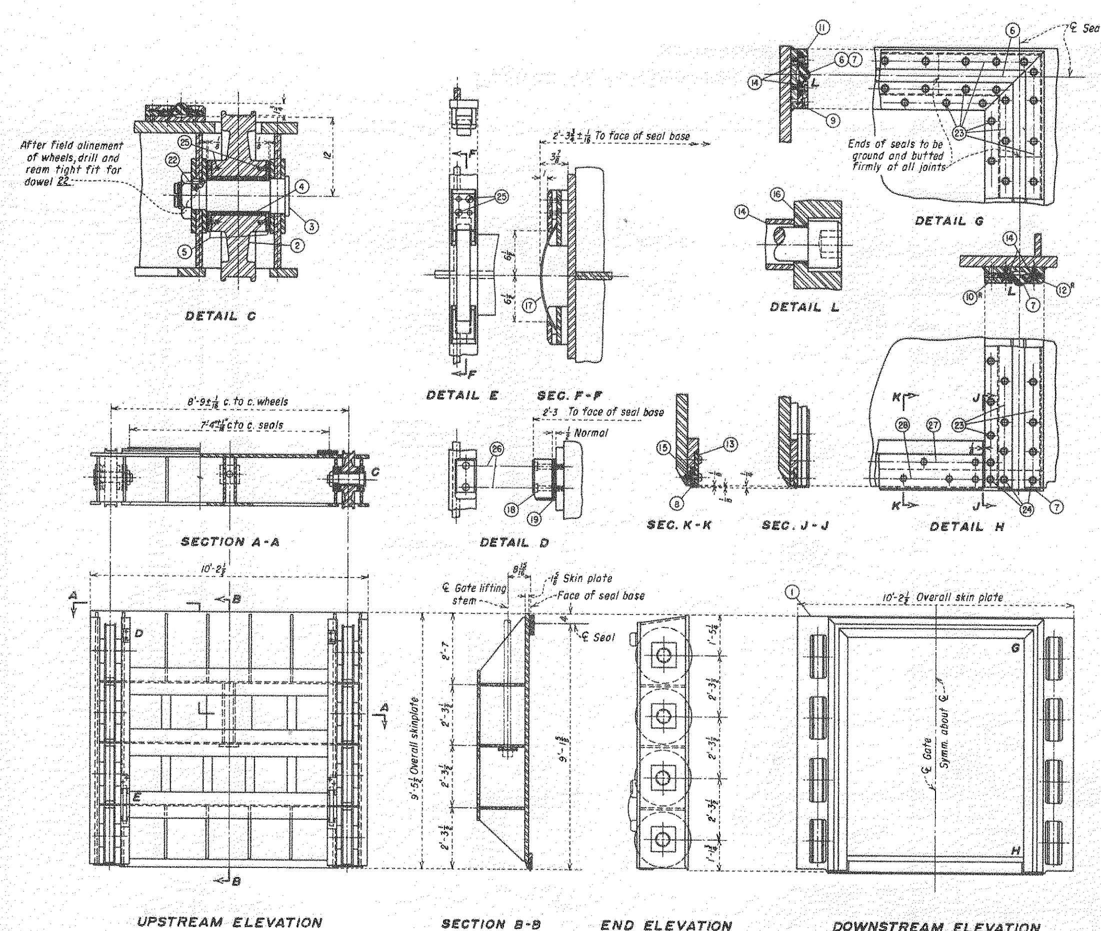


Figure 39.--General installation of 7.08- by 9-foot fixed-wheel gate in pressure tunnel at station 255+30 (surge tank).



LIST OF PARTS - ONE GATE LEAF

DRAWING NUMBER	PART NO.	NO. REQ'D	DESCRIPTION	MATERIAL CLASSIFICATION	MATERIAL REF. NO.	USED WITH
783-D-100	1	1	Structural unit	Steel	B55	
783-D-101	2	8	Wheel	Wrought steel	B42	
"	3	8	Eccentric pin	Steel	C12	
"	4	8	Split bushing	Bronze - Lubrite or similar	*	
"	5	16	Washer	Naval brass	J7	
"	6	2	Corner seal	Rubber - brass	See Specs.	
"	7	22 Lin. ft + excess	Seal	Rubber - brass	See Specs.	
"	8	9 lin. ft	Seal	Rubber	See Specs.	
"	9	1	Clamp	Steel	B55	
"	10R	1	Clamp	Steel	B55	
"	10L	1	Clamp	Steel	B55	
"	11	1	Clamp	Steel	B55	
"	12R	1	Clamp	Steel	B55	
"	12L	1	Clamp	Steel	B55	
"	13	1	Clamp	Steel	B55	
"	14	110+6	Spacer	Steel	*	6,7,23,24
"	15	20+2	Spacer	Steel	*	8,28
"	16	53+10	Ring seal	Rubber	*	9,10$^{R}_{L}$,23,24
"	17	2	Spring	Stainless steel - 13% Cr. min.		
"	18	2	Shoe	Steel	B55	
"	19	2	Shim	Steel	*	1,18
"	20	2	Hole saw	Steel	*	6,7
X-D-311	21	2	1"ϕ Drill for rubber	Steel	*	8
No detail	22	8	Dowel ⅝"ϕ x 1½"	Steel	*	1,3
"	† 23	156+8	⅝" x 1⅛" Socket hd. cap screw	Stainless steel 13% to 18% Cr.	C153	1,9,10$^{R}_{L}$,11,12$^{R}_{L}$
"	† 24	6+1	⅝" x 2" Socket hd. cap screw	Stainless steel 13% to 18% Cr.	C153	1,10$^{R}_{L}$,12$^{R}_{L}$
"	25	100+7	⅝" x 1⅛" Flat hd. cap screw	Steel	*	1,2,5
"	26	4+1	⅝" x 3½" Socket hd. cap screw	Steel	*	1,18,19
"	27	13+2	⅝" x 1½" Hex. hd. cap screw	Stainless steel 13% to 18% Cr.	C153	1,13
"	28	14+2	⅝" x 2" Hex. hd. cap screw	Stainless steel 13% to 18% Cr.	C153	1,8,13

* Contractor to furnish high class commercial materials that are satisfactory to the contracting officer.
† Furnish four hex. bar wrenches for 23 and 24.

MATERIALS-SPECIFICATIONS AND MINIMUM PHYSICAL PROPERTIES

MATERIAL REF. NO.	MATERIAL	ULTIMATE TENSILE STRENGTH #/□"	YIELD POINT TENSION #/□"	% ELONG IN 2"	% RED. IN AREA	SPECIFICATION NUMBER	REMARKS
B42	Wrought steel wheels	—	—	—	—	⊗ A57-48	Class A Heat treat rim only
B55	Structural steel	(a)	(a)	(a)	(a)	◉ QQ-S-741	Type II, Grade A, Class 1
C12	Steel	120,000	90,000	20	40		
C153	Corrosion resisting steel (Stainless 13% to 18% Cr.)	70,000	35,000	20	50	◉ QQ-S-763a	Bars & forgings
J7	Naval brass	(a)	(a)	(a)	—	◉ QQ-B-636a	Class A, half hard

(a) See indicated specification for physical properties.
◉ Federal specification.
⊗ A.S.T.M. specification.

LIST OF DRAWINGS

ASSEMBLY - LIST OF PARTS - MATERIALS 783-D-99
STRUCTURAL UNIT 783-D-100
WHEEL - PIN - BUSHING - SEALS - CLAMPS 783-D-101

REFERENCE DRAWINGS

7.08' x 9' FIXED WHEEL GATE
GENERAL INSTALLATION 783-D-97
RUBBER DRILL X-D-311

NOTES

Field to install wheels, seals and springs. Adjust the downstream treads of wheels to a common plane, parallel to the finished surface of the seal base, before installing seals.
Gate designed for 180 foot head.
Mark numbers to be placed on parts in accordance with instructions in the specifications. Mark numbers for undetailed parts to have same prefix number as detailed parts followed by the proper part number.
All threads to be coated with Crane Co's. "Thread Lubricant" or equivalent before permanent assembly of parts in shop or field.
All threads free fit unless otherwise noted.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
EKLUTNA PROJECT - ALASKA
PRESSURE TUNNEL - STA. 255+30
SURGE TANK
7.08' x 9' FIXED WHEEL GATE LEAF
ASSEMBLY - LIST OF PARTS - MATERIALS
DRAWN N.M.B. SUBMITTED [signature]
TRACED E.M.W. RECOMMENDED [signature]
CHECKED [signature] APPROVED [signature] CHIEF, MECHANICAL BRANCH
DENVER, COLORADO, DEC. 18, 1951 SHEET 1 OF 3
783-D-99

Figure 40.--7.08- by 9-foot fixed-wheel gate leaf in pressure tunnel at station 255+30 (surge tank)--Assembly, list of parts, and materials.

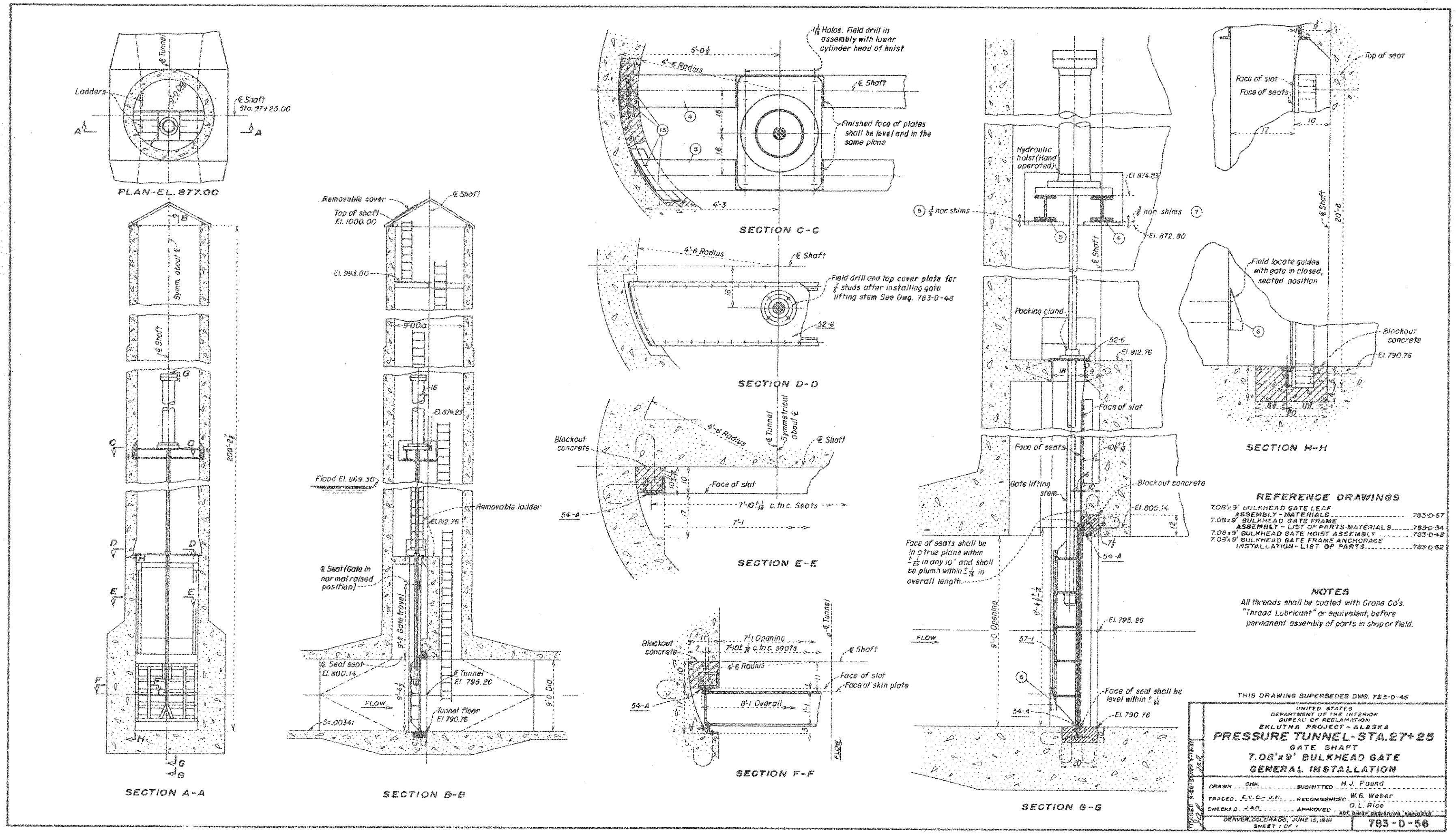
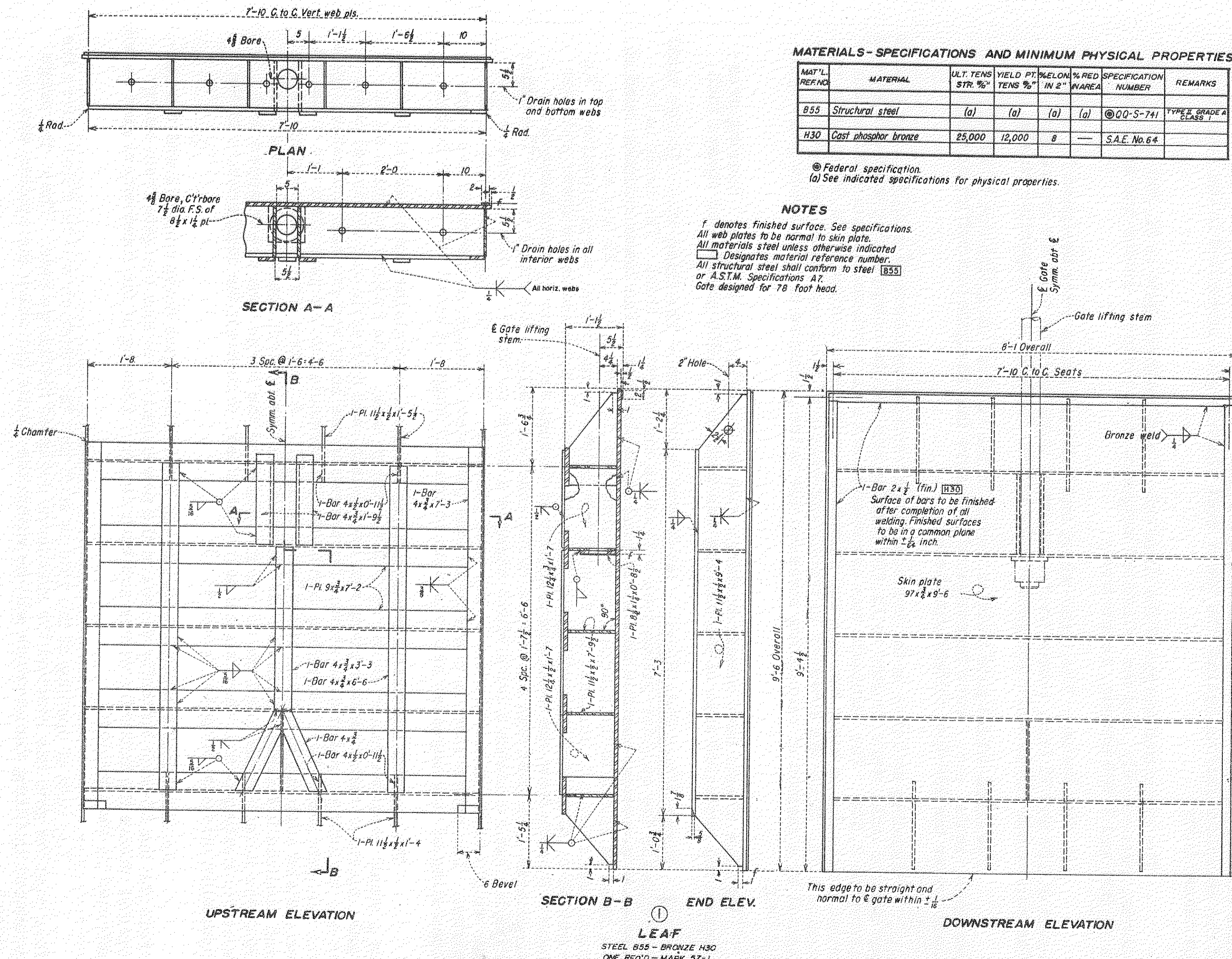


Figure 41.--General installation of 7.08- by 9-foot bulkhead gate in pressure tunnel at station 27+25 (gate shaft).



MATERIALS - SPECIFICATIONS AND MINIMUM PHYSICAL PROPERTIES

MAT'L. REF. NO.	MATERIAL	ULT. TENS STR. %"	YIELD PT. TENS %"	% ELON. IN 2"	% RED. IN AREA	SPECIFICATION NUMBER	REMARKS
B55	Structural steel	(a)	(a)	(a)	(a)	⊛ QQ-S-741	TYPE II, GRADE A, CLASS 1
H30	Cast phosphor bronze	25,000	12,000	8	—	S.A.E. No. 64	

⊛ Federal specification.
(a) See indicated specifications for physical properties.

NOTES

f denotes finished surface. See specifications.
All web plates to be normal to skin plate.
All materials steel unless otherwise indicated
▭ Designates material reference number.
All structural steel shall conform to steel B55 or A.S.T.M. Specifications A7.
Gate designed for 78 foot head.

Figure 42.--7.08- by 9-foot bulkhead gate leaf in pressure tunnel at station 27+25 (gate shaft)--Assembly and list of materials. From drawing 783-D-57.

The bulkhead gate is sealed by metal to metal contact of the top and side gate seats bearing against the seats which are embedded in the concrete and by the lower edge of the skinplate bearing against the lower seat which is also embedded in the concrete at the tunnel floor.

The estimated weight of the fixed-wheel and bulkhead gate is 21,200 and 5,100 pounds, respectively, and the estimated weight of their frames, guides and anchorages is 15,300 and 7,800 pounds, respectively.

(d) *Gate Design.*-- The fixed-wheel and bulkhead gates were designed for nominal heads of 180 and 78 feet, respectively, assumed to be uniform over the entire gate leaf. The hoist connections were designed for the pullout force of the respective hoists.

The fixed-wheel gate friction forces in the vertical direction due to wheels, bearings, seals, etc., were investigated to assure that the gate had sufficient weight to close under the 180-foot differential head.

Bending stresses in the horizontal and vertical members of each gate, in pounds per square inch, were limited to 15,000 tension and 14,000 compression with web shears limited to 9,500. The skinplate was assumed to act as a continuous beam and its combined stress due to beam bending and skinplate bending was limited to 20,000 pounds per square inch. Shearing stresses in tracks and wheels of the fixed-wheel gate were investigated by a method of calculating stresses due to the pressure of one elastic solid upon another.

The wheels have bronze bushings with self-lubricating inserts. Bearing pressure on the projected area of the bushing was limited to 4,000 pounds per square inch.

36. Fixed-Wheel Gate Hoist. - (a) *General Description.*-- The fixed-wheel (surge tank) gate hoist is the cylinder-piston type with oil as the operating fluid. The hoist is installed in a vertical position on a structural steel platform. The lower cylinder head of the hoist is bolted to the platform at elevation 885.52, which is 16.22 feet above the maximum reservoir surface, but about 8 feet below the maximum surge elevation. An adjustable, chevron-type packing for the piston stem is provided in the lower cylinder head. Forces from the hoist are transferred through the lower cylinder head to the structural steel platform and thence to the concrete walls of the surge tank. The upper cylinder head contains a latch which engages a button on top of the piston stem to hold the weight of the gate and stem in the open position. Three oil rings are used on the piston. The piston stem is connected to the gate stem through an intermediate stem consisting of nine unguided sections with an overall length of about 147 feet 9 inches.

The control equipment for operating the hoist is contained in a cabinet located in a small concrete house on the roof of the surge tank. The cabinet contains an oil tank, electric-motor-driven pump and hand pump, and hydraulic and electrical equipment, including a pushbutton station for operating the hoist and position indicating lights for the gate leaf. Limit switches mechanically connected to the gate stem are installed on a stand adjacent to the top of the hoist cylinder. A control switch for closing the gate and position indicating lights are also installed on the control board in the powerplant. Both the hoist cylinder and the oil piping located in the surge tank are wrapped with electric heating cable, thermostatically controlled, to prevent the temperature of the hydraulic oil from dropping below 40° F.

An electrical interlock between the fixed-wheel gate hoist controls and the controls for the 66-inch butterfly valves in the powerplant prevents the gate from being opened unless the butterfly valves are both closed. Closing of the fixed-wheel gate is not affected by the interlock.

The rate of opening of the gate is such that the penstock will be filled before the flow past the gate has reached the maximum designed discharge rate. Thus, the surge produced in filling the penstock will be within the limits for which the system was designed.

(b) *Hoist Design.*-- The hoist was designed to lift the dead weight of the gate, stems and piston, plus friction from the gate seals, axles and wheel rolling, and downpull due to the unbalanced water pressure between the top and bottom of the gate. The cylinder was designed for a relief valve pressure of 1,000 pounds per square inch, which will produce a gross lifting force of about 100,000 pounds. The hoist load with the water pressure balanced on the gate leaf is 30,000 pounds which requires a cylinder pressure of 300 pounds per square inch. The hoist load with unbalance pressure on the leaf is about 80,000 pounds and requires a cylinder pressure of 800 pounds per square inch. The opening cycle will require about 35 minutes with electric motor operation. This time may be increased with low temperatures and viscous oil. The closing cycle operates by gravity and requires about 1-1/2 minutes.

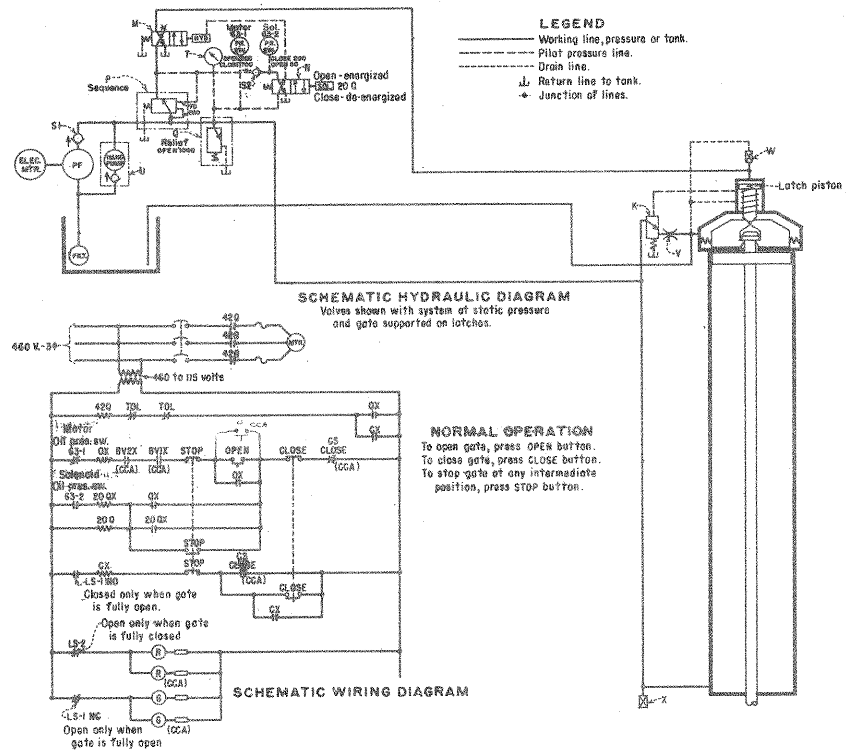
(c) *Controls.*-- The hydraulic system (fig. 43) is powered by a 2-horsepower, 1,200-r.p.m. open-type, 440-volt, 3-phase, 60-cycle induction motor driving a rotary positive-displacement pump with a capacity of 2 gallons per minute at 750 pounds per square inch pressure, using SAE No. 10 oil at a temperature range between 40° F. and 100° F. A transformer in the cabinet supplies 115-volt current for operating the controls. Heater elements are not provided in the cabinet since the control house is heated. The limit switches are installed in a case mounted on a stand adjacent to the hoist cylinder and are mechanically operated through a chain attached to the hoist stem. A pilot-operated check valve is installed near the top of the hoist cylinder. A control switch for closing only and position indicating lights are mounted on the main control board in the powerplant. With the above exceptions, all of the hydraulic and electrical operating equipment is contained in the control cabinets.

37. Bulkhead Gate Hoist. - (a) *General Description.*--The 7.08- by 9-foot bulkhead (gate shaft structure) gate hoist is the cylinder-piston type with oil as the operating fluid. It is installed in a vertical position on a structural steel platform. The lower cylinder head of the hoist is bolted to the platform at elevation 874.23, which is 4.93 feet above the maximum reservoir surface. An adjustable, chevron-type packing for the piston stem is provided in the lower cylinder head. Forces from the hoist are transferred through the lower cylinder head to the structural steel platform and thence to the concrete walls of the gate shaft. The upper cylinder head contains a piston-operated latch, which engages a button on top of the piston stem to hold the weight of the gate and stems in the open position. Three oil rings are used on the hoist piston. The piston stem is connected to the gate stem through four intermediate stems with an overall length of about 60 feet 9 inches.

A watertight concrete chamber, which is large enough to contain the bulkhead gate when raised to the open position, is located immediately above the tunnel on the upstream side of the gate shaft. A slot in the top of the concrete chamber allows the gate to be removed from its operating position in the chamber. The slot is normally made watertight by bolting a steel plate to a structural steel frame anchored in the concrete. The lower intermediate stem is made of stainless steel and operates through a watertight packing gland installed on the top of the steel plate.

The control equipment for operating the hoist is located on a steel platform at elevation 993.00 near the top of the gate shaft. The equipment is not encased in a cabinet, but is supported on a structural steel stand bolted to the platform. It consists of an oil tank, one high-pressure hand pump and one low-pressure hand pump, 4-way valves, relief valves, pressure gage, piping and appurtenances. A glass sight gage is installed on the side of the oil tank and acts as a gate position indicator. Oil piping along the side of the shaft connects the controls to the hoist cylinder.

(b) *Hoist Design.*--The hoist is designed to lift the dead weight of the gate, stems and piston, plus friction from the gate seats and seals, and downpull due to the unbalanced water pressure between the top and bottom of the gate. The cylinder is designed for a relief valve setting of 1,000 pounds per square inch, which will produce a gross lifting force of about 204,000 pounds. The hoist load with unbalanced water pressure on the gate leaf is estimated to be not more than 170,000 pounds, and a hoist cylinder pressure of from 300 to 830 pounds per square inch will be required to raise the leaf. With the water pressure on the gate leaf balanced, the hoist load will be about



LIST OF EQUIPMENT

ITEM	DESCRIPTION
Mtr.	Motor, 2HP, 1200 RPM, 440 volt. Vickers Group A1 or similar
PF	Pump, rotary positive displacement type, 2.05 GPM at 750 p.s.i. Vickers No. V-105-E or similar. Mark No. 213-14.
M	¾" 4-way valve, pilot operated, spring offset, closed center. Vickers No. C-440-58 or similar. Mark No. 213-15.
N	¼" 4-way pilot valve, solenoid operated, spring offset. Vickers No. GK-2502-115-AC-50 or similar. Mark 213-16.
P	¾" Sequence valve, directly operated. Vickers No. R-106-D-2-58 or similar. Mark 213-17
Q	¾" Relief valve. Vickers No. C-167-C or similar. Mark No. 213-18.
S1	¾" In-line check valve. Vickers No. DT 8P1-06-5 or similar. Mark No. 213-19.
S2	¼" In-line check valve. Vickers No. DT 8P1-02-5 or similar. Mark No. 213-20.
T	Pressure gage, 0-1500 p.s.i. Marsh type 100 or similar. Mark No. 213-26.
U	Hand pump, 1.5 cu. in. per cycle. Electrol No. 525 or similar. Mark No. 213-27.
K	1¼" Pilot operated check valve. Vickers No. 2C-112 B-X or similar. Mark No. 212-6.
V	1¼"-600# Angle valve. Crane No. 3625 X or similar. Mark No. 212-7.

ITEM	DESCRIPTION
W	¾" Bar stock angle valve. Crane No. 223½ H or similar. Mark No. 212-8.
X	1"-600# globe valve. Crane No. 3624-X or similar. Mark No. 212-9.
63-1	Pressure switch, S.P.S.T. circuit opens as pressure rises. Mercoid Type DA-23-125 or similar. Mark No. 213-24.
63-2	Pressure switch, S.P.S.T. circuit closes as pressure rises. Mercoid Type DA-23-3-125 or similar. Mark No. 213-25.
LS-1, LS-2	Limit switches in position indicator, actuated by gate travel. Allen-Bradley No. 6SJ24-4 or similar. Mark No. 166-11.
42 Q	Motor starter.
OX, CX, 20 QX	Auxiliary relays.
20 Q	Solenoid of 4-way pilot valve
CS	Control switch
CCA	Control board (Power plant)
TOL	Thermal overload relay
BV2X, BV1X	Auxiliary relays (interlock with butterfly valves), close only when butterfly valves are closed.

OPERATING INSTRUCTIONS

GENERAL:

1. Gate is normally opened, closed or stopped by operation of push buttons located on control cabinet in gate-control house. Gate may be closed in an emergency by operation of control switch (CS) located on main control board in power plant.
2. Position of gate is indicated both locally and in power plant by red and green lights. Red light on indicates gate is fully open. Green light on indicates gate is fully closed. Both lights on indicate gate is in some intermediate position.

OPENING CYCLE:

1. With gate closed and system at static pressure, press OPEN button. Relay OX is energized and seals in. Relay 42Q is energized through OX and starts oil pump motor. Solenoid 20Q is energized and seals in through OX, shifting four-way valve N. Pressure switch 63-2 closes at 200 psi, energizing relay 20 QX, which seals in through 63-2.
2. As pressure builds up, sequence valve P opens at 70 psi and gate begins to open at 500 to 600 psi, limit switch LS-2 closes and red lights come on.
3. As gate approaches fully open position, limit switch LS-1 N.O. closes control circuit and LS-1 N.C. opens green-light circuit. Green lights go out.
4. When piston rises against diaphragm, pressure builds up to 900 psi, opening pressure switch 63-1. OX drops out. 42 Q drops out. Motor stops. Solenoid 20 Q remains energized through relay 20 QX.
5. As gate settles on latches and pressure drops to 50 psi, pressure switch 63-2 opens. 20 QX drops out. 20Q is de-energized. Four-way valve N shifts to spring offset position, and opening cycle is completed.

REVERSING OPENING CYCLE:

1. With gate partly open, press CLOSE button or close control switch CS at power plant. Relay OX drops out. Since LS-1 N.O. in control circuit is open, relay CX will not be energized. 42Q drops out. Motor stops. Relay 20 QX drops out. Solenoid 20 Q is de-energized. Four-way valve N shifts to spring offset position.
2. Pressure is directed to pilot of four-way valve M. Valve M shifts. Pressure is directed through valves P and M to latch piston, which shifts and directs pressure to pilot of check valve K. Check valve K opens, allowing oil to by-pass from bottom to top of piston. Gate will close.

STOPPING GATE DURING OPENING CYCLE:

1. Press STOP button. Relay OX drops out. 42Q drops out. Motor stops. Solenoid 20Q remains energized through relay 20 QX and pressure switch 63-2. Gate stops and will remain in position except for leakage around piston and valve spools.

CLOSING CYCLE:

1. With gate open and system at static pressure, press CLOSE button or close control switch CS at power plant. Relay CX is energized and seals in. Relay 42Q is energized through CX and starts oil pump motor. As pressure builds up, four-way valve M shifts.

CLOSING CYCLE CONT'D:

2. At about 300 psi piston rises against diaphragm, pressure builds up to 550 psi and sequence valve P opens. Pressure is directed through valves P and M to latch piston. Latch piston shifts, latches open and pressure is directed to pilot of check valve K. Check valve K opens, allowing oil to by-pass from bottom to top of piston, and gate begins to close.
3. As gate closes slightly, limit switch LS-1 N.O. in control circuit opens. Relay CX drops out. 42 Q drops out. Motor stops. Also LS-1 N.C. in green light circuit closes and green lights go on. As gate approaches fully closed position, limit switch LS-2 opens. Red lights go out.
4. When gate is fully closed, pressure drops to static, and all valves return to spring offset position.

REVERSING CLOSING CYCLE:

1. With gate partly closed press OPEN button. Relay OX is energized and seals in. Relay 42 Q is energized through OX and starts motor. Solenoid 20 Q is energized, shifting four-way valve N.
2. Pressure switch 63-2 closes at 200 psi. Relay 20 QX closes and seals in. Pilot of four-way valve M is opened to drain. Valve M shifts to spring offset position. Latch piston is opened to drain and shifts to spring-offset position. Pilot of check valve K is opened to drain and check valve K closes. Oil is directed from pump to bottom of piston, and gate opens as described in OPENING CYCLE, 3 to 5 inc.

STOPPING GATE DURING CLOSING CYCLE:

1. Press STOP button. Solenoid 20 Q is energized and shifts four-way valve N. Pressure switch 63-2 closes at 200 psi. Relay 20 QX seals in through 63-2. Four-way valve M shifts to spring offset position. Latch piston shifts to spring offset position. Check valve K closes. Gate stops and will remain in position except for leakage around piston and valve spools.

INFORMATION:

1. In case pressure switch 63-1 should fail to stop motor at end of opening cycle, relief valve Q will open at 1,000 psi to prevent damage to the system.
2. Current failure when gate is being held in an intermediate position will cause gate to close; since four-way valve N will shift to spring offset position allowing pressure from under hoist piston to shift valve M and open check valve K.
3. To close gate during power failure, operate hand pump U to actuate system.
4. For cold weather operation, hoist and piping are heated by thermostatically controlled 440-volt heating cables.
5. Hoist requires about 35 minutes to open the gate and about 1½ minutes to close it.
6. An electrical interlock between hoist and butterfly valves in power plant prevents hoist from opening gate unless both butterfly valves are closed.

SERVICING INSTRUCTIONS

VALVE AND SWITCH SETTINGS:

1. Set sequence valve P to open at 550 psi; it will also open with 70 psi on remote connection.
2. Set relief valve Q to open at 1,000 psi.
3. Set pressure switch 63-1 to break at 900 psi and remake at 700 psi.
4. Set pressure switch 63-2 to make at 200 psi and break at 50 psi.
5. Adjust angle valve V so that gate will close in about 1½ minutes.
6. Close valves W and X.

PUMP AND MOTOR:

1. Follow manufacturer's recommendations for servicing pump and motor.
2. If noisy pump operation is encountered, clean oil filter by removing from tank, washing in kerosene, and blowing with air (from inside to out).

FILLING SYSTEM WITH OIL:

1. Start with gate in closed position. Fill tank to level indicated by sight gage with clean, light, hydraulic oil, similar to Texaco Regal Oil (R&O) Type AZ. Oil will run through drain line to top of cylinder. Add oil to tank as required during process of filling. Approximately 130 gallons of oil will be required to fill the system.
2. Press OPEN button. When pump motor has run for 5 to 10 minutes, press STOP button.
3. Open vent valve W, and press CLOSE button. After 5 minutes, close valve W.
4. Open and close gate, cracking vent valve W during closing cycle. Repeat until all air is vented from system.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
EKLUTNA PROJECT - ALASKA
PRESSURE TUNNEL-STA. 255+30
SURGE TANK
7.08'x 9' FIXED WHEEL GATE HOIST CONTROLS
OPERATING INSTRUCTIONS

DRAWN E.O.G.-G.M.G. SUBMITTED
TRACED E.M.W. RECOMMENDED
CHECKED LCJ APPROVED
DENVER, COLORADO, JULY 22, 1952
SHEET 1 OF 1
783-D-281

Figure 43.--List of equipment and operating and servicing instructions for surge tank fixed-wheel gate hoist controls.

12,000 pounds which will require a hoist pressure of about 60 pounds per square inch. It will require about 45 minutes to open the gate 1 foot for filling the tunnel by means of the high-pressure hand pump. The tunnel will fill in about 5 hours additional time through the 1-foot gate opening. The closing cycle operates by gravity.

(c) *Controls.*-- The controls (fig. 44) are manually operated by means of the hand pumps since electric power is not available at the tunnel gate shaft and the gate will be operated only to drain the tunnel at very infrequent intervals. The controls are designed to prevent the gate being opened more than 1 foot until the tunnel is filled with water in order to prevent damaging water discharges in the tunnel. A minimum oil pressure of 300 pounds per square inch is required under the piston to open the gate with unbalanced water pressures on the leaf. When the leaf has opened 1 foot, the piston uncovers a relief valve connection in the sidewall of the hoist cylinder, which limits the oil pressure under the piston to 150 pounds per square inch and prevents the leaf from opening further until the water pressure becomes balanced on the leaf. With balanced pressures on the leaf, an oil pressure of 60 pounds per square inch will open the gate and it can then be fully opened with the low-pressure pump. The controls are arranged so that power operation could be added in the future.

38. Penstock Tunnel. - The entire length of the penstock tunnel was excavated in weathered rock, except for a portion at the lower end where the tunnel section emerged to overburden material. In order to traverse this overburden material, which lay between the rock tunnel section and the pile-supported penstock anchor, it was necessary to design a special tunnel section (fig. 45). In effect, this reach of tunnel was designed as a length of conduit supported at one end by the tunnel rock and at the other end by a pile-supported bent.

39. 66-Inch Butterfly Valves. - (a) *Requirement.*-- Valves (fig. 46) installed in each of the two 51-inch penstock branches which provide water for the turbines, must serve as service valves by relieving the turbine wicket gates of penstock pressure during periods of shutdown, and must also be used for emergency closure in case of damage to or failure of the turbine gate operating mechanism. The valves must withstand a head of 1,165 feet (505 pounds per square inch) including water hammer for normal operation, and a head of 1,500 feet including water hammer under emergency conditions.

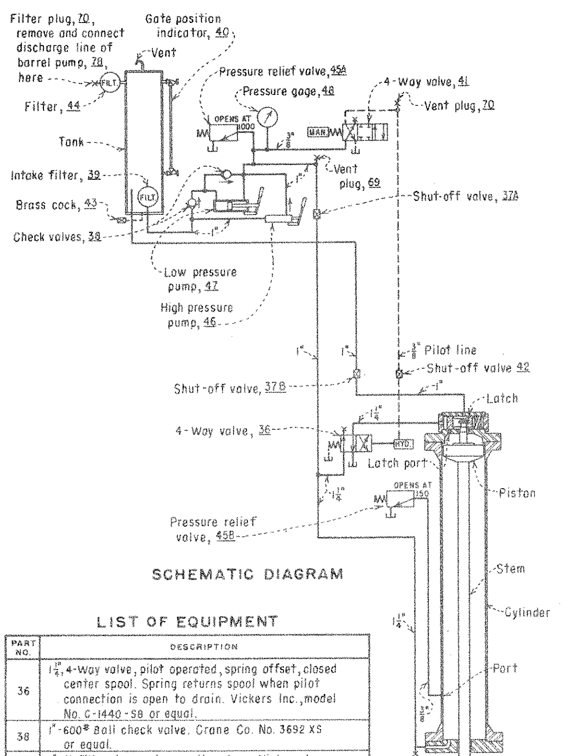
A 66-inch butterfuly valve installed in each penstock branch about 6 feet upstream from the turbine spiral case met all the above requirements.

(b) *General Description.*-- An expansion joint is provided at the downstream end of each valve to facilitate installation and alinement. The valves are rigidly bolted to the penstocks which carry the hydrostatic loads on the closed valves (fig. 47). The weight of the valves and the weight of the water in the valves is carried by the valve pedestals with provision for horizontal movement to take care of any expansion.

Each valve consists of a body, a leaf, and a hydraulic cylinder for opening and closing the valve. The leaf is provided with a nonadjustable bronze seal on its periphery, and the valve body is provided with a mating bronze seal. The body seal is adjustable from outside the valve and is designed for adjustment when the valve is closed and under pressure.

The leaf is mounted on a horizontal shaft which rotates 90° to open or close the valve with the bottom of the leaf moving in the direction of water flow when closing. The shaft is supported by bronze bushings in the valve body. Both ends of the shaft extend through the valve body and one end is provided with a crank for operating the leaf. Packing and glands are provided to seal the shaft at both ends.

A cylinder-piston type operating mechanism is mounted directly on each valve so that all operating forces are transmitted to the valve body. The crank on the end of the leaf shaft is connected to the piston in the operating cylinder by a self-lubricating link, crosshead, and stem mechanism. Leaf position indicators are provided on the crank ends of the leaf shafts. Pointers give visual local indication and limit switches operate red and green lights at the control cabinet for the valves and the main control board in the powerplant to show open and closed positions of the leaf.



SCHEMATIC DIAGRAM

LEGEND

———	Working line
– – – –	Pilot pressure
- - - - - -	Drain line
•	Junction of lines
⊥	Line to tank

LIST OF EQUIPMENT

PART NO.	DESCRIPTION
36	$1\frac{1}{4}$", 4-Way valve, pilot operated, spring offset, closed center spool. Spring returns spool when pilot connection is open to drain. Vickers Inc., model No. C-1440-58 or equal.
38	1"-600# Ball check valve. Crane Co. No. 3692 XS or equal.
39	1" oil filter, immersion suction type. Vickers Inc., part No. 17415 or equal.
41	$\frac{3}{8}$" 4-Way valve, lever operated, spring offset, closed center spool. Spring returns lever to "extreme in" position. Vickers Inc., model No. C-476-C-B or equal.
44	$\frac{3}{4}$" Filter, $\frac{7}{8}$" cartridge, 0.008" spacing, continuously cleanable, edge filtration type. Cuno Engineering Corp., specification sheet No. AK-120, type DS, or equal.
45	$\frac{1}{4}$" Pressure relief valve. Direct action, spring loaded type - adjustable pressure range of 75 to 3000 p.s.i. Vickers Inc., model No. C-175-F or equal.
46	Hand pump, $1\frac{1}{2}$ cubic inches displacement per cycle, 1500 p.s.i. operating pressure, suction and pressure check valves built in Electrol Inc., No. 525 or equal.
47	Hydraulic oil cylinder, 2" bore, $1\frac{3}{8}$" dia. piston rod, 1500 p.s.i. operating pressure, flange mounting, 6" stroke. Vickers Inc., model No. LA-1040-H-2"x 6" or equal.
48	Hydraulic pressure gage. 0 to 1500 p.s.i. range, $4\frac{1}{2}$" dial. J. F Marsh Corp., type 9, with plain cast iron case and plain ring, or equal.

NOTE:
For part numbers and Hoist Control Assembly, see drawing No. 783-D-64.

OPERATING INSTRUCTIONS

GENERAL:

The bulkhead gate is located near the intake end of the pressure tunnel and is used to unwater the tunnel.

The gate will be opened or closed by the hand operated, hydraulic hoist under balanced pressure only, except for the first foot of travel in the opening cycle. The 1-foot opening is provided to fill the tunnel slowly and eliminate large pressure surges.

OPENING CYCLE:

1. Pressure tunnel empty and gate closed.
2. Downstream end of tunnel closed at either surge tank or power plant.
3. Oil level in position indicator 40, placed at CLOSED mark by adding oil from barrel if necessary. Valve 37A open.
4. Operate high pressure pump 46, until gate opens 1-foot. It will require about 45 minutes to open gate 1-foot with pressure between 300 and 800 psi. Then piston will uncover opening to relief valve 45B and pressure will drop to 150 psi and remain constant. Oil above piston returns to tank through tank line. Rise of oil level in tank is proportional to stem displacement and indicates gate position. Friction and oil pressure under piston will hold gate in the 1-foot open position until tunnel fills in about 5 hours. Water pressure will be balanced on gate when tunnel is filled and oil pressure will drop to about 60 psi and remain there if hand pump is operated.
5. Operate low pressure pump 47, to complete opening of gate. Piston reaches end of travel in about 45 minutes and oil level in 40 will stand at OPEN position and pressure will rise to and remain constant at 150 psi. Stop pumping and as pressure drops, gate will settle on latch and be held in open position.

NOTE: If pressure tunnel is filled and gate closed, operate low pressure pump 47, and open gate without stopping at the 1-foot position. Gate will remain in any intermediate position except for oil leakage past hoist piston and valves.

CLOSING CYCLE:

1. Gate open.
2. Downstream end of tunnel closed at either surge tank or power plant.
3. Oil level in position indicator 40, placed at OPEN mark by adding oil from barrel if necessary. Valve 37A open.
4. Operate low pressure pump 47, until pressure rises to 150 psi. This will raise gate and release weight from latch.
5. Close shut-off valve 37A. Shift 4-way valve 41, and hold in shifted position. Operate high pressure pump 46 as necessary to maintain pressure gage reading at 200 psi or higher. This directs pressure to pilot of 4-way valve 36, which shifts and opens latch. As latch moves, latch port opens and permits oil to flow from bottom to top of hoist piston. Gate lowers by gravity. As gate closes oil required above piston is greater by volume of stem than quantity being forced from below. Extra oil is supplied from tank to top of piston by tank line and lowers level in tank to indicate gate position. When oil level reaches CLOSED position, release 4-way valve 41 and open shut-off valve 37A.

SERVICING INSTRUCTIONS

VALVE SETTINGS:

1. Pressure relief valve 45A located at tank, set to open at 1,000 psi.
2. Pressure relief valve 45B located at cylinder, set to open at 150 psi.
3. Shut-off valve 37A normally open, closed only as directed in closing cycle.
4. Shut-off valves 37B and 42, open.
5. Brass cock valve 43, closed.
6. Valves for gate position indicator 40, open.

FILLING SYTEM WITH OIL:

1. Approximately 145+55 gallons of clean, light hydraulic oil equal to Texaco Regal Oil (R and O) Type AZ, will be required. A drum of oil is to be left connected to 44 through 78.
2. With gate in closed position, pump oil into tank using barrel pump 78, keeping oil level in extreme lower end of gate position indicator 40. Oil will fill hoist cylinder and oil lines except for air pockets by gravity. Occasionally turn handle of filter 44, to clean filtering element while adding oil.
3. Loosen vent plug 69, and pump slowly with low pressure pump 47, until oil appears at vent. Repeat using high pressure pump 46. When air is released, stop pumping and tighten 69.
4. Loosen vent plug 70. Shift 4-way valve 41, and pump with 46 filling pilot line. When air is released, tighten 70 and release 41.
5. Pump with 47 until pressure remains steady at approximately 60 psi. Close valve 37A, shift 41 and hold while pumping with 46. When gage reads 250 psi, release 41 and open 37A. Adjust oil level in 40 to CLOSED position. Resume pumping with 47 until gate is fully open. Oil level should be at OPEN position. Pressure should remain constant at 150 psi if pumping is continued. Adjust setting of relief valve 45B at cylinder, if necessary.
6. Loosen pipe plug in 41, to release oil. When approximately 1-quart of oil has drained, pressure should drop to 0 psi, indicating gate is hanging on latch. Tighten pipe plug.
7. Close gate as directed in Paragraphs 4 and 5 of the CLOSING CYCLE.
8. When system is full with gate closed, oil level in 40 should be at CLOSED position. Adjust by adding oil through 44 or removing through brass cock 43.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
EKLUTNA PROJECT - ALASKA

PRESSURE TUNNEL-STA. 27+25
GATE SHAFT
7.08'x9' BULKHEAD GATE HOIST CONTROL
OPERATING INSTRUCTIONS

DRAWN J.A.D. SUBMITTED [signature]
TRACED E.M.W. RECOMMENDED [signature]
CHECKED [signature] APPROVED [signature] CHIEF DESIGNING ENGINEER
DENVER, COLORADO, AUG. 5, 1952 SHEET 1 OF 1 783-D-283
REV. 3-19-54

Figure 44. --List of equipment and operating and servicing instructions for gate shaft bulkhead gate hoist control.

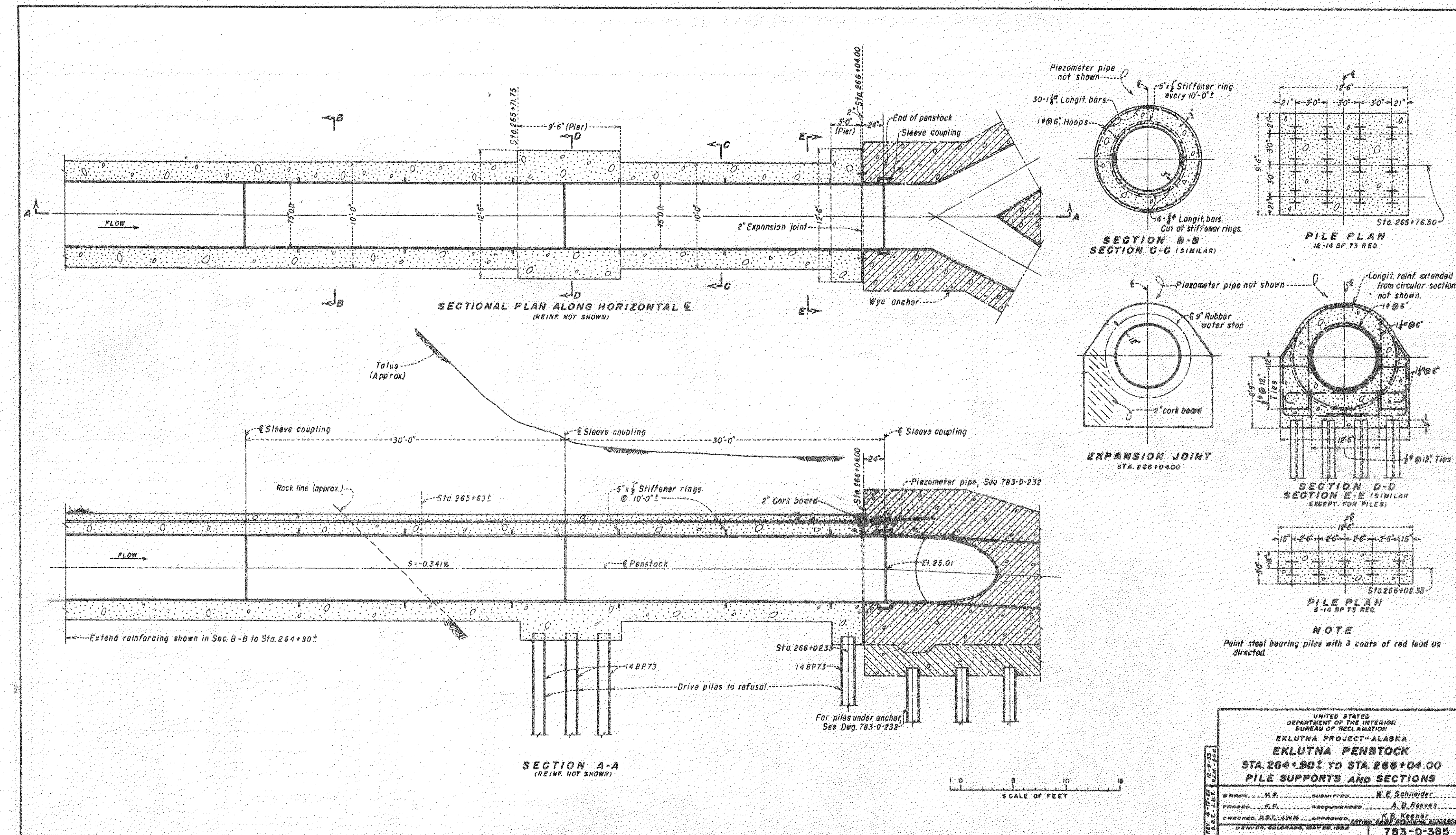


Figure 45.--Penstock, station 264+90± to station 266+04.00--Pile supports and sections.

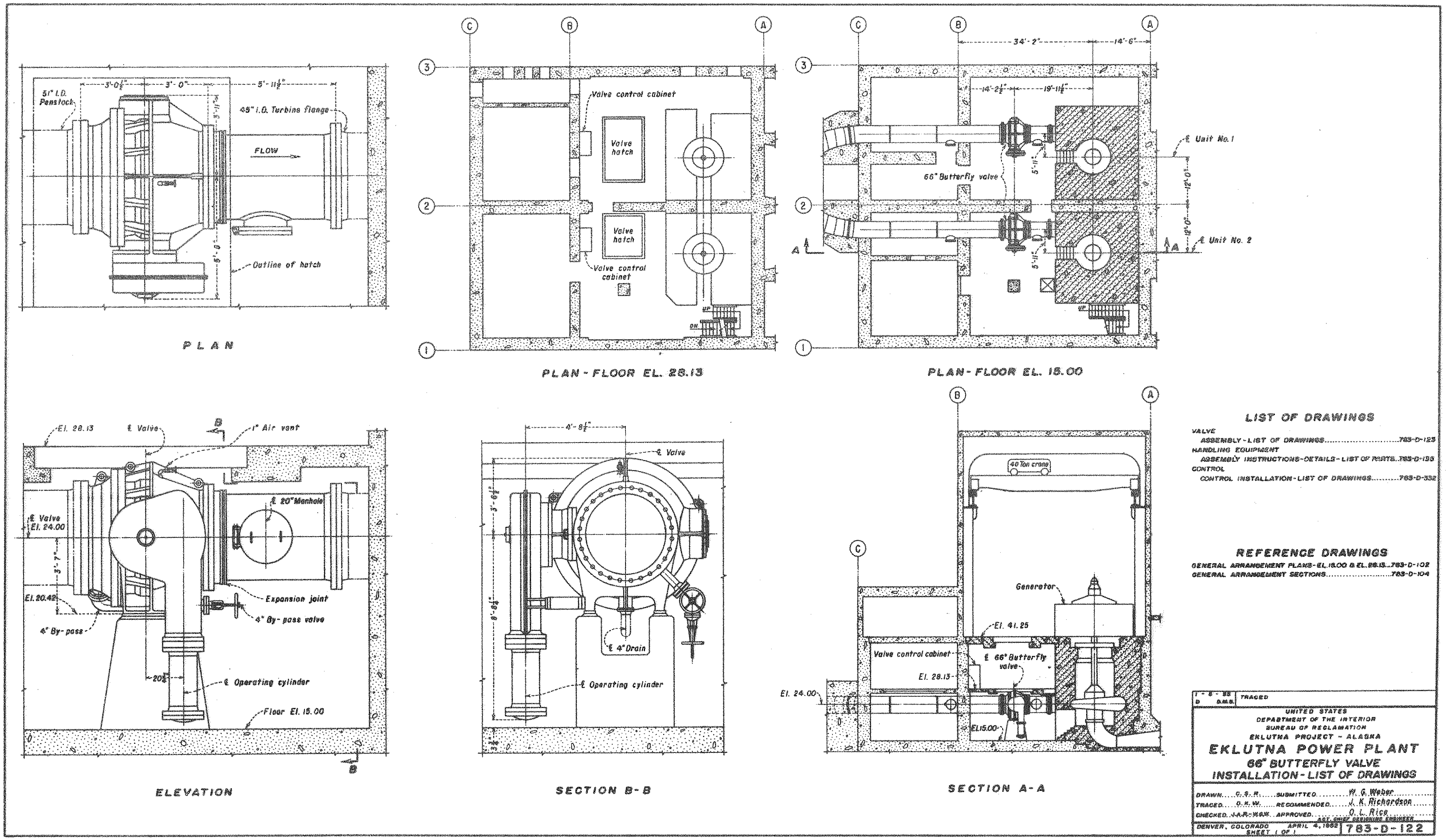


Figure 46.--Installation of 66-inch butterfly valve in powerplant.

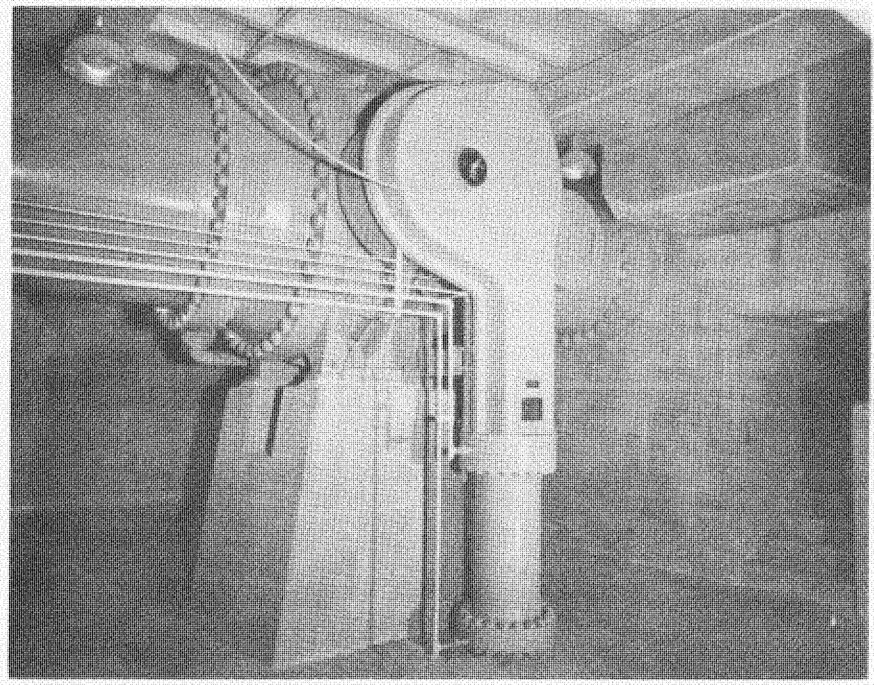


Figure 47.--Portion of penstock and butterfly valve installation. P783-908-1788, May 22, 1955.

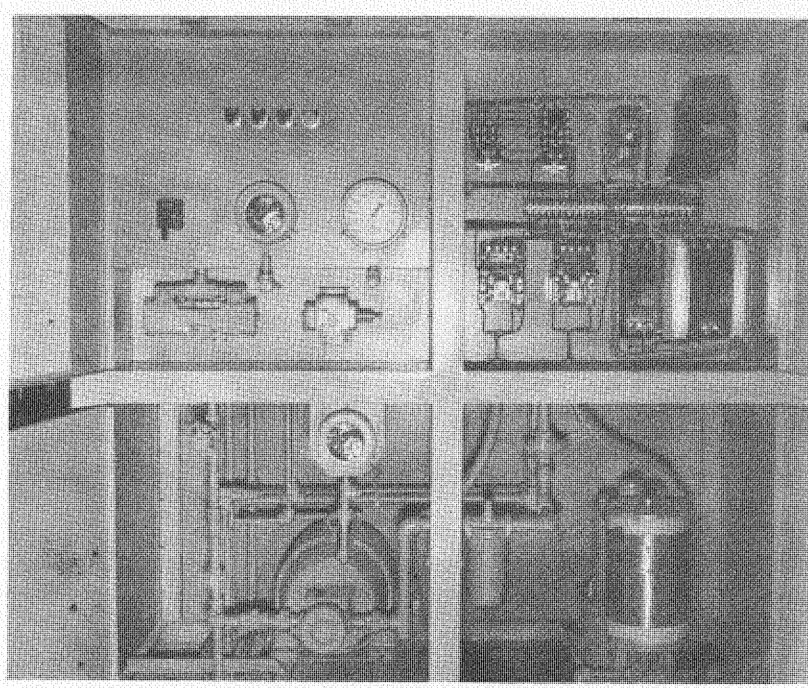


Figure 48.--Interior view of butterfly valve control cabinet. P783-908-1772, May 3, 1955.

A grease pump is provided for each valve which forces grease under high pressure to the leaf shaft bearings whenever the valve is operated. In addition, a push-button station is provided so that the grease pump can be operated independently of the valve for lubrication during long periods of nonoperation of the valve.

The valves are provided with 4-inch bypass pipes with suitable valves to fill the downstream portion of the valves and balance the pressure before opening the valves. A 4-inch drain and a 1-inch air vent are also provided in the downstream portion of each valve.

The controls for each valve are assembled in a cabinet located on the floor above the penstocks at elevation 28.13 (fig. 48). Each cabinet contains a complete set of hydraulic and electrical equipment for the control and operation of one valve. Push-buttons for opening, closing, and stopping the valve and for operating the grease pump are located at the control cabinet for each valve. A control switch for emergency closing of the valve is located on the main control board in the powerplant. A pressure switch is incorporated in the control circuit which prevents the valve being opened until the pressure is balanced on both sides of the valve.

(c) *Design.*--No special treatment of the valve supporting pedestal was required, as the axial thrust of the water on the valve is transferred to the penstock and thence into the penstock anchors, and the expansion joint between the valve and spiral case prevents temperature and misalinement stresses in the valve. Also, the valve operating cylinder is an integral part of the valve body.

The valves were designed for a normal operating pressure of 550 pounds per square inch, which includes water hammer. The valves were also designed for safe closure with a flow of 330 second-feet under a static head of 800 feet. Emergency conditions can produce a pressure of 650 pounds per square inch, including water hammer, and under such conditions the stress in any part of the valve will not exceed 67 percent of the yield point of the materials used.

The torque required to operate the valve leaf under normal conditions is 1,600,000 inch-pounds, which is equivalent to a pressure of approximately 535 pounds per square inch in the operating cylinder. The cylinder and connecting parts were designed for a maximum pressure of 1,000 pounds per square inch, which makes approximately 3,000,000 inch-pounds of torque available for unseating the valve leaf.

40. Turbine Draft Tube Bulkhead Gate. - (a) *Purpose and General Description.*--The purpose of the draft tube gate is to close off the end of the draft tube in the event it is necessary to unwater a unit for inspection and maintenance of either equipment or structure. A gate having nominal dimensions of 12 feet wide by 4 feet high is available for either of the two openings. The gate is lowered, raised, and transferred from one opening to the other by means of a 2-ton, hand-operated, twin-lift hoist, suspended from a jib crane attached to the wall of the powerhouse superstructure.

The gate is normally stored in the upper portion of the gate slots, immediately below the deck, where it is supported on both sides by latches so located that the gate is just below the cover plates and, therefore, easily accessible from the deck. The latches consist of hinged bars which will automatically engage the gate and may be "laid back" out of position during the lowering of the gate.

The gate is designed for lowering and raising only under conditions of no flow in the draft tube and balanced pressure on either side of the gate leaf; but, in case high-pressure penstock water is unintentionally admitted to the turbine and draft tube while the gate is in place, the gate will be blown from its seat due to the relatively few bolts fastening the shear angles to the gate. In order to equalize the pressure on each side of the gate, a pair of filling valves have been installed on the gate. The filling valves are an integral part of the lifting stem, so that by raising the lifting stem approximately 3 inches with the hand-operated hoist, the valves will be in an open position. After allowing sufficient time to elapse for filling the draft tube (about 4.5 minutes at minimum tailwater or about 2 minutes at maximum tailwater), the gate may be raised and stored.

(b) *Design.*-- The gate is of welded construction and is fabricated of structural steel beams and a steel face plate. The water load is transferred to the structure through a brass-to-brass contact of the gate side seat bearing against the embedded frames, and sealing is obtained by a continuous music-note type of molded rubber seal, installed around the gate. Water pressure compresses the side and top seal against the brass seats, and the weight of the gate compresses the bottom seal against the embedded steel sill. The gate is equipped with leaf springs, which, by contacting the guides, provide initial seating before the water pressure is introduced. This initial seating prevents "banging" from suddenly applied pressure. The guides are offset in such a manner that the gate seats only during the last 1 foot of lowering, thus protecting the rubber seals from drag.

Vertical guide angles installed on anchor bolts are embedded in blockouts in the powerplant substructure, and guide the gate to a seated position. The gate frame consists of two vertical side seats, a horizontal top seal seat, and a plate steel sill, the side and top seats having brass bars riveted to steel framing members. The entire frame was installed in blockouts and on anchor bolts for proper alinement, after which it was concreted in place.

Maximum stresses were calculated on the basis of a dry draft tube and maximum tailwater surface. Under this condition, the combined stress of the face plate and beams was permitted to reach 24,000 pounds per square inch. Other stresses conformed to the American Institute of Steel Construction requirements.

41. Tailrace. - The pressurized tailrace conduit (figs. 21, 49, and 50) is approximately 200 feet in length. The velocity of flow at the conduit entrance is 5.38 feet per second for a flow of 640 second-feet, and the velocity at the outlet headwall is 3.25 feet per second for the same rate of flow.

The shape of the structure was proportioned to minimize hydraulic loss in the tailrace (fig. 51). In studying the hydraulics for the tailrace design, the following tailwater elevations were used:

	Elevation
Minimum (two units operating)	21.00
Minimum (one unit operating)	20.00
Minimum	18.00
Maximum	35.00

Structural design of the conduit was based on the following loads and stresses:

Unit weight of dry earth	--100 pounds per cubic foot.
Unit weight of wet earth	--120 pounds per cubic foot.
Unit weight of concrete	--150 pounds per cubic foot.
Horizontal pressure from dryfill	-- 30 pounds per square foot.
Horizontal pressure from wetfill	-- 80 pounds per square foot.
Amount of dead load (earth and concrete)	--2,425 pounds per square foot.
Live load, type H20-S16-44	-- 65 pounds per square foot.
Ground water level	--Elevation 27.0.
Foundation material	--Sand and gravel.

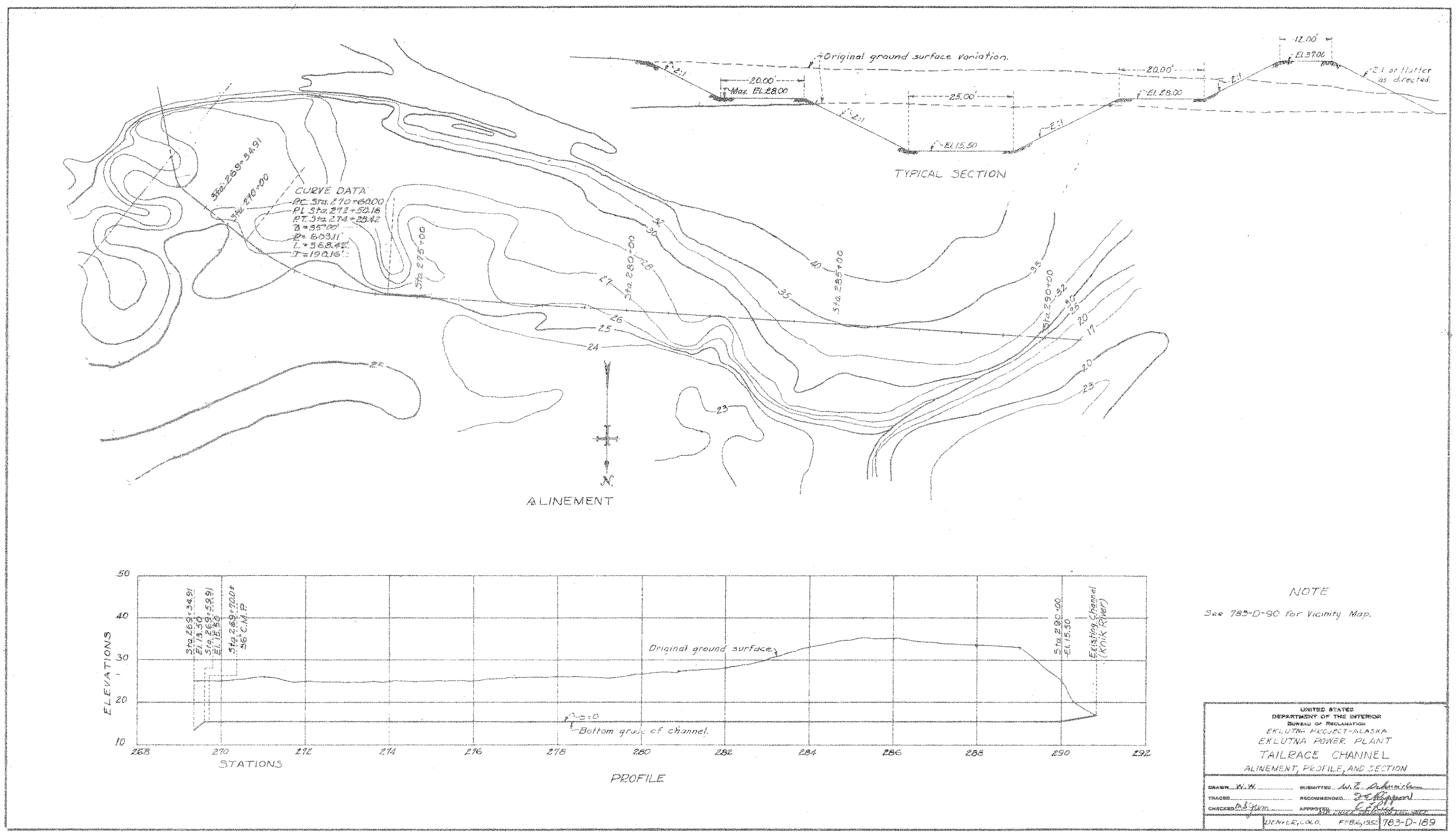


Figure 49.--Alinement, profile, and sections of tailrace channel.

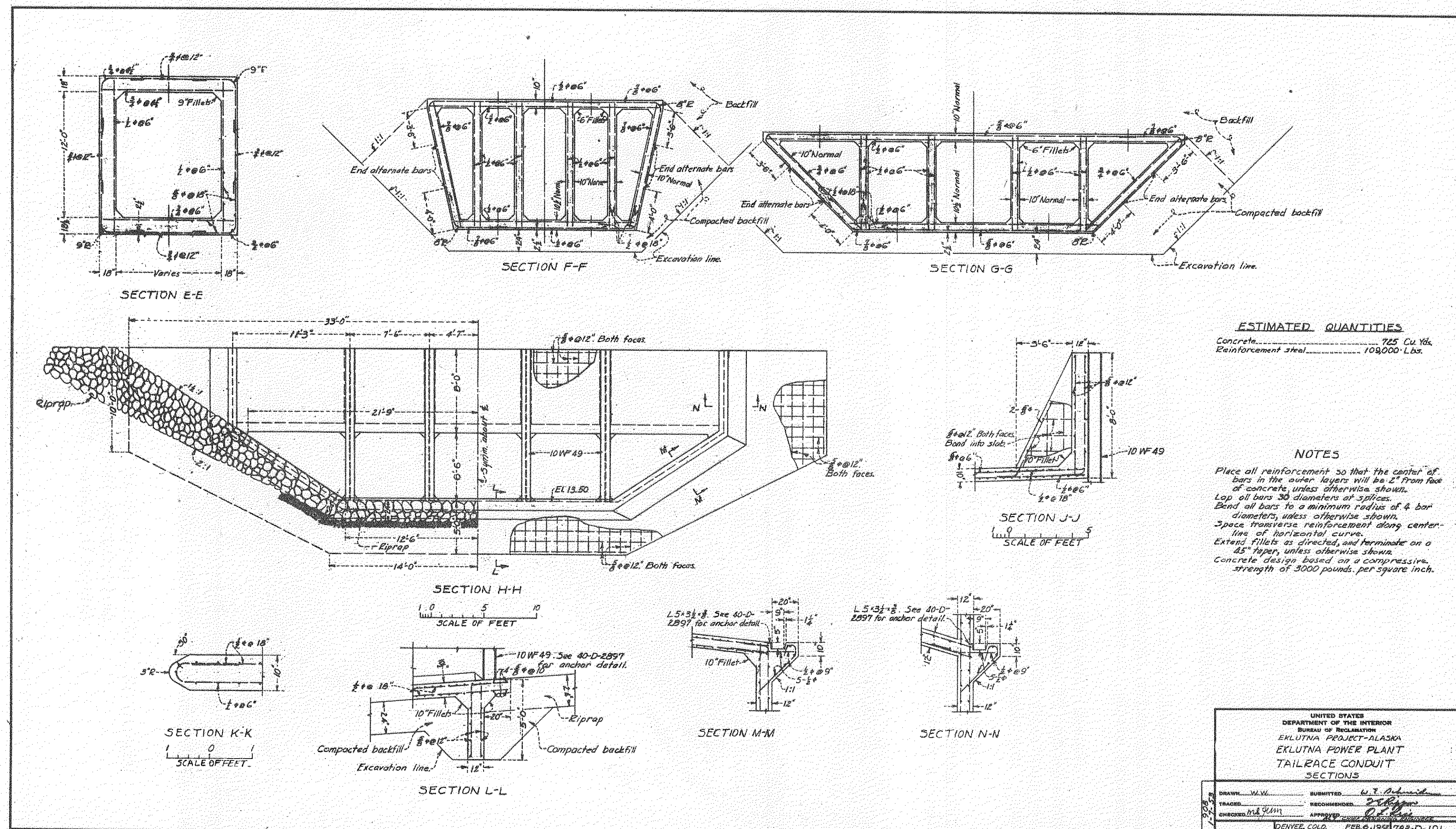


Figure 50.--Sections of tailrace conduit.

Allowable stresses:

	Pounds per square inch
Compressive strength of concrete	3,000
Unit shear stress	90
Unit bond stress	300
Tensile strength of reinforcement steel (bending or combined)	24,000

Consideration was given to supporting the tailrace conduit on piling, but because of the extra expense involved, as well as the favorable indications derived from settlement study, it was decided to place the structure on a compacted gravel blanket.

Annual flooding in the tailrace outlet area was considered in the final design. Heavy riprap (24 inches) was specified around the structure outlet and was also extended partially down the channel. Immediately adjacent to the outlet of the tailrace conduit, the channel walls were brought to a 1-1/2 to 1 slope with riprap.

Based upon the available history of tides and flows in the Knik River, the bottom grade of the tailrace channel was set at elevation 15.5 to meet conditions expected to prevail in the channel area in future years.

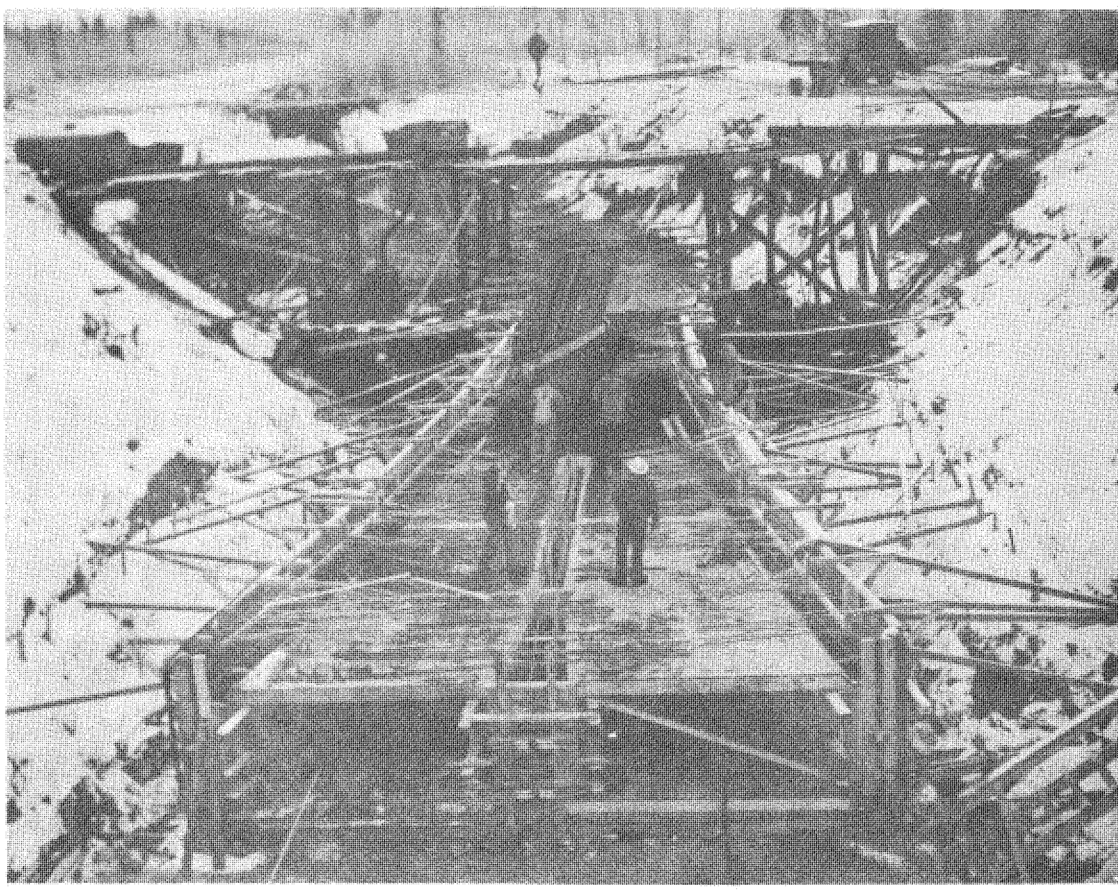


Figure 51.--View north from Palmer-Anchorage highway, showing powerhouse footings and tailrace conduit tunnel with forms in place. P783-908-1129, October 25, 1952.

CHAPTER VI --*Design*-- POWERPLANT

42. General. - The powerplant is divided into three main structures: the powerhouse containing the generating units and accessories, the machine shop located at the northwest corner of the powerhouse, and the transformer structure located at the southwest corner of the powerhouse (fig. 52).

The powerplant structure is of reinforced concrete throughout except for the superstructures of the powerhouse and the machine shop which are of structural steel framing with reinforced concrete slabs, walls, and roofs.

A. General Description

43. Architecture. - The exterior walls are plain concrete and devoid of window openings because of the extremely cold weather conditions. The interior walls of the generator room, control room, electrical equipment room, and machine shop are lined with 2 inches of cork to relieve the possibility of condensation on the interior faces of exterior walls; however, a concrete wainscoat 5 feet high is provided in the generator room and the machine shop. The floors of the foregoing rooms, except the control room, have a bonded concrete finish. The finish floor of the control room consists of rubber tile with a rubber cove base, while the ceiling is of suspended acoustical material. Ceilings, otherwise, consist of the exposed structural system.

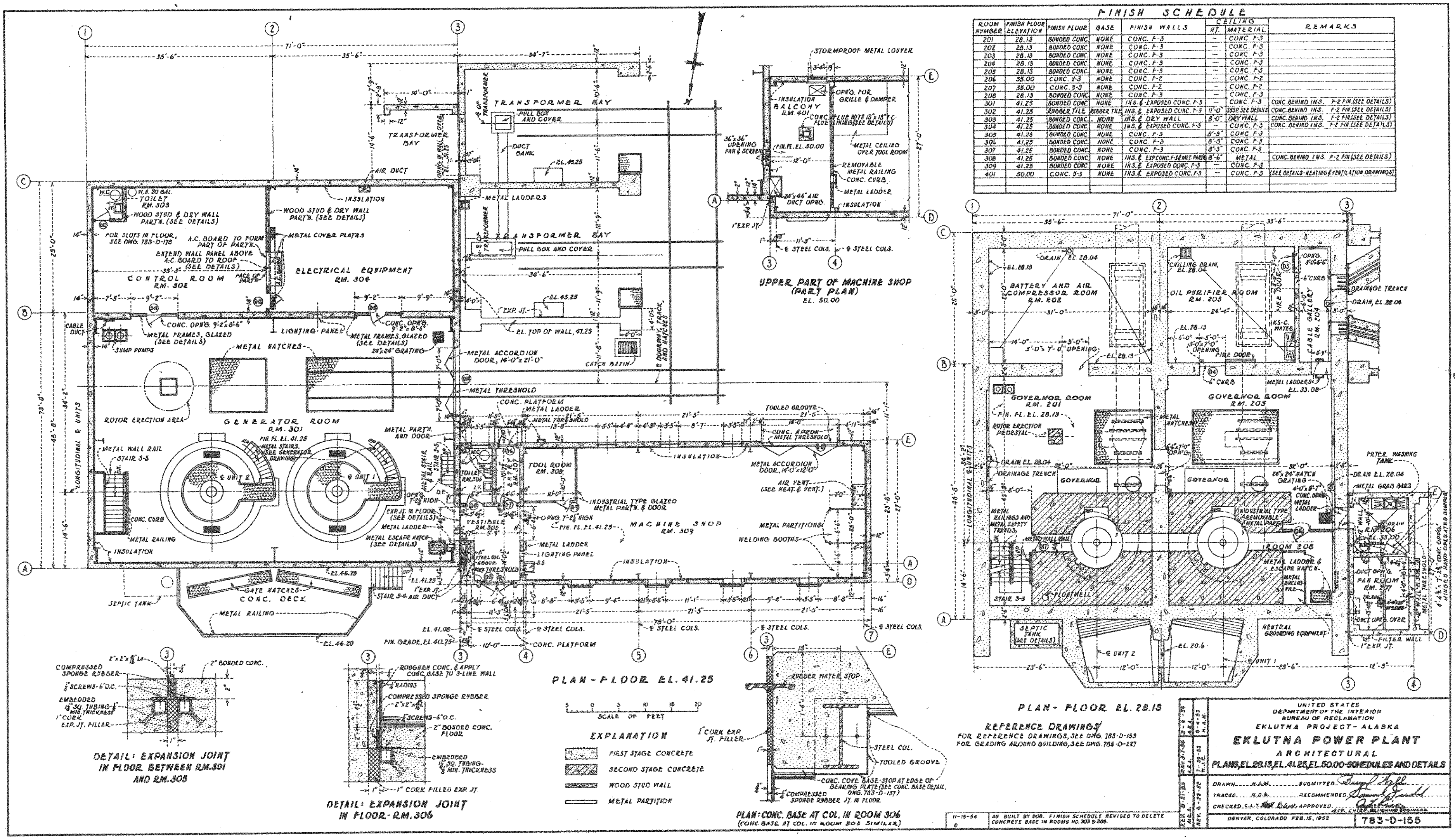
A protective metal railing surrounds the switchyard structures located on the powerplant roof. Access to the roof is by means of metal stairs located on the west wall of the powerplant.

44. Powerplant Layout. - The powerplant is divided into three main structures: the powerhouse containing the generating units and accessories, the machine shop, and the transformer structure. Each of these structures is arranged to perform a functional part of the generation of electric power. They are separated physically from each other by 1-inch expansion joints because of size, foundation requirements, and ease of construction. The conventional indoor-type installation was used because of the intemperate winter conditions at the site and the possibility of snow or rock slides from the mountain at the rear of the plant.

(a) *Powerhouse.*--The two generating units and accessories are housed in a structure 71 feet long and 80 feet 8 inches wide. The generator size essentially established the spacing between units, and the width of the high section was established by the generator size and the space requirements for handling the butterfly valves. The height of the building from the generator floor was determined by the handling requirements of the rotor and shaft and the untanking of the transformers by the powerhouse crane. The depth of the building from the generator floor to the base slab was determined by the turbine, minimum tailwater surface, and headroom requirements in accessory rooms. The low section of the powerhouse for housing of the accessory equipment was located on the upstream side of the generating units to satisfy the foundation requirements and for a central location of the equipment (fig. 53).

A longitudinal section and a transverse section through the centerline of units is shown on figure 54. On the roofs are shown the switchyard equipment, consisting of the power circuit breakers, disconnecting switches, main buses, and lightning arrestors. Access to the roof is provided by structural steel stairs partially indoors and partially outdoors. These stairs are used also for access to the powerhouse crane.

The generator floor covers the main part of the building, with the floor level at elevation 41.25 as shown on figure 55. At each unit, a hatch is located directly over the butterfly valve to provide access to the powerhouse crane. At the east end of the generator room, rotor erection, stairs, and sump pump areas are provided. The gate deck is on the outside and downstream from the generators. This deck provides a working area for lowering the bulkhead gate to the discharge mouth of the turbine draft tube. Also, the chamber underneath the gate deck acts as a surge chamber for the tailrace conduit. Immediately upstream from the generator room are the control and the electrical equipment



FINISH SCHEDULE

ROOM NUMBER	FINISH FLOOR ELEVATION	FINISH FLOOR	BASE	FINISH WALLS	CEILING HT.	CEILING MATERIAL	REMARKS
201	28.13	BONDED CONC.	NONE	CONC. F-3	—	CONC. F-3	
202	28.13	BONDED CONC.	NONE	CONC. F-3	—	CONC. F-3	
203	28.13	BONDED CONC.	NONE	CONC. F-3	—	CONC. F-3	
204	28.13	BONDED CONC.	NONE	CONC. F-3	—	CONC. F-3	
205	28.13	BONDED CONC.	NONE	CONC. F-3	—	CONC. F-3	
206	33.00	CONC. U-3	NONE	CONC. F-2	—	CONC. F-2	
207	33.00	CONC. U-3	NONE	CONC. F-2	—	CONC. F-2	
208	28.13	BONDED CONC.	NONE	CONC. F-3	—	CONC. F-3	
301	41.25	BONDED CONC.	NONE	INS. & EXPOSED CONC. F-3	—	CONC. F-3	CONC. BEHIND INS. F-2 FIN. (SEE DETAILS)
302	41.25	RUBBER TILE	RUBBER TILE	INS. & EXPOSED CONC. F-3	11'-0"	SUSP. SEE DETAILS	CONC. BEHIND INS. F-2 FIN. (SEE DETAILS)
303	41.25	BONDED CONC.	NONE	INS. & DRY WALL	8'-0"	DRY WALL	CONC. BEHIND INS. F-2 FIN. (SEE DETAILS)
304	41.25	BONDED CONC.	NONE	INS. & EXPOSED CONC. F-3	—	CONC. F-3	CONC. BEHIND INS. F-2 FIN. (SEE DETAILS)
305	41.25	BONDED CONC.	NONE	CONC. F-3	8'-3"	CONC. F-3	
306	41.25	BONDED CONC.	NONE	CONC. F-3	8'-3"	CONC. F-3	
307	41.25	BONDED CONC.	NONE	CONC. F-3	8'-3"	CONC. F-3	
308	41.25	BONDED CONC.	NONE	INS. & EXP. CONC. F-3 & MET. PARTN.	8'-6"	METAL	CONC. BEHIND INS. F-2 FIN. (SEE DETAILS)
309	41.25	BONDED CONC.	NONE	INS. & EXPOSED CONC. F-3	—	CONC. F-3	
401	50.00	CONC. U-3	NONE	INS. & EXPOSED CONC. F-3	—	CONC. F-3	(SEE DETAILS - HEATING & VENTILATION DRAWINGS)

Figure 52. --Architectural plans for powerplant at elevations 28.13, 41.25 and 50.00.

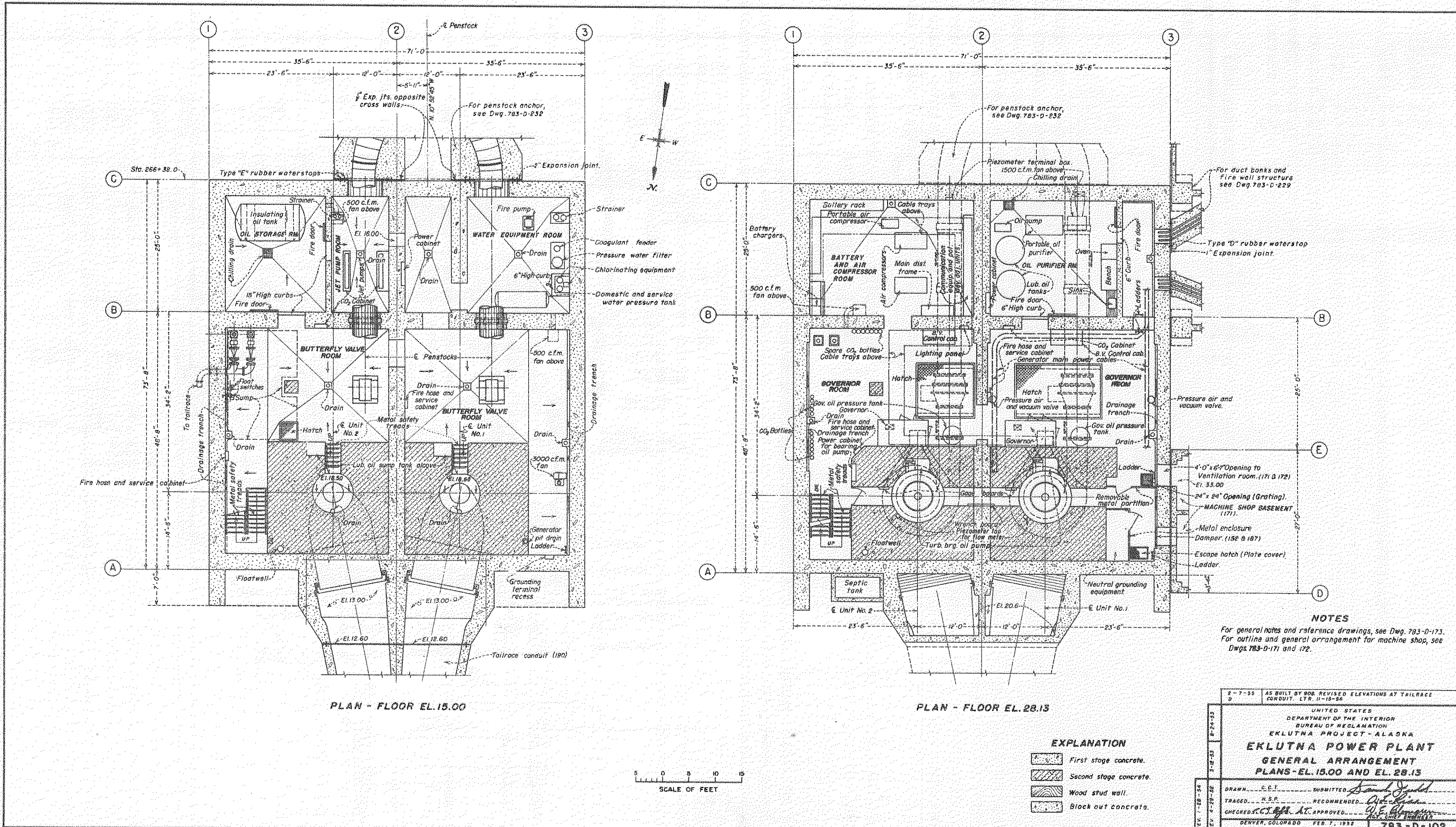


Figure 53. --General arrangement of powerplant at elevations 15.00 and 28.13.

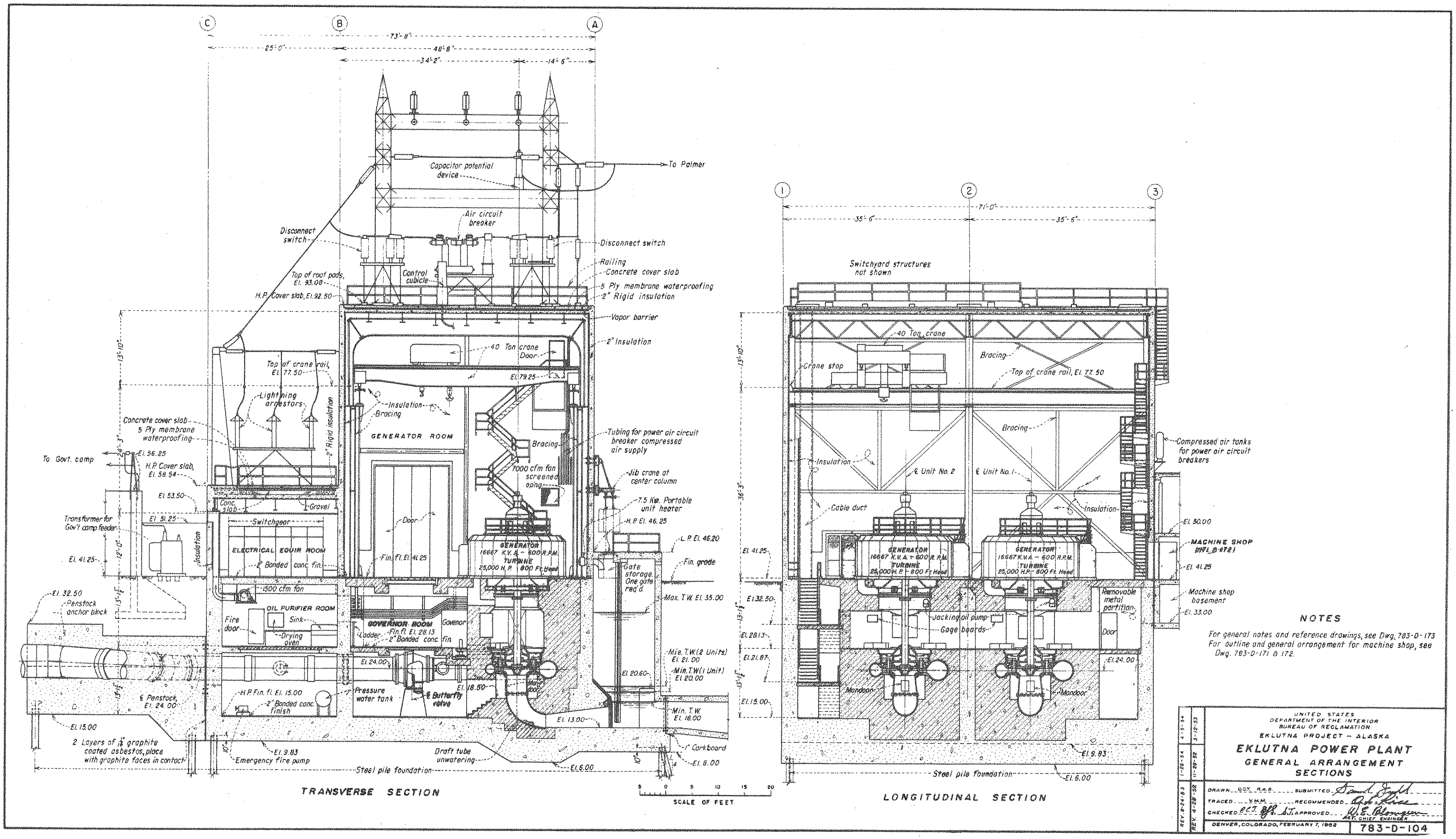


Figure 54. --General arrangement and sections of powerplant.

rooms. The control room contains the main control board, alternating-current board, recording board, and toilet. Provisions were made in the structural concrete framing under the main control board and recording board for future additions to the boards. The electrical equipment room contains the switchgear, lighting transformer, station-service transformers, and disconnect switches.

At the governor room floor level at elevation 28.13 are located the governor rooms, the battery and air compressor room, oil purifier room, and a generator lead room (fig. 53). The governor rooms as indicated previously are wide enough to provide access hatches to the butterfly valves. The governor rooms accommodate the governors, governor oil pressure tanks, butterfly valve control cabinets, generator main power cables, neutral grounding equipment, fire protection equipment and controls, and stairs. The turbine access galleries also act as a plenum chamber for the ventilation of the generators. The battery and air compressor room accommodate the batteries, battery charger, communications, main distribution frame, and air compressors. This room is also used as the cable spreading room for the control room above. The oil purifier room accommodates lubricating oil tanks, portable oil purifier, oil pump, work bench, sink, and oven. This room has automatic fire doors and 6-inch-high curbs under the doors to contain any inflammable materials and prevent them from entering the governor room. Separated from this room by a concrete wall is the room containing the generator main power leads going to the switchgear and then from the switchgear to the transformers.

At elevation 15.00 are located the butterfly valve rooms, oil storage room, jet pump room, and water equipment room (fig. 53). The butterfly valve rooms provide space for the butterfly valves, access to the draft tubes, sump pump controls, stairs, and ventilation equipment. The transformer oil storage room is enclosed by fire doors and 15-inch-high curbs so that the room may be isolated in case of fire. The jet pump room accommodates the jet pumps for the cooling water supply for turbine packing boxes, unit bearings, and generator air coolers. The water equipment room accommodates the fire pump, strainer, coagulant feeder, pressure water filter, chlorinating equipment, and domestic and service water tank.

(b) *Machine Shop.*-- Adjacent to the west wall of the powerhouse is a machine shop 78 feet long, 27 feet wide, and 20 feet high (fig. 56). The machine shop is equipped with tools of such type as to allow performing work covering general maintenance and repair service of the mechanical, hydraulic, and electrical equipment. Extensive repairs on large machine parts requiring the use of larger and heavier machines must be done elsewhere. In addition, the shop houses the heating and ventilating equipment for the powerhouse and the compressed air system for the roof-mounted air circuit breakers. The main entrance to the powerhouse, and the lobby, toilet, tool rooms, and machine shop are at elevation 41.25. At the floor elevation 33.00 are the fan and the air filter room for supplying cooling air to the generators. This air after passing through the generators is used as the principal means of heating the powerplant. On the balcony at floor elevation 50.00 are located the compressed air system for the air circuit breakers and two direct-oil-fired heater units and accessories to furnish heat to the building in the event of generator shutdown.

(c) *Transformer Structure.*-- The main power transformers that "step up" the generator low voltage are located in the transformer structure adjacent to and southwest of the powerhouse at elevation 41.25. Protective walls for the transformers were placed on the south side of the structure to protect the transformers from snow and rock slides. Fire walls are provided between the transformers, which also serve as foundations for the takeoff structures carrying the power lines to the switchyard on the powerhouse roof. The transformer area is provided with trackage to permit untanking of the transformer within the powerhouse. The arrangement of the transformer structure is shown on figure 55.

45. Foundation Conditions. - The powerplant site is underlain by glaciofluvial material which was deposited from the outwash of early space advances of the Matanuska and St. George glaciers. The bedrock is 60 to 90 feet below the surface and is overlain by heterogeneous layers of silt, sand, boulders, clay, and about 6 feet of muskeg at the surface. The water table is a few feet below the surface. The graywacke bedrock was extremely fractured and contained numerous fault seams filled with gouge.

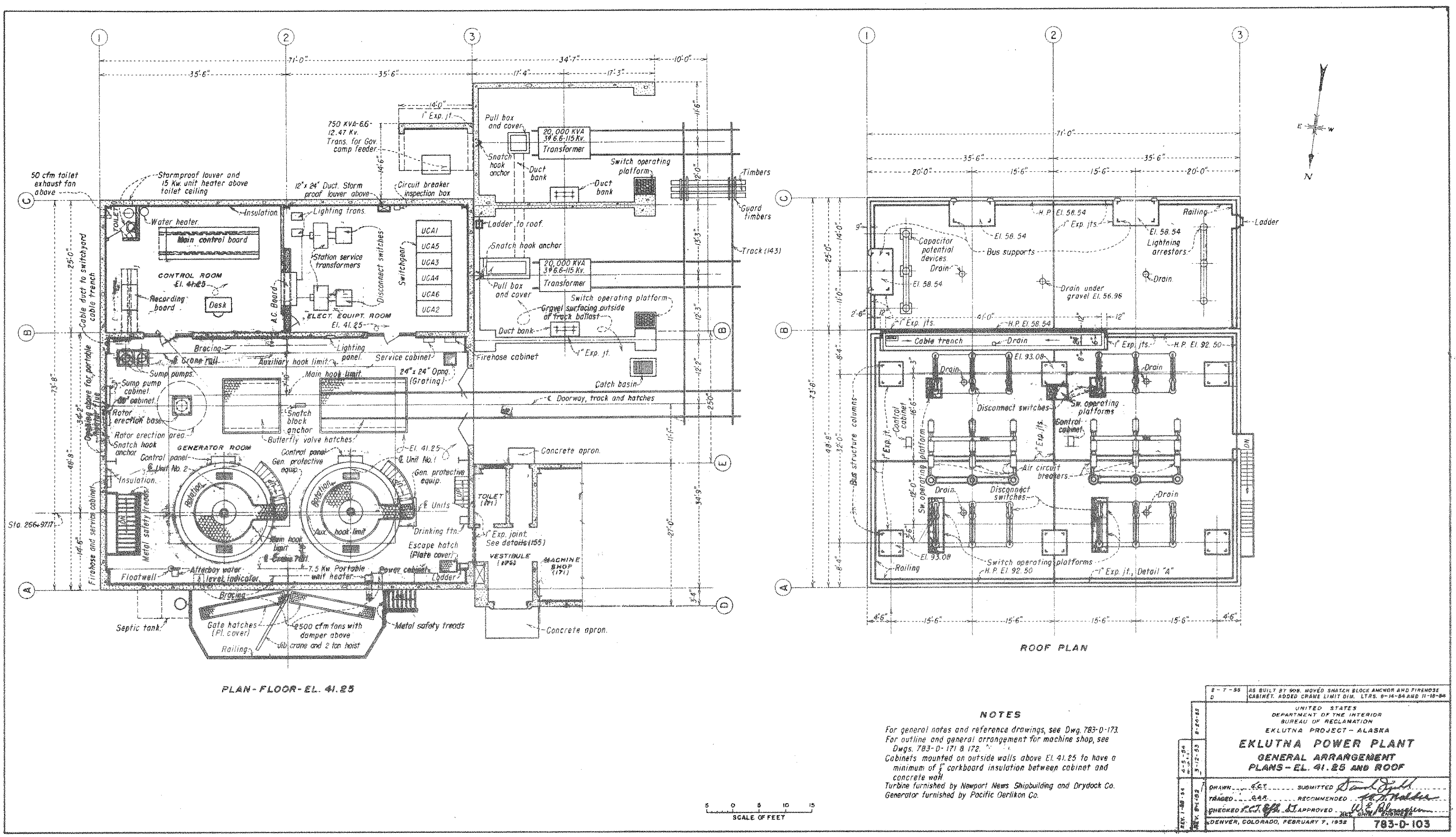


Figure 55. --Powerplant general arrangement--Plans at elevation 41.25 and at roof.

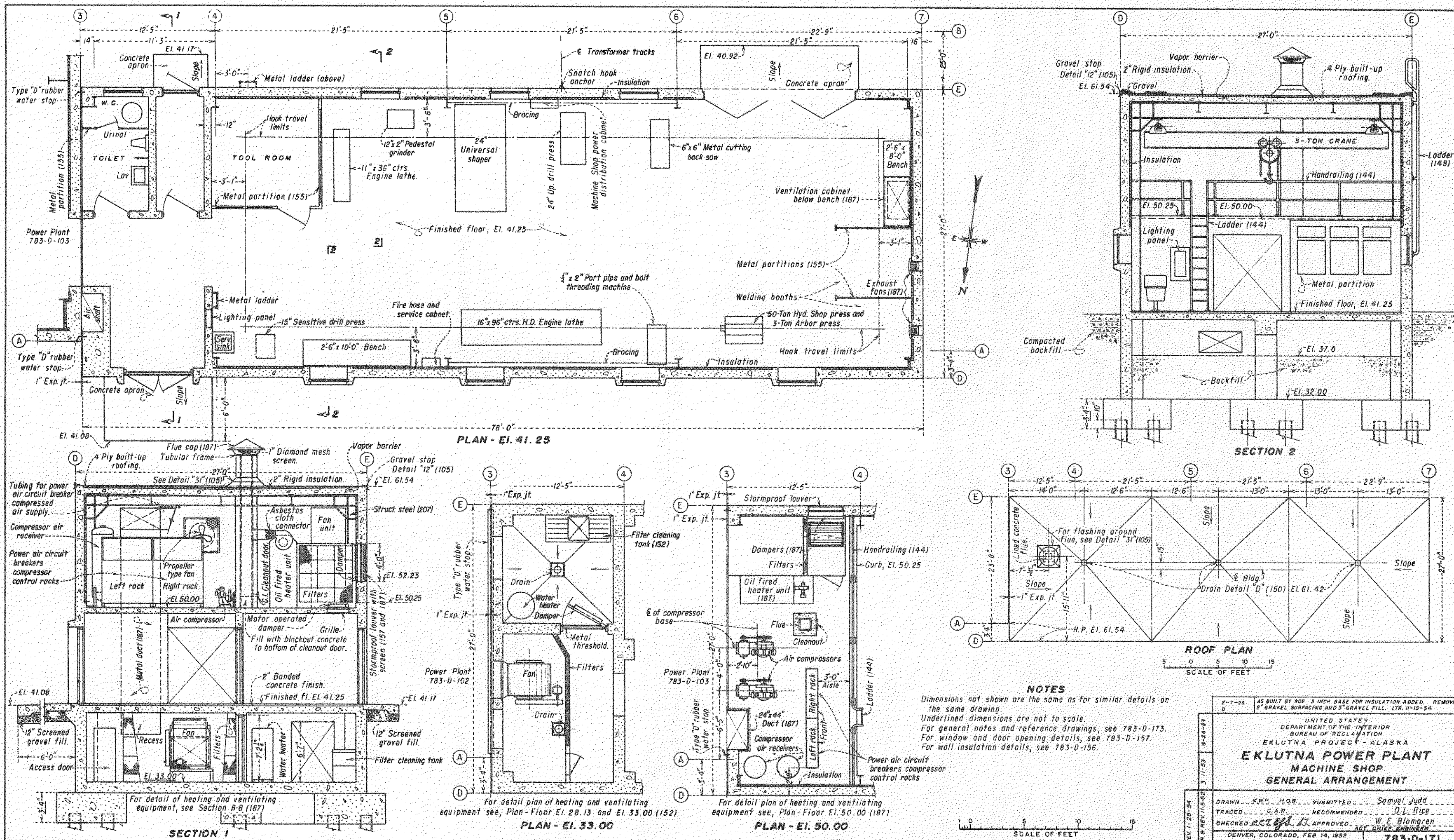


Figure 56. --General arrangement of powerplant machine shop.

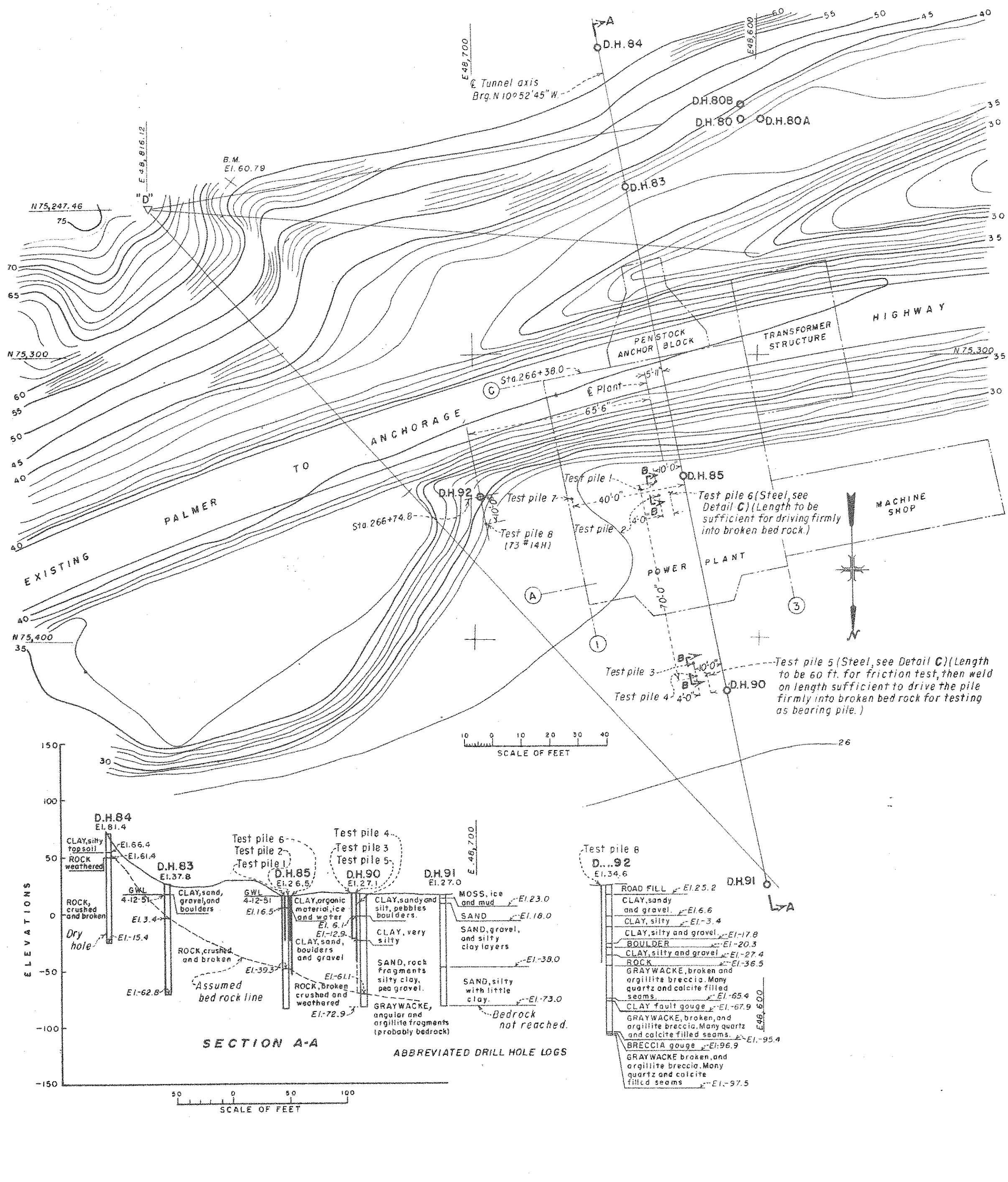
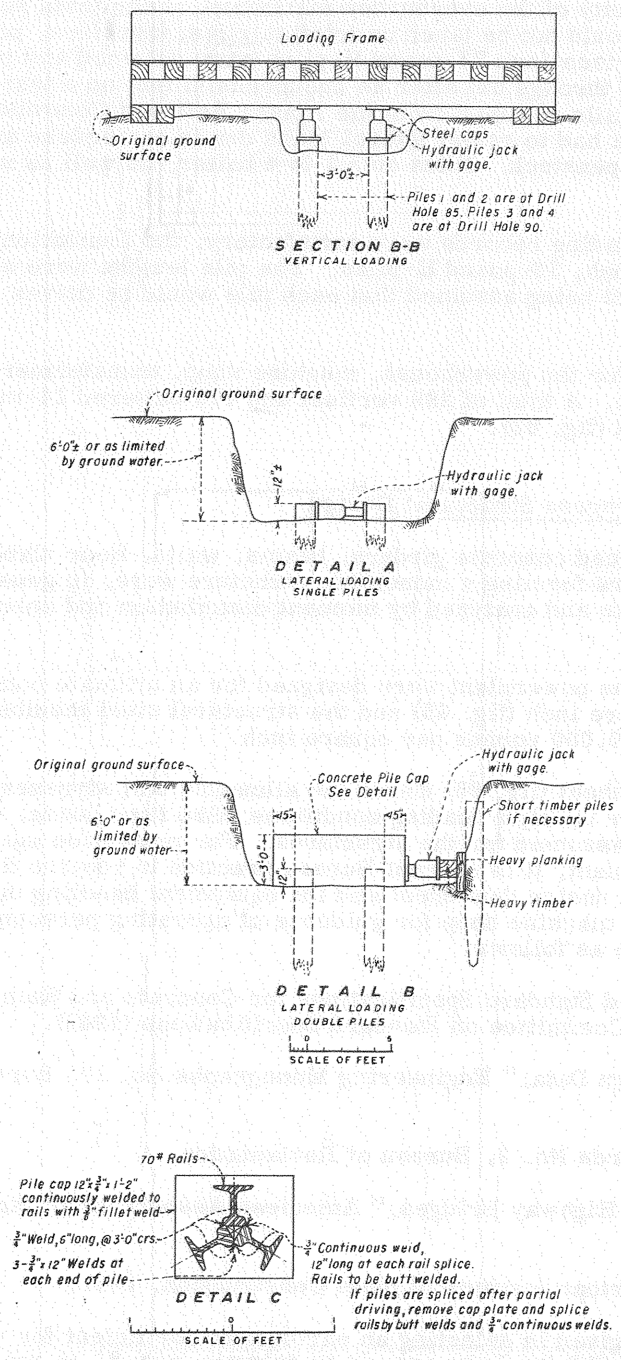


Figure 57. --Logs of drill holes and pile testing data for powerplant foundation. (Sheet 1 of 2.) From drawing 783-D-43.



NOTES

Water jetting may be used only if required with the following stipulations:

Piles 1,2,3,4, and 5-stop jetting at such a distance before required penetration is reached that driving to full penetration produces a minimum safe bearing value of 30 tons for piles 1,2,3 and 4 (wood piles) and 50 tons for pile 5 (steel friction pile) as determined by the pile equations below. *

Piles 6 and 8-Jet only the minimum required to make it possible to drive the pile firmly into broken bed rock.

Piles 1, 2, 3 and 4 are to act as friction piles. Pile 5 is to act as a friction pile and bearing pile, see note and location of pile. Piles 6 and 8 are to act as bearing piles and must therefore be driven firmly into broken bed rock.

$P = \frac{2WH}{S+1.0}$ for gravity hammers,

$P = \frac{2WH}{S+0.1}$ for single acting steam or air hammers,

$P = \frac{2H(W+AP)}{S+0.1}$ for double acting steam or air hammers,

where

P = bearing power in pounds,
W = weight in pounds of striking parts of hammer,
H = fall in feet,
A = area of piston in square inches,
P = steam or air pressure in pounds per square inch at the hammer,
S = average penetration in inches per blow for the last 5 to 10 blows for gravity hammers and the last 10 to 20 blows for steam or air hammers.

Metal shoes should be provided for all timber piles.

The tests of these piles are to be made according to the method specified by the American Society of Testing Materials "Tentative Method of Test to Determine the Load-Settlement Relationship for Individual Piles A.S.T.M. Designation: D1143-50T

The timber piles are to conform to class A piles of the "Federal Specifications", MM-P-371, March 31, 1947 with diameters as follows: butt end 14" minimum diameter, 18" maximum diameter, tip end 9" minimum diameter. In these tests, the piles should be as uniform and as alike as possible, and driven to a penetration of 40 feet except pile No. 7. See below.

All piles to be tested to twice the safe bearing load given above and then to failure if practicable.

Lateral tests as described below will be ordered later pending the results of the vertical tests.

After the vertical load tests, as indicated in Section B-B, have been completed, excavate the ground around the piles as shown in Detail A and test for horizontal load and movement by placing the hydraulic jack between the piles. Apply the loads in increments of 2.5 tons to a maximum of 10 tons.

After this test retamp the soil around the piles to as close to the original state as possible. Then place a concrete cap over the pile ends and test for horizontal load and movement as indicated in Detail B. Apply the load in increments of 5 tons until a load of 30 tons is reached or failure. Test procedures horizontally should be the same as specified for vertical testing, except that the load should be returned to zero for each increased load increment. The horizontal recovery of the piles should be measured each time.

Any possible twisting of the pile cap should be observed, that is any transverse movement directly above each pile.

Records should be kept of any crack forming in the pile cap.

The load testing is not to be done in frozen ground.

Anticipated design load of timber piles 30 T, steel 50 T.

Piles to be driven by hammer which delivers a blow of at least 15,000 ft. lb.

* Piles should be driven to double these values if possible.

Test pile No. 7 is to be a timber pile as specified above and driven to a penetration of 25 feet and tested vertically only.

Test pile No. 8 is to be a 73#-14"H steel bearing pile.

For corrosion test piles, see Dwgs. 783-D-183 and 227.

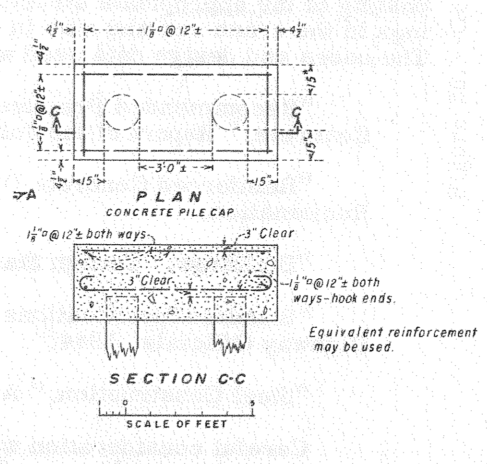


Figure 57.--Logs of drill holes and pile testing data for powerplant foundation. (Sheet 2 of 2.) From drawing 783-D-43.

Caissons, piles, spread footings, and a mat foundation were all considered as a plant foundation. Because of the unwatering conditions and unstable foundations, comparative estimates indicated that either point bearing or friction piles would provide the most economical and satisfactory foundation. The complexity of foundation conditions required extensive pile tests (figs. 57 and 58). Two timber test piles were driven to refusal and loaded to determine the bearing capacity of the overburden materials. Load tests showed that the proposed powerhouse loads could not be taken on friction piles; therefore, point bearing H-piles were selected. Fourteen-inch 73-pound H-piles were obtained and tested both vertically and laterally (figs. 59 through 62) after an unsuccessful test on a test pile made up of three 90-pound railroad rails obtained from the Alaska Railroad Commission. In addition to vertical loads, the piles had to resist lateral loads due to earthquake and horizontal thrust from the high-head penstock. Piles on a 1 to 4 batter, as well as vertical piles were used.

Since both the driving and loading records were satisfactory, the foundation design incorporated point-bearing 14-inch, 73-pound H-piles. The pile lengths were estimated from a bedrock contour map, it being assumed that each pile would be driven 8 feet into bedrock.

Pile foundations were used for the powerhouse, machine shop, transformer structure, and penstock anchor block. A total of 289 vertical and 110 battered 14-inch, 73-pound, H-bearing piles were used (fig. 63).

B. Powerhouse Structural Design

46. General. - The reinforced concrete girders, beams, walls, floor slabs, columns, and combination of members forming a monolithic structure were, in general, considered as statically indeterminate and analyzed by moment distribution and column analogy (fig. 64).

The concrete members of the powerplant were designed for an ultimate compressive stress of 3,000 pounds per square inch (fig. 65) and the structural steel members were designed for a base stress of 20,000 pounds per square inch.

The structural design data sheet (fig. 66) shows the allowable unit stresses and the allowable unit stress increase for multiple loading conditions; also floor loads, miscellaneous loads, and special loads assumed for the structures. For protection against overloading during operation of the plant, it is current Bureau practice to require the posting of the appropriate structural design data sheet and the equipment handling drawings in the crane cab and also in the machine shop for guidance of operating personnel. The codes and design data used were as follows:

"Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete," Report of the Joint Committee on Standard Specifications (1940).

"Reinforced Concrete Design Data," Engineering Monographs No. 10, Bureau of Reclamation.

"Buildings," Design Standards No. 9, Bureau of Reclamation.

"Standard Specifications for Highway Bridges," American Association of State Highway Officials, 1944.

"Steel Construction," American Institute of Steel Construction, 1941.

Careful consideration was given in selecting an earthquake coefficient for use in calculating earthquake forces. The Eklutna Lake area is in seismic zone 3, an area of major damage probability. This is similar to hilly and mountainous country in some parts of California, where an earthquake factor of 0.15 gravity has proved suitable for earthquake design. Therefore, an earthquake force equal to 15 percent of dead load plus the fixed live loads applied at the center of gravity of the loads was selected. This coefficient assumes an acceleration of the foundation of 4.8 feet per second per second. Earthquake

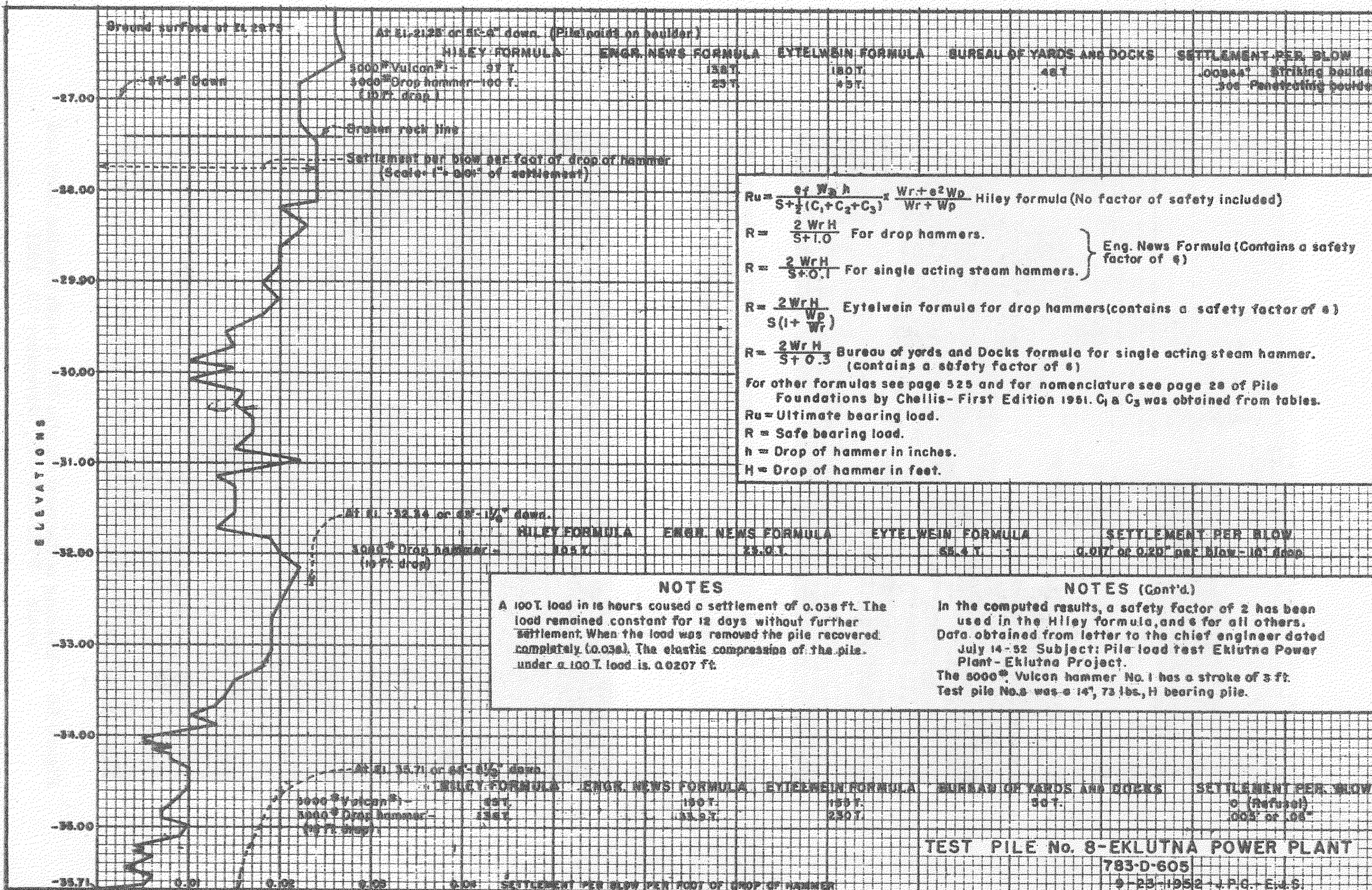


Figure 58. --Test data for pile No. 8 of powerplant.

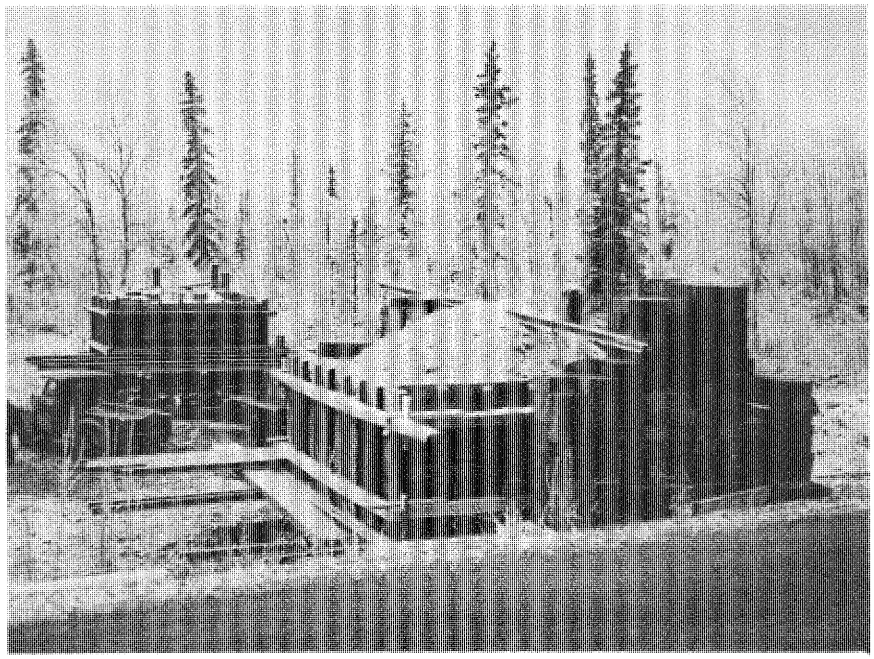


Figure 59. --Boxes filled with sand and gravel, concrete blocks, and iron rail for obtaining the maximum load required in pile testing. P783-908-439, November 18, 1951.

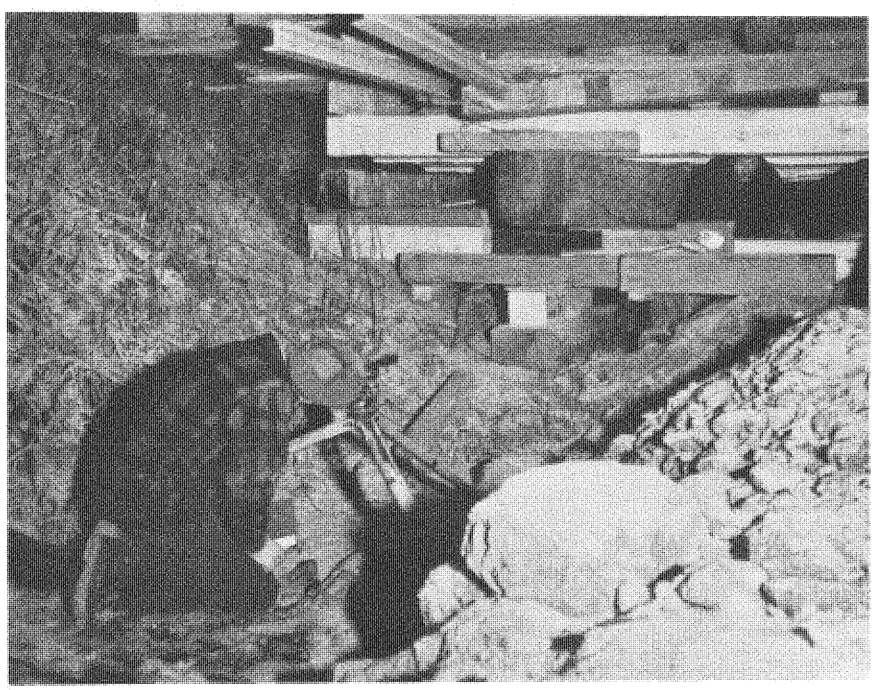


Figure 60. --Reading settlement on pile No. 1 with precise level and scale. P783-908-442, November 19, 1951.

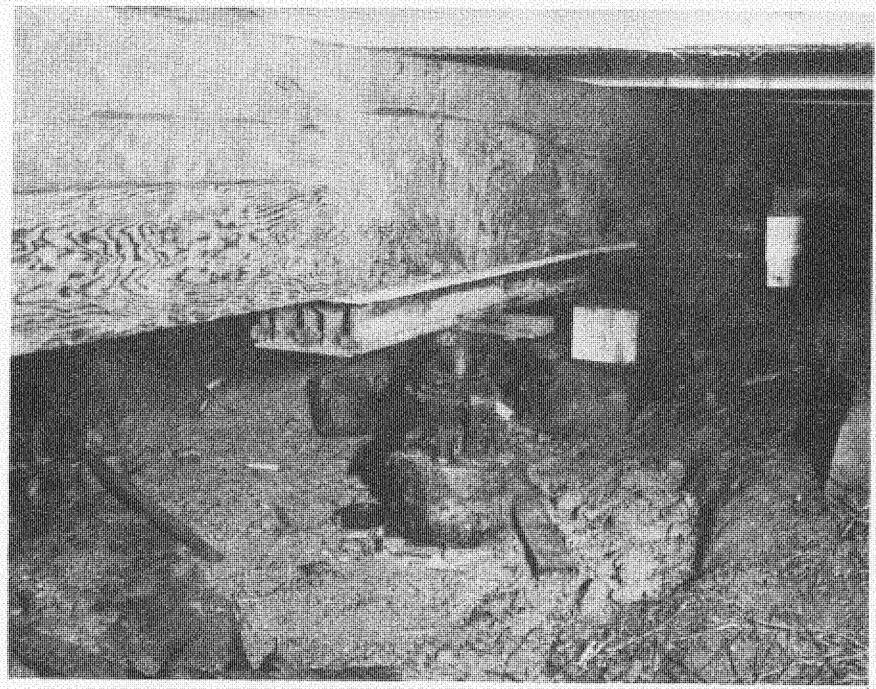


Figure 61.--Test setup for pile No. 1. Hydraulic jack is in position on pile which is supporting 60 tons of weight. This is a typical example of the method used in pile testing. P783-908-443, November 19, 1951.

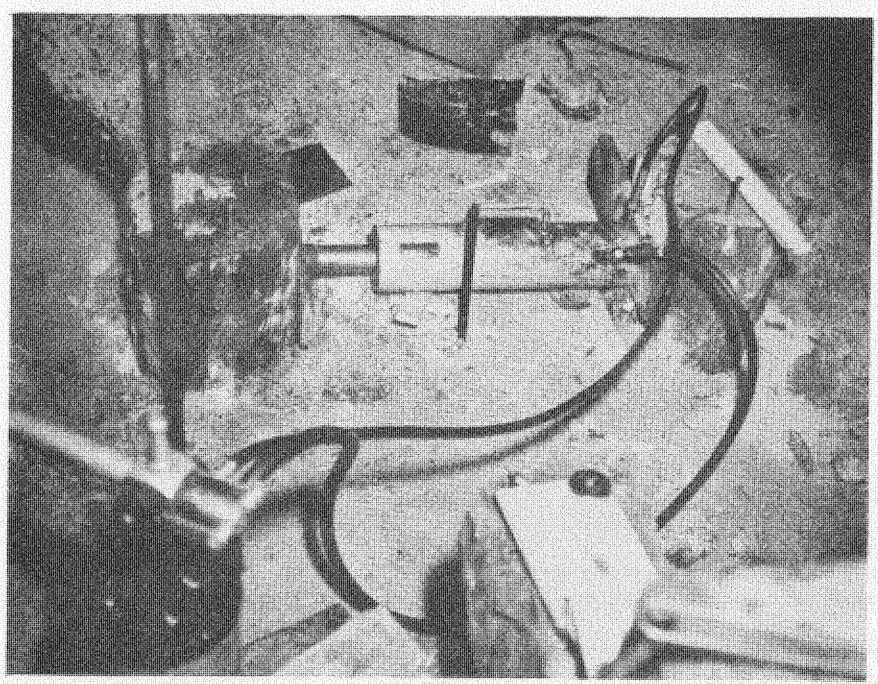


Figure 62.--Closeup view of hydraulic jack used for testing piles No. 3 and 4 for horizontal movement with loading. Check tests were made at 2-1/2, 5, 7-1/2, and 10 tons. P783-908-454, November 26, 1951.

Figure 63. --A 3,000-pound drop hammer operating on steel H-pile at the powerplant site. Vertical and battered piles show at right prior to being cut off to grade. P783-908-1412, July 15, 1953.

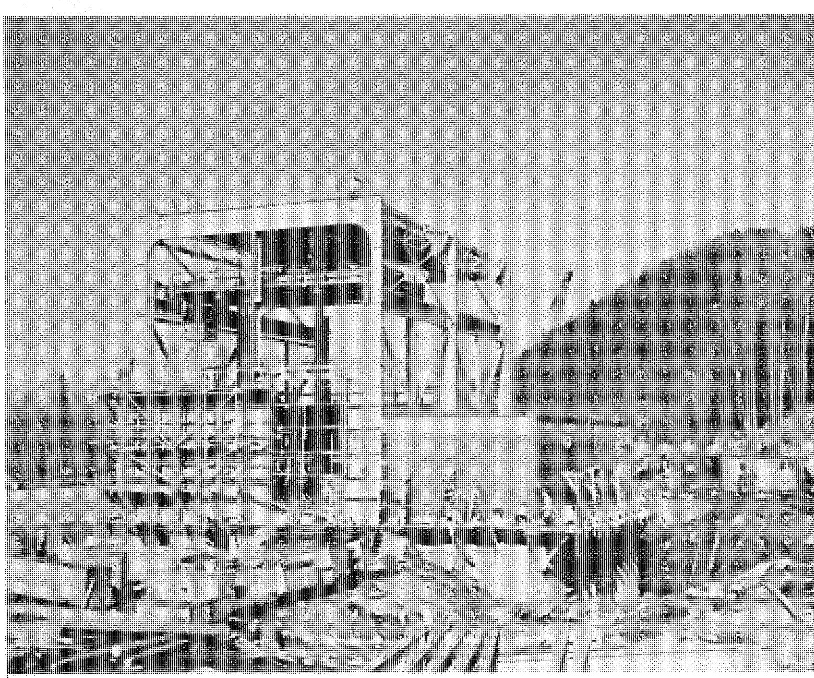


Figure 64. --General view of nearly completed powerplant. P783-908-1597, April 28, 1954.

WORKING STRESSES FOR CONCRETE

		2000	2,500	3000	3500
STRENGTH CLASSIFICATION, LB. PER SQ. INCH AT 28 DAYS	f'_c	2000	2,500	3000	3500
FLEXURE: f_c, f_t, lb. per sq. inch					
Extreme fiber stress in compression	$0.45 f'_c = f_c$	900	1125	1350	1575
Extreme fiber stress in tension (for plain concrete footings only)	$0.03 f'_c = f_t$	60	75	90	105
SHEAR: V_c, lb. per sq. inch					
Beams with no web reinforcement	$0.03 f'_c = V_c$	60	75	90	105
Beams with properly designed web reinforcement (when V_c is in excess of $0.06 f'_c$ web reinforcement should provide for total shear)	$0.12 f'_c = V$	240	300	360	420
Footings	$0.03 f'_c$ (max. 75) $= V_c$	60	75	75	75
‡ **BOND**: u, lb. per sq. inch of surface area of bar					
⁂ Top bars	$0.07 f'_c$ (max. 245) = u	140	175	210	245
In two-way footings (except top bars)	$0.08 f'_c$ (max. 280) = u	160	200	240	280
All others	$0.10 f'_c$ (max. 350) = u	200	250	300	350
BEARING; f_c lb. per sq. inch					
Full area loaded	$0.25 f'_c = f_c$	500	625	750	875
Load on partial area, maximum	$0.375 f'_c = f_c$	750	940	1125	1310

⁂ Top bars are horizontal bars so placed that more than 12 inches of concrete is cast in the member below the bar. In case of uncertainties regarding classification of horizontal bars, use bond stress for top bars.

‡ Deformations for high bond bars shall conform to the requirements of A.S.T.M. Designation A. 305 - (latest edition)

CONSTANTS					
	n	15	12	10	10
	p	0.0068	0.0084	0.0101	0.0131
	j	0.880	0.880	0.880	0.868
	k	0.360	0.360	0.360	0.396
	R	143	178	214	271

WORKING STRESSES FOR REINFORCEMENT

REINFORCEMENT

Tension in flexural members with or without axial loads. Intermediate and hard-grade steel	f_s	24,000
Tension in web reinforcement. Intermediate grade steel	f_s	20,000
Compression in column verticals and flexural members (Intermediate grade steel)	f_s	16,000
Compression in column verticals (hard grade steel)	f_s	20,000

NOTE

For conditions not listed, use the report of the Joint Committee, for plain and reinforced concrete, published in A.S.C.E. Proceedings, June 1940, and if the report does not cover the conditions use "Standards of Design for Concrete" No. 3YB by U.S. Navy Department Bureau of Yards and Docks. Values of bond from ACI Bldg Code 318-51

3-1-55 D-H.H.B.	A.S.T.M. DESIGNATION CHANGED FROM A305-53T TO A305-(LATEST EDITION)
1-17-55 D-S.H.T.	REVISED A.S.T.M. DESIGNATION FROM A305-50T TO A305-53T.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

WORKING STRESSES
FOR CONCRETE AND REINFORCEMENT
HIGH-BOND BARS

DRAWN E.L.W. SUBMITTED H.W. Talon
TRACED E.E.D. RECOMMENDED A. L. Lise
CHECKED C.E.H. APPROVED Grant Bloodgood
Act. CHIEF ENGINEER

DENVER, COLO. JUNE 19, 1952 103-D-352

Figure 65. --Working stresses for concrete and high-bond reinforcement bars.

LOADS

ELEVATION	LOCATION	LIVE LOAD LBS. PER SQ. FT.	SPECIAL LOAD	FLOOR FINISH	WT. FL. F. LBS. PER SQ. FT.
	POWER PLANT				
92.50	Roof	150	K, M	Cover slab & insul.	80
58.54	Roof	150	L, N	Gravel and slabs	200
46.25	Gate deck	200		Monolithic	
41.25	Control room	200	Cable tray	2" Concrete	25
	Electrical equipment room	200	"D," "S"	2" Concrete	25
	Generator room	500	C, G, H, & S	2" Concrete	25
	Toilet	100		2" Concrete	25
28.13	Oil purifier room	200	R	2" Concrete	25
	Battery room	200		2" Concrete	25
	Cable gallery	200		2" Concrete	25
	Governor room	300	F, R	2" Concrete	25
15.00	Oil storage room	200	R	2" Concrete	25
	Storage room	200		2" Concrete	25
	Pump room	150		2" Concrete	25
	Water supply equipment room	150		2" Concrete	25
	Butterfly valve room	300	J	2" Concrete	25
Varies	Stairways and landings	100		1½" Concrete	19
	MACHINE SHOP				
61.54	Roof	50		Built up roof	8
50.00	Balcony	100	E	Monolithic	
41.25	Vestibule	200		2" Concrete	25
	Entry	200		2" Concrete	25
	Toilet	100		2" Concrete	25
	Tool room	250		2" Concrete	25
	Machine shop	300	H	2" Concrete	25
33.00	Fan room	150		Monolithic	

MISCELLANEOUS LOADS

Wind: 20 lbs. per sq. ft. of projected area.
Earthquake: Forces equal to 15% (of dead load, plus fixed live load) applied at center of gravity of load, vertically or horizontally. See Memo. to Head S. & A. 4-2-51.
Max. static water pressure at El. 24.00 = 847.5 ft. or 368 psi.
Max. water pressure under water hammer conditions = 1480 ft. or 642 psi.
Pressure in scroll case during placing of concrete = 350 psi.
Hydraulic thrust on runner = 86.4^K.
Torque from governor = 43'^K.
Torsional load, normal = 175.9'^K.
Max. short circuit torque = 2,287.'^K
Uplift to El. 35.00 for flotation.
Uplift to El. 24.00 for constr. and operation.

LOADING CONDITIONS FOR PILE DESIGN

First stage concrete complete plus switchyard
Penstocks unwatered
Both units operating
Both units shut down at butterfly valve
One unit operating, the other shut down at butterfly valve
Max. load per "H" pile = 75^K

LOADING CONDITIONS FOR ANALYSIS

Case 1. Dead loads
Case 2. Live loads
Case 3. Crane loads and thrusts incl. impact
Case 4. Backfill loads
Case 5. Hydrostatic loads
Case 6. Wind loads
Case 7. Earthquake forces
Case 8. Temperature change ± 50°

STRESSES DWG. 103-D-352

Concrete: 3,000 psi at 28 days
f_s = 24,000 psi in flexure
f_s = 20,000 psi web reinf.
f_s = 16,000 psi column verticals

ALLOWABLE INCREASES OF UNIT STRESSES

Any combination of cases 1-2-3-4-5, no increase.
Any combination of cases 1-2-3-4-5 and 6 or 8, 25% increase
Any combination of cases 1-2-3-4-5 and 7 33% increase
Any combination of cases 1-2-3-4-5 and any two of cases 6-7-8, 50% increase
Temporary and construction loads, 33% increase

Figure 66.--Powerplant structural design data. (Sheet 1 of 3.)
From drawing 783-D-230.

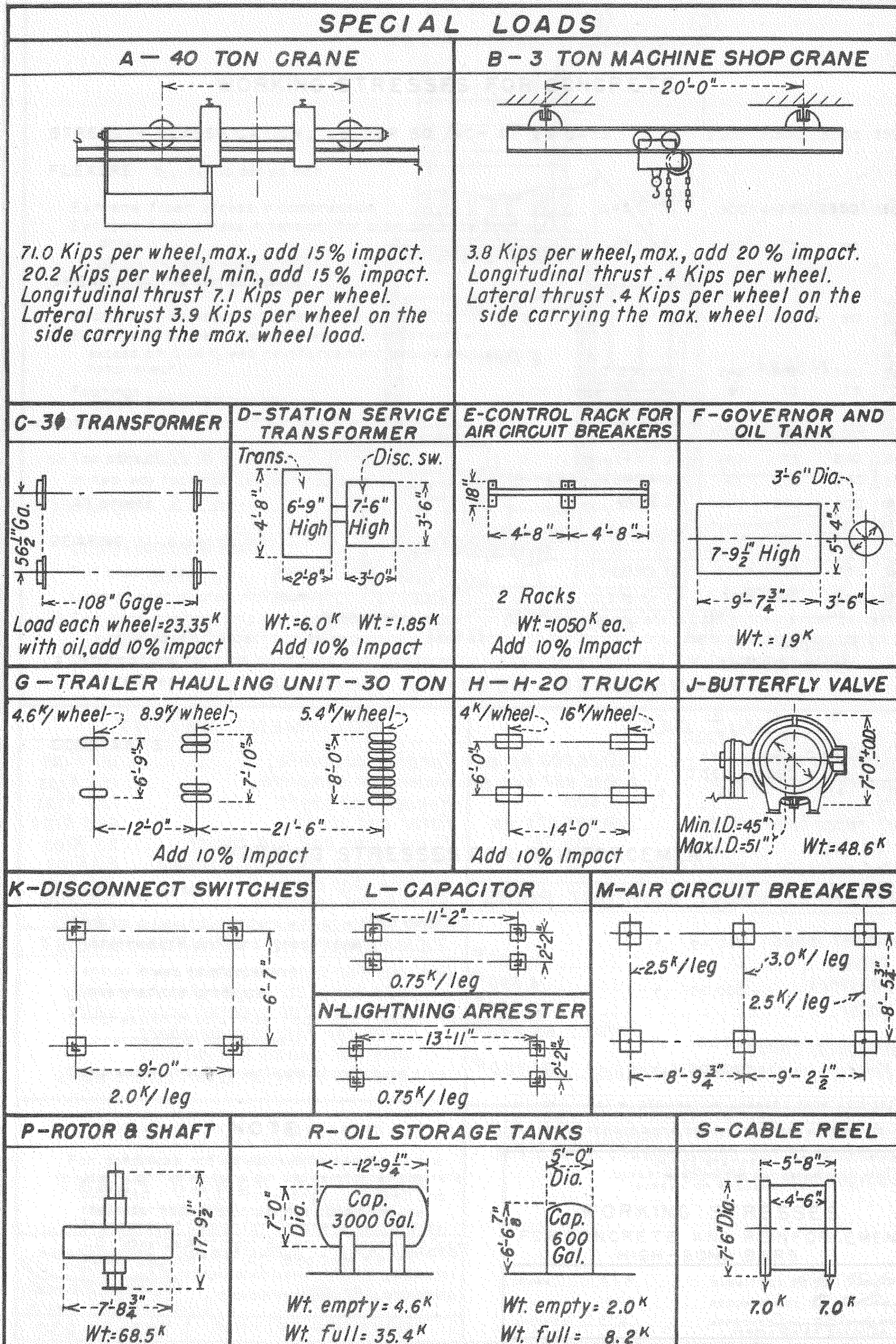
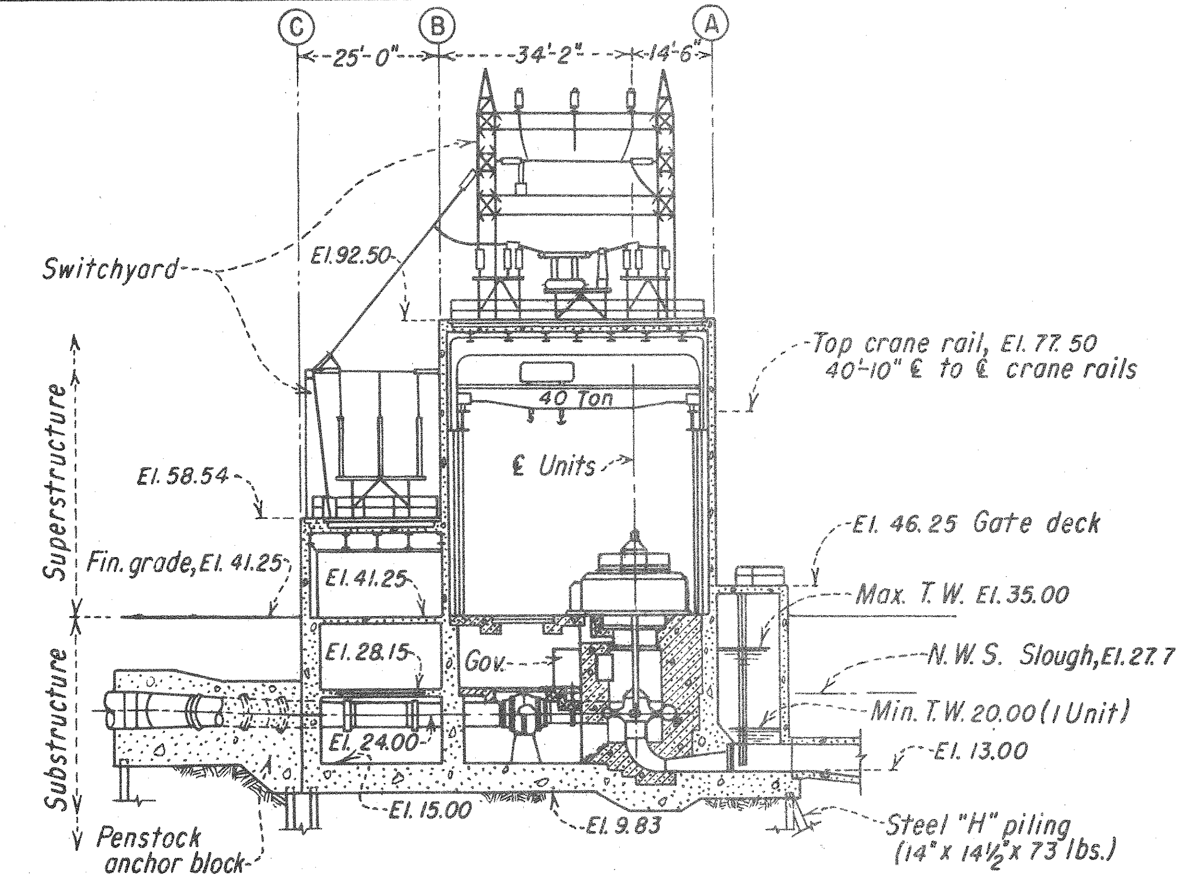


Figure 66.--Powerplant structural design data. (Sheet 2 of 3.)
From drawing 783-D-230.



TRANSVERSE SECTION THRU UNITS

UNIT DATA

Capacity of turbine	2 @ 25,000 hp ea.
Capacity of generator	2 @ 16,667 kva ea.
rpm	600
Q at rated head and hp	2 @ 303 cfs ea.
Rated head	800 ft.
Water velocity in scroll case	27.4 ft./s

EQUIPMENT WEIGHT

Turbine complete	127 Kips
Generator complete	150 Kips
Runner and shaft	13.1 Kips
Rotor and shaft	68.5 Kips
Sump pump and hyd. thrust	3.0 Kips
Power house crane, D.L. & trolley	80 Kips
Machine shop crane, D.L.	2.3 Kips
Switchyard complete	200 Kips
Governor	19 Kips

BUTTERFLY VALVE SUPPORT PIERS

Vertical loads	
Valve	48,600#
Penstock	4,690#
Water	12,950#
Total	66,240#
Horizontal force	
Friction (rusted plate) .5 vert. load	33,120#

TEMPERATURE REINFORCEMENT

Use .005 for superstructure roof
.004 horiz. for superstructure walls
.003 vert. for superstructure walls
.0025 for interior members
.005 for beams and girders
.004 for exterior substructure walls

Deformations for reinforcement bars shall conform to the requirements of A. S. T. M. Designation A 305-50 T.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
EKLUTNA PROJECT — ALASKA

EKLUTNA POWER PLANT

STRUCTURAL DESIGN DATA

DRAWN R.A.B. SUBMITTED S. H. Thompson
TRACED V.M.M. RECOMMENDED [signature]
CHECKED J.P.C. [initials] APPROVED [signature]
CHIEF DESIGN. ENG'R.
DENVER, COLO., OCT. 1, 1952 | 783-D-230

Figure 66.--Powerplant structural design data. (Sheet 3 of 3.)
From drawing 783-D-230.

design is a dynamic rather than a static problem. Because of the complexity of the problem, a constant static force was assumed in the design procedure. An increase in working stress of 33-1/3 percent above the normal allowable was used with earthquake design on the subject structures. A vibration analysis was made and the lowest fundamental frequency of the powerhouse and pile foundation was computed for comparison with the impressed forces that might result from earthquake or rotating parts of the generating units. No revision was made in the structural arrangement of the powerhouse as a result of the vibration analysis.

47. Structural Details. - Construction joints, appropriately spaced to satisfy structural and architectural requirements, were used in the structure to facilitate construction and prevent destructive or unsightly cracking. The types used in the structure are expansion joints, construction joints, and control joints. Expansion joints were formed by 1-inch and 2-inch corkboard. The 1-inch corkboard separated the powerhouse from the machine shop and from the transformer structure. The 2-inch corkboard separated the powerhouse from the penstock anchor block. At the penstock openings in the upstream wall of the powerhouse, the joint was sealed against water leakage by two rubber waterstops. Between the machine shop and the powerhouse and between the transformer structure and the powerhouse, the joint was sealed against water leakage by one rubber waterstop. Construction joints were used when it was necessary to interrupt continuous placement of concrete and reduce the effects of restraint and temperature rise of the concrete after placement. Reinforcement was placed continuous across joints to provide a bond between the two placements of concrete. When necessary to increase shearing resistance, the joints were keyed together. The horizontal and vertical construction joints exposed to external water pressures below elevation 35.15 had rubber waterstops in the joints to prevent flow of water through the joints. Control joints were used in the superstructure walls to prevent unsightly cracking around openings. A surface groove and a metal parting strip or a surface groove and painted keyed joint were used to make these joints. Reinforcement was placed continuous through the joints. The concrete cover slabs on the roof on the powerhouse were sloped to drain and provided with expansion joints and weakened plane joints to control the cracking. For the building details, see figure 67. For roofing, insulation, vapor barrier, membrane waterproofing, and flashing details, see figure 68. For rubber waterstop details, see figure 69.

A certain amount of pipe and electrical conduit was necessarily embedded in the concrete walls and floors. In structural members, the conduits or pipes were located away from critical zones and limits were placed on the amount of concrete permitted to be displaced in order to avoid cracking or weakening the structure. In floors and walls, pipes and conduit were located at middepth and outside diameters were limited to the following percentages of section thickness: 20 percent for horizontal runs in walls; 10 percent for vertical runs in walls; and 15 percent for runs in floor slabs.

48. Foundation and Stability Analysis. - The pile foundation selected for the powerhouse consisted of four pile groups--one vertical group, and three battered groups in which the piles were driven on a slope of 1 horizontally to 4 vertically (fig. 70). In this arrangement all piles are parallel to the longitudinal and transverse centerlines of the units. Because of the wide range in magnitudes of the horizontal components, dead loads and uplift loads, a number of pile arrangements were investigated for the resultants of different conditions. The piles were assumed to take all the load, and no allowance was made for bearing of the structure on the earth between piles. Horizontal loads were carried to the foundation material by the battered piles. The pile arrangement was made so that the elastic center of the pile groups was as close as possible to the larger resultant forces for the different loading conditions (cases). The eccentricity of the penstock horizontal load in relation to the vertical load of the powerplant was considered in the computation for the pile loading.

The loading conditions for the pile foundation are shown on figure 66. The arrangement of the piles was such that all piles are in compression. The solution was made by a method discussed by Mr. C. P. Vetters.[3]

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[3] Vetters, C. P., "Design of Pile Foundations," Transactions ASCE, 1939, volume 104, page 758.

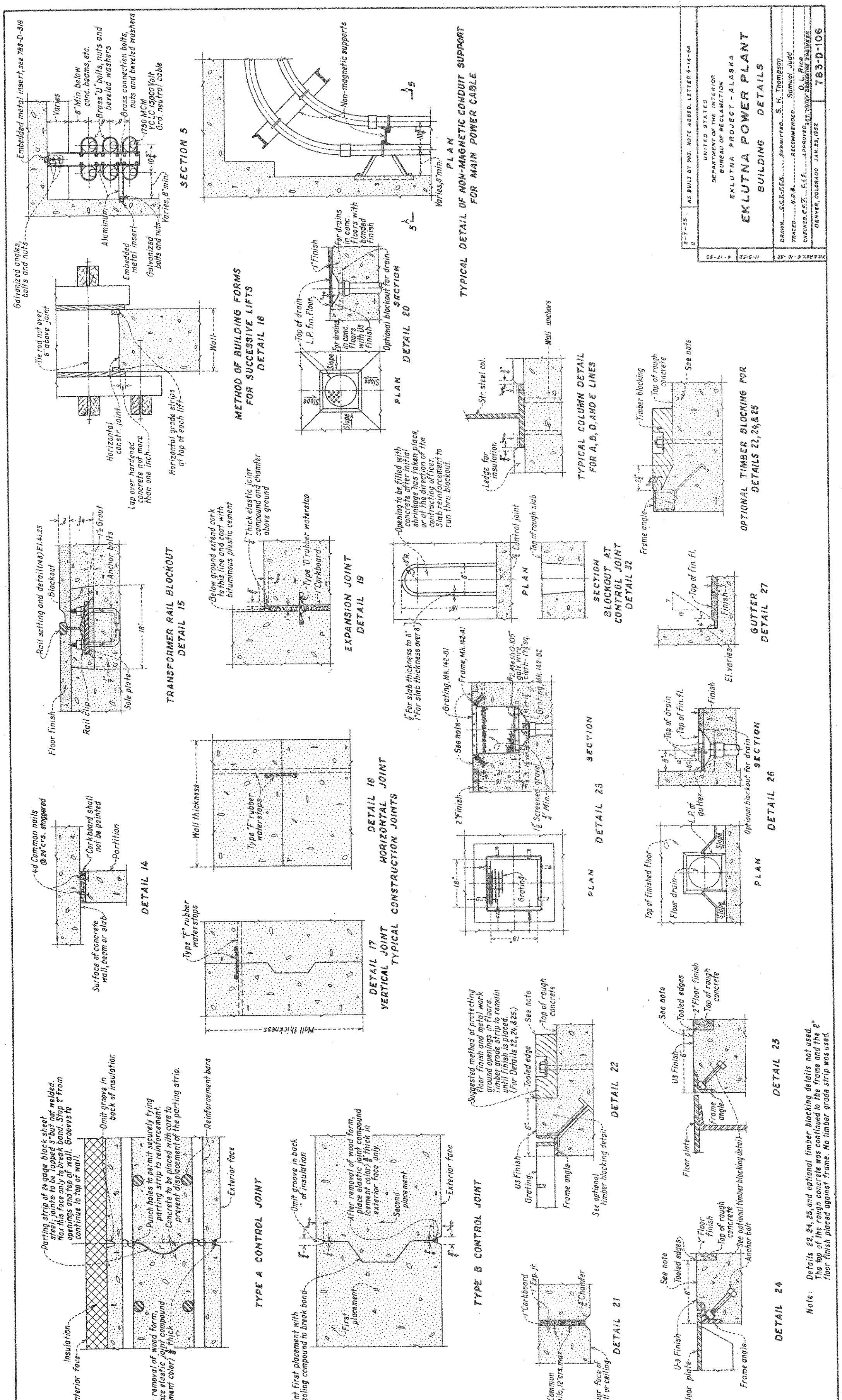


Figure 67. --Powerplant building details.

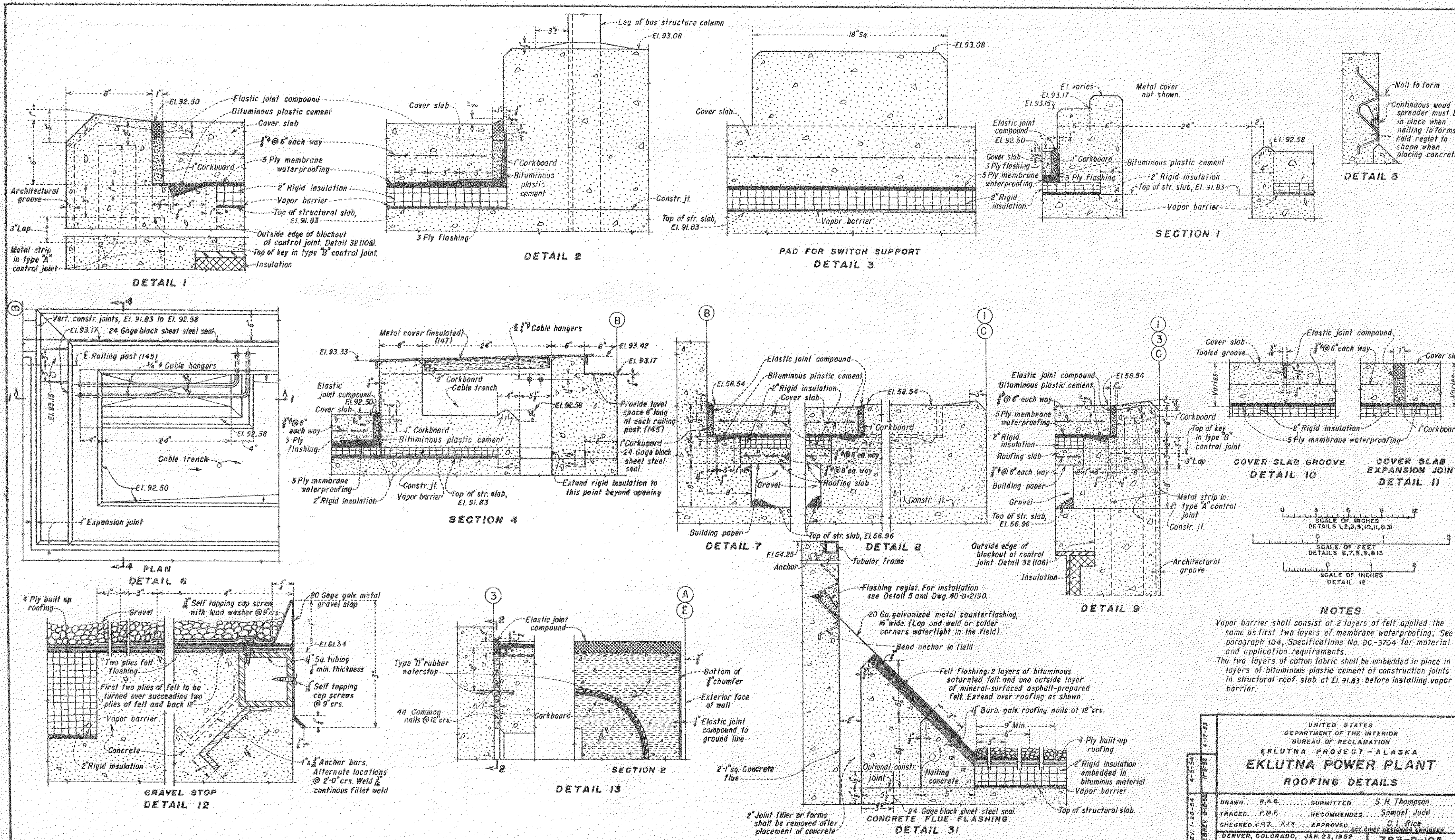


Figure 68. --Powerplant roofing details.

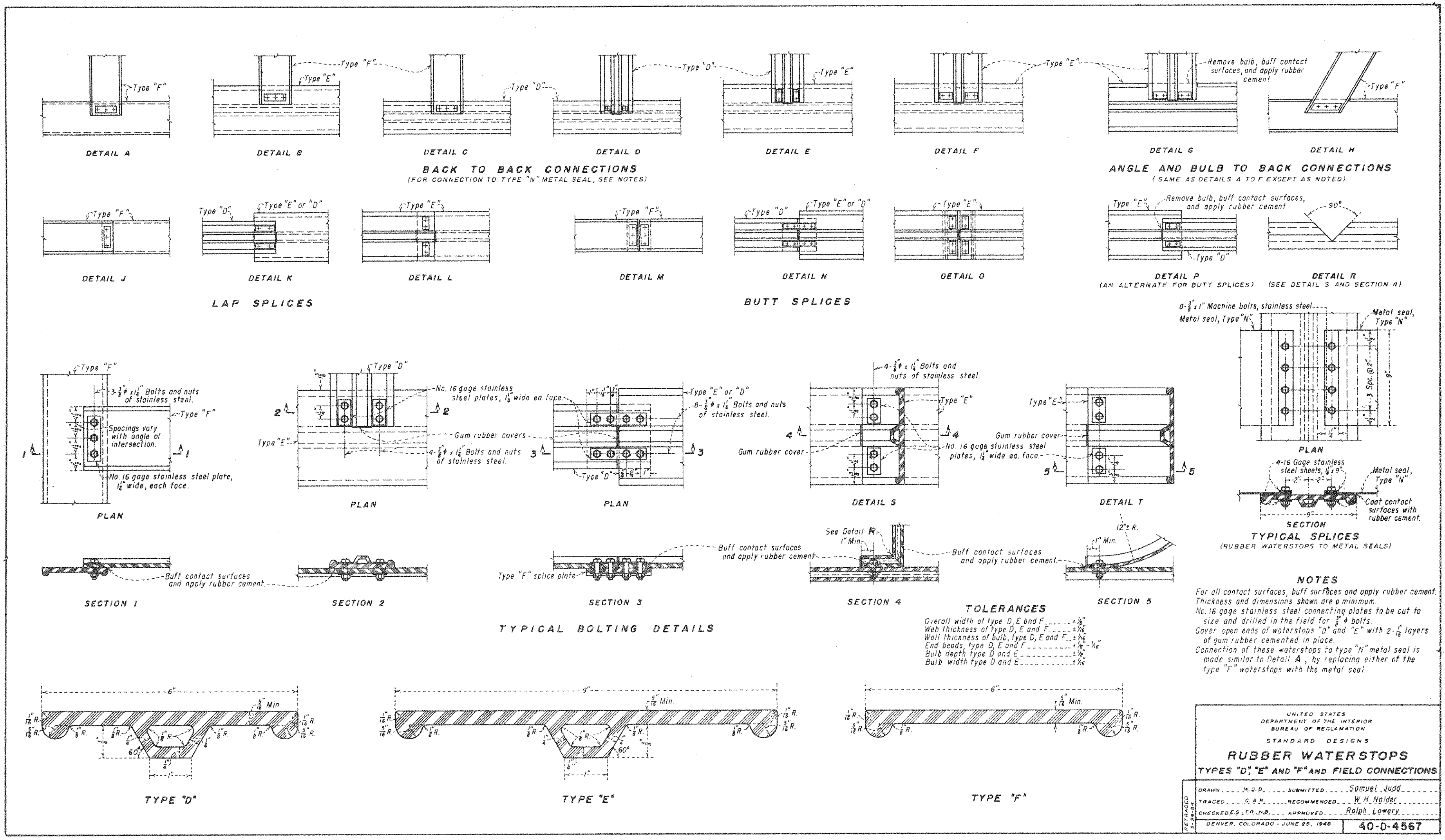


Figure 69. --Standard designs of rubber waterstops.

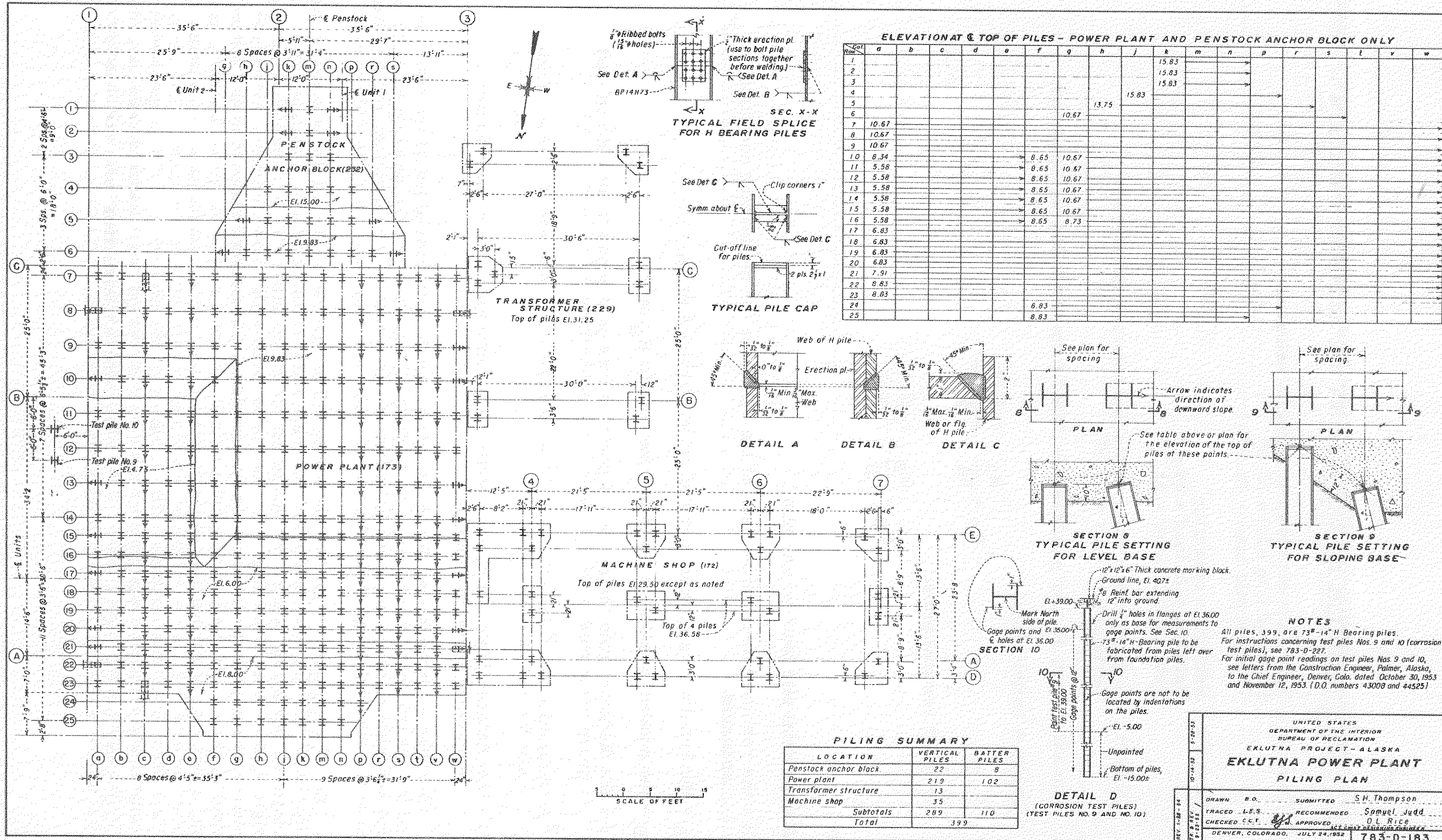


Figure 70. --Piling plan for powerplant.

For normal operating conditions the following maximum pile loads were computed for the pile arrangements shown on figure 70.

Case IIa. Both units shutdown at butterfly valves.
Battered pile load = 75.2^k
Vertical pile load = 45.9^k

Case IIb. Both units operating.
Battered pile load = 68.7^k
Vertical pile load = 51.2^k

Case VII. Both units shutdown, units and penstock unwatered.
Vertical pile load = 68.9^k

The axial load, P, per pile was calculated from the following equations:

Group A batter piles:

$$P_A = \frac{R_A}{n_A} \pm \frac{r_A R_1 e_1}{\Sigma r^2}$$

Group B vertical piles:

$$P_B = \frac{R_B}{n_B} \pm \frac{r_B R_1 e_1}{\Sigma r^2}$$

Where:

P = the total pile load for any pile,

R = the resultant force at the base of the structure for the loading condition assumed,

R_A; R_B = the resultant component parallel to pile group A or B,

n_A; n_B = the number of piles in the group parallel to R_A or R_B,

r = the distance from the center of gravity of the pile group to any pile of that group measured perpendicular to the centerlines of the piles,

Σr^2 = summation of r^2 for all piles of both groups = the moment of inertia of the pile foundation, and

e = the distance from the elastic center to the resultant, R, measured perpendicular to the resultant.

Because of the adjacent fill on the north, south, and west sides of the machine shop and the transformer structure, it was assumed that the potential passive earth pressure was adequate to resist any unbalanced horizontal loads. The maximum vertical load on piles at the machine shop and at the transformer structure was about 70,000 pounds.

49. Powerhouse. - (a) *Superstructure.*--The superstructure of the powerplant has structural steel framing and reinforced concrete walls 12 inches thick, insulated by a 2-inch layer of insulating board. Principal structural members of the superstructure are three rigid frame-steel bents (fig. 71), built up of wide-flange steel columns to support the 40-ton-capacity powerplant crane and a horizontal plate girder supporting the structural steel purlins. The purlins support a 6-inch concrete roof slab, vapor barrier, insulation, membrane waterproofing, 6-inch cover slab, and the switchyard. The bents are braced by structural steel members placed diagonally between columns. The crane girder is a structural steel member with a crane rail mounted on top. The superstructure of the control and electrical equipment rooms is a pin-supported structural steel lean-to bolted to the rigid-frame steel bents. Structural steel purlins support an 8-inch concrete roof slab, gravel cushion, 3-inch concrete slab, insulation, membrane waterproofing,

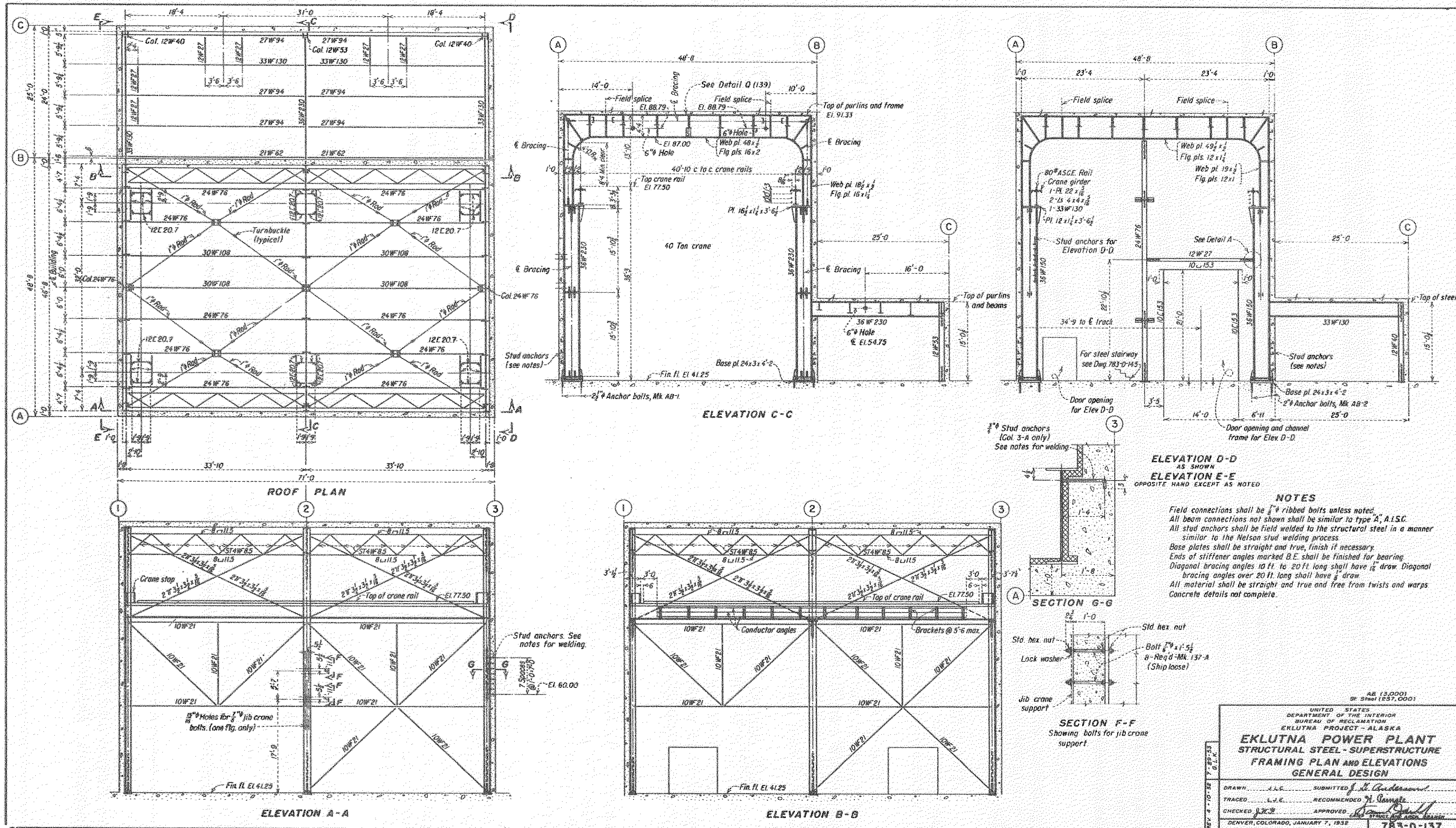


Figure 71. --Framing plan and elevations of structural steel for powerplant superstructure.

6-inch cover slab, and lightning arresters. The concrete wall of the lean-to was designed to resist snowslides. The design of rigid-frame members was done by methods of moment distribution and column analogy.

The superstructure was framed, built, and designed to provide for installation of the equipment after the skelital first-stage concrete construction. The design of the first-stage substructure concrete, therefore, must resist stresses that are later imposed on the second stage concrete.

(b) *First-Stage Concrete Substructure.*-- All moments, thrusts, and shears from the main structural steel frames and concrete walls of the superstructure above elevation 41.25 are transmitted to transverse and longitudinal walls. Below elevation 41.25 the walls function as load distributing members through their stiffness by moment and shear. The distribution of loads was from the walls to the base slab and thence to the piles.

The base slab design with the upward pile loadings was accomplished for both a homogeneous and a cracked section. This design, of course, was without the second-stage concrete in place. Also, the design was checked with second-stage concrete in place and the operating condition that would produce the maximum loadings on the slab.

The interior transverse and longitudinal walls, that acted as distributing walls for the superstructure loads, presented a critical design loading for diagonal tension in the walls because of the numerous openings for passageways, adits, and penstocks.

The governing design loading for the exterior walls under the high section of the superstructure was from the earthfill and surcharge from the service yard. The design was based on coefficients obtained from a photoelastic analysis study.4/ The moments were distributed at the vertical walls and at the base slab. Continuous support was provided for these walls by the second-stage concrete during the later stages of construction.

(c) *Second-Stage Concrete.*--The generator floor concrete was designed for dead and live loads and for the torque caused by generator braking, synchronizing, and short circuit. The shearing forces of the generator loadings are transmitted through bearing by an octagonal sole plate beam. The slab and beam framing of the floors was designed as a continuous monolithic structural system.

The steel turbine spiral cases were designed for the entire bursting pressure of the water. At the time of embedment in concrete, the spiral cases were subjected to normal operating pressures. Reinforcement was provided around the spiral cases to resist water-hammer pressures. Shrinkage reinforcement was provided at exposed surfaces and around openings.

50. Machine Shop. - (a) *Superstructure.*--The superstructure of the machine shop has structural steel framing (fig. 72) and reinforced concrete walls 10 inches thick, insulated by a 2-inch layer of insulating board. Principal structural members of the superstructure are five rigid-frame steel bents (fig. 73), built up of wide-flange steel columns and girders to support the structural steel purlins and 3-ton-capacity crane. The purlins support a 6-inch concrete roof slab, vapor barrier, insulation, and membrane waterproofing. The bents are braced with diagonal tie rods.

The first-stage concrete slabs, beams, and walls were designed for the dead and live loads and for the vibration of the air compressors supplying the air circuit breakers.

(b) *Substructure.*-- All moments, thrusts, and shears from the main structural steel frames and concrete walls of the superstructure above elevation 41.25 are transmitted to crosswall framing. The distribution of these loads is from the walls to pile caps and into the piles. The tops of the piles were considered as pinned connections. The exterior walls were designed for earth loads and surcharge.

4/ Moody, W.T., "Moments and Reactions for Rectangular Plates Fixed Along Three Edges and Free Along the Fourth," Photoelastic Unit Report No. 30, Bureau of Reclamation, December 1, 1954 (unpublished).

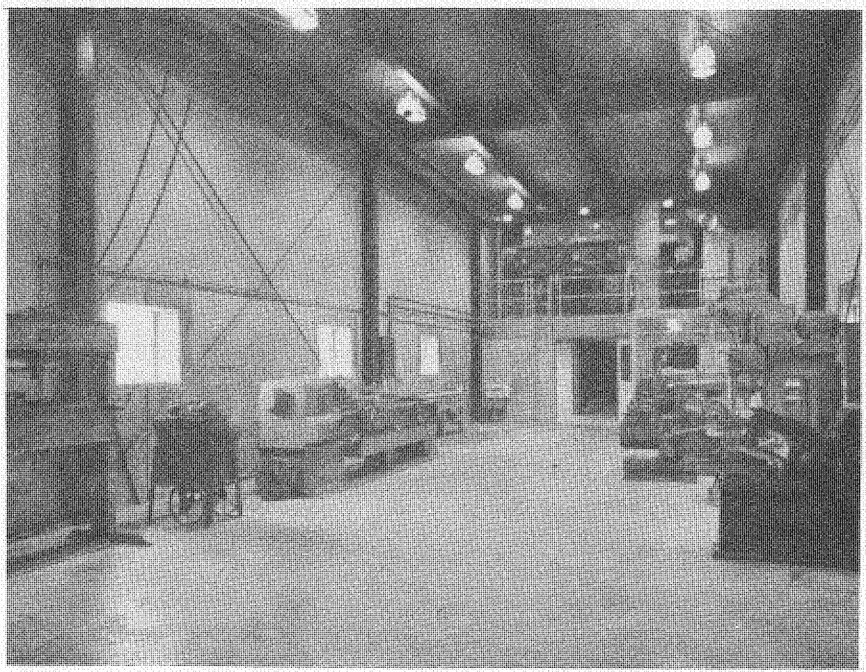


Figure 72.--Interior view of machine shop showing location of equipment. Note air conditioning equipment and air-blast circuit breaker controls on balcony in background. P783-908-1764, May 3, 1955.

51. Transformer Structure. - All moments, thrusts, and shears from the structural steel take-off towers are transmitted to the framing of the concrete structure. The distribution of these loads is from the walls and struts to the pile caps and into the piles. The exterior walls on the upstream side of the structure were designed to resist snow and rock slides.

C. Building Facilities

52. Heating and Ventilating System. - (a) *General Conditions.*-- A dry bulb temperature of -50° F. was assumed in computing heating loads for the powerplant. This temperature was based on weather data from the area where the powerplant is located. Heating of the plant is normally done by warm air discharged from the generators. During shutdown conditions in winter, the high heating loads and costs of available electrical power nullified the possibility of using electricity for the major heating units. In considering other fuels for heating, it was found that fuel oils were the most advantageous on the basis of availability and cost. Electricity has been used to a limited extent for heating purposes, but only where the use of oil-fired equipment did not appear to be feasible. Further consideration of economics involved in heating the powerplant and machine shop during shutdown conditions required that:

(1) Temperatures within the structure be kept above freezing but below usually accepted comfort standards.

(2) Quantities of outside air which entered the structure in the coldest weather be kept to a minimum.

(3) Insulation of walls and ceiling be considered and used where costs could be justified.

(b) *Basis of Design.*--The generators are water cooled but were modified to permit generous quantities of air to bypass through the cooling coils. A centrifugal fan

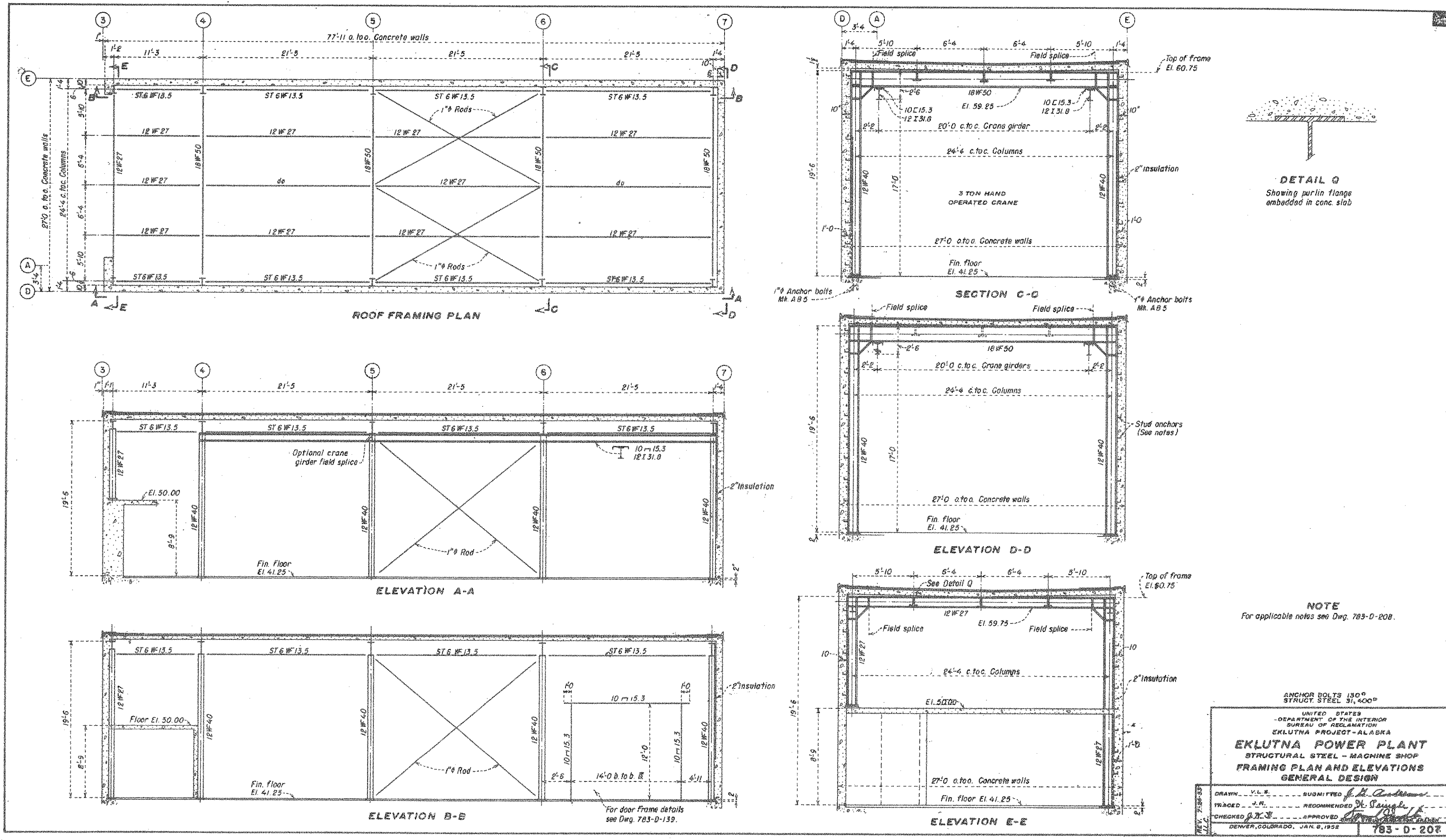


Figure 73. --Framing plan and elevations of structural steel for machine shop.

delivers filtered air to spaces below the generators. In rising and passing through the operating generators, this air is warmed before being discharged into the generator room. This air serves as the principal means of heating the powerplant structure. Wall and floor openings and recirculating fans were located so as to assure effective movement of generator-warmed air throughout the structure when heating is required. Reasonably comfortable conditions should prevail in all areas of the powerplant when one or both of the generators are operating.

Two direct oil-fired heater units, one a stationary and the other a portable unit, were provided to furnish heat for the building when the generators are shut down in the winter. The stationary heater provides sufficient heat to prevent freezing temperatures in critical areas, and the portable heater provides spot heating when needed by work parties.

One electric unit heater with a centrifugal fan was provided to maintain comfort conditions in the control room area. A second unit heater with a propeller fan was provided to discharge heated air into the draft tube gate chamber when there is danger of freezing within the chamber.

Exhaust fans were provided to discharge vitiated or contaminated air directly to the outside. Two exhaust fans are located high in the A-line wall of the generator room. In summer these fans serve to discharge warm air from the generator room directly to the outside. The total capacity of the operating exhaust fans in the winter is somewhat less than the outside air supplied to the plant. This will produce a slight positive pressure within the plant, and so reduce heat losses caused by the infiltration of outside air.

53. Sanitary System. - The entire sanitary system is gravity flow. The septic tank is designed for 6 operating personnel at 50 gallons per day per operator and 40 visitors at 17 gallons per day per visitor, with a 24-hour retention period plus 15 percent for sludge capacity.

54. Lighting. - (a) *General Description.*--The number of lighting fixtures and the wattage of lamps used in obtaining desired levels of illumination for varied seeing tasks were established by the Lumen method and/or the point-by-point method of calculation. Prismatic glass reflectors were used for the general direct-type incandescent lighting fixtures in order to avoid dark ceiling areas and to maintain performance requirements. In order to control the brightness of the lighting fixtures, the direct and reflected glare, and to maintain accepted contrast ratios in accordance with the seeing tasks, fluorescent lighting fixtures were selected for use in areas where higher levels of illumination were desired.

Two types of fixtures were used in the control room (fig. 52). General illumination is provided by direct-type, louvered, fluorescent fixtures (type AA in fig. 74), using slim-line lamps. The control boards are provided with supplementary lighting by the use of incandescent, vertical-surface lighting units (type L).

The 1,000-watt fixtures (type N) used for the high-bay lighting in the generator room provide adequate illumination in this area. The 750-watt lamps (type P fixtures) located directly over the generators are high-bay reflector-lamps which provide concentration of light for use during repair of generators. Adequate illumination is provided in the machine shop by dual units (type Q), utilizing two 500-watt incandescent lamps. The 150-watt, R-40 reflector flood lamps (type F fixtures) used in the oil storage and oil purifier rooms simplify maintenance and provide adequate illumination.

The exterior lighting around the plant is designed to provide general illumination from wall-mounted and flush-type incandescent fixtures mounted on the outside walls of the powerplant. These fixtures have a wide beam spread of down-light and a small amount of light directed upward. The draft tube gate deck is lighted by two handrail-mounted incandescent units which produce a widespread downward light pattern. The service and tailrace areas are lighted by pole-mounted street lighting-type units. The units are equipped with disconnecting lowering hangers for servicing.

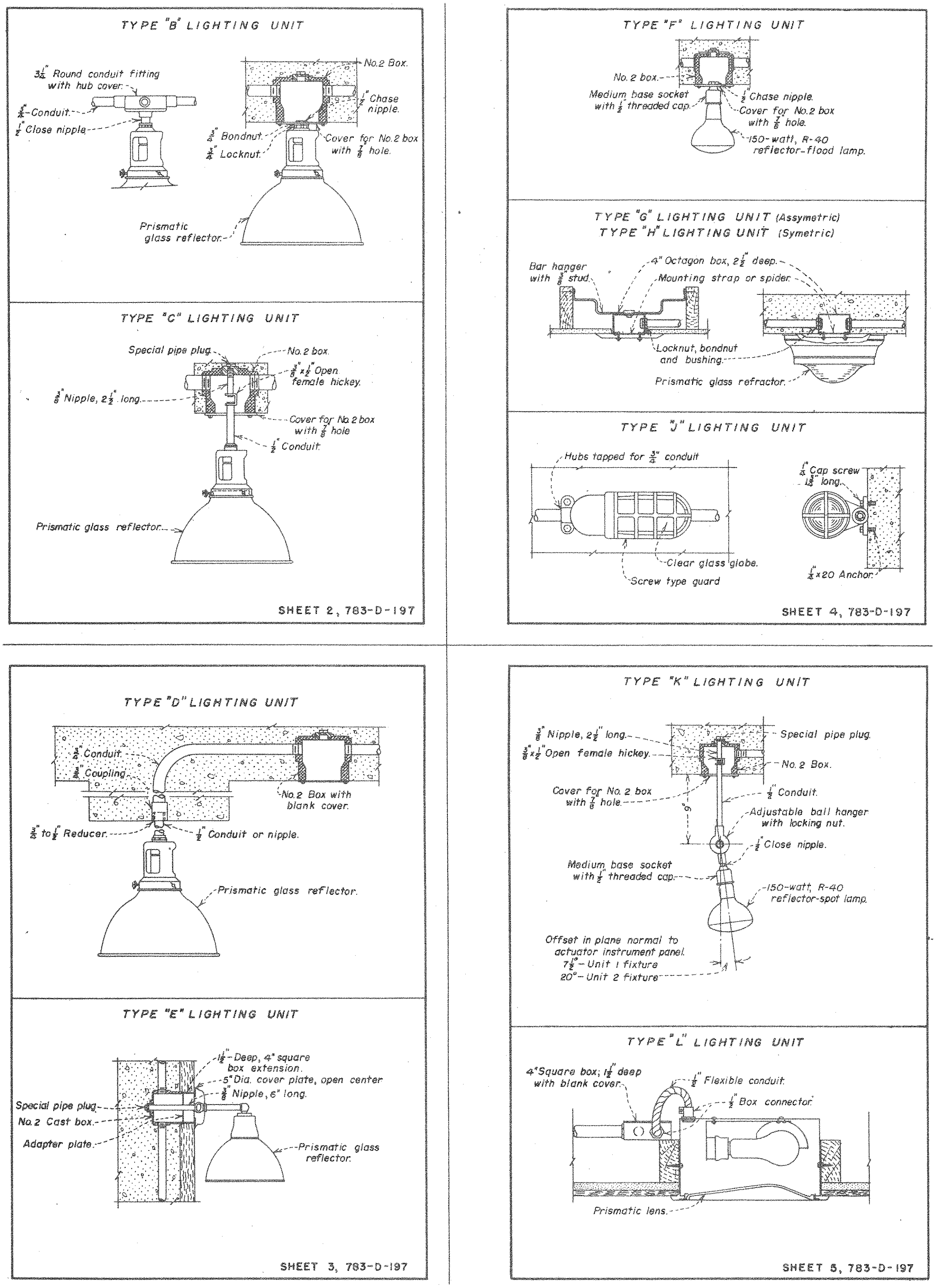


Figure 74. --Some of the lighting fixtures used at Eklutna Powerplant. (Sheet 1 of 2.) From drawing 783-D-197.

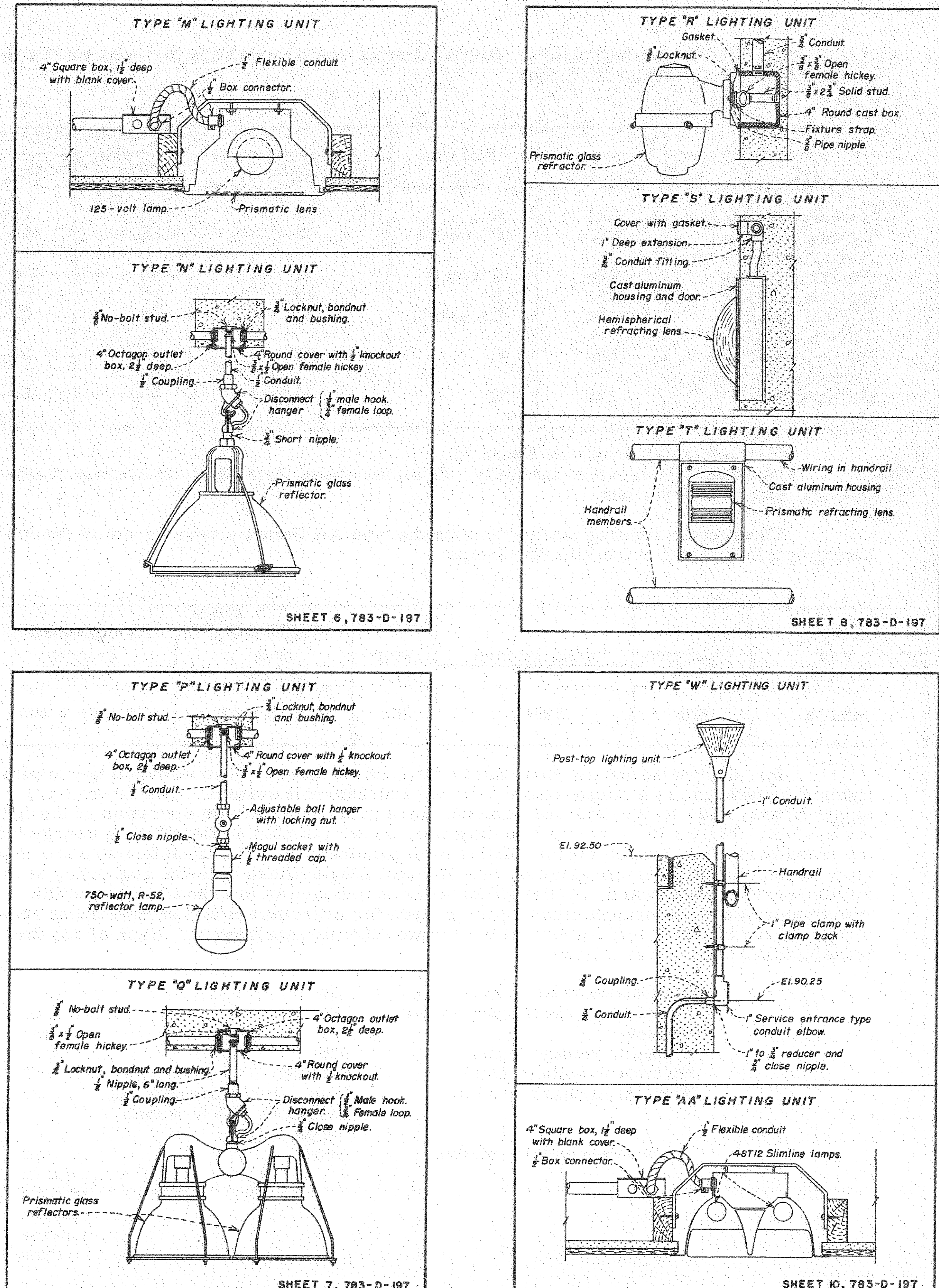


Figure 74. --Some of the lighting fixtures used at Eklutna Powerplant. (Sheet 2 of 2.) From drawing 783-D-197.

(b) *Illumination Intensities.*— Illumination design calculations for specific areas are shown in the following tabulation:

Room	Number	Fixture type*	Intensity,** foot candles	Assumed reflection factors, percent Ceiling	Walls
Governor room	201	D	21	30	10
Battery and air compressor room	202	C and D	19	30	10
Governor room	205	C and D	21	30	10
Generator room	301	N	23	50	50
Control room (front area)	302	AA and L	50	75	50
Electrical equipment room	304	C	21	50	50
Machine shop	309	Q	53	50	50

*Fixture types shown on figure 74.
**Average "in service" intensity, 30 inches above floor, with an average maintenance factor of 70 percent.

Fluorescent lighting calculations for the type AA fixtures were based on the following lumen values for the slimline lamps:

Length and diameter	Current (ma)	Initial lumens W/W	Watts: Lamp only	Single lamp and ballast	Two lamps and 2-lamp ballast
48T12	430	2350	36	36 + 15 = 51	72 + 28 = 100

(c) *Alternating-Current Power Supply for Lighting System.*— The alternating-current lighting installation is a single-phase 3-wire, 120/240-volt system. Two 50-kv.-a., single-phase, 480- to 120/240-volt transformers provide power for operation of the lighting system. Figure 75, a single line diagram, shows the plan of distributing energy from the transformers to branch circuit distribution panelboards. The transformers are dry-type air-cooled and are energized by two 480-volt single-phase circuits orginating at the station-service panelboard. A circuit-breaker panelboard is interposed between the transformers and the branch circuit panelboards for overcurrent and short-circuit protection of the 120/240-volt feeders to the branch-circuit panelboards. Each of the two transformers is rated as follows:

Continuous rating, kv.-a.	50
Frequency, cycles per second	60
Phases	1
Primary voltage (rated)	480
Secondary voltage (rated)	120/240
Taps on primary winding	Four, 2-1/2 percent full capacity below normal taps
Taps on secondary winding	None

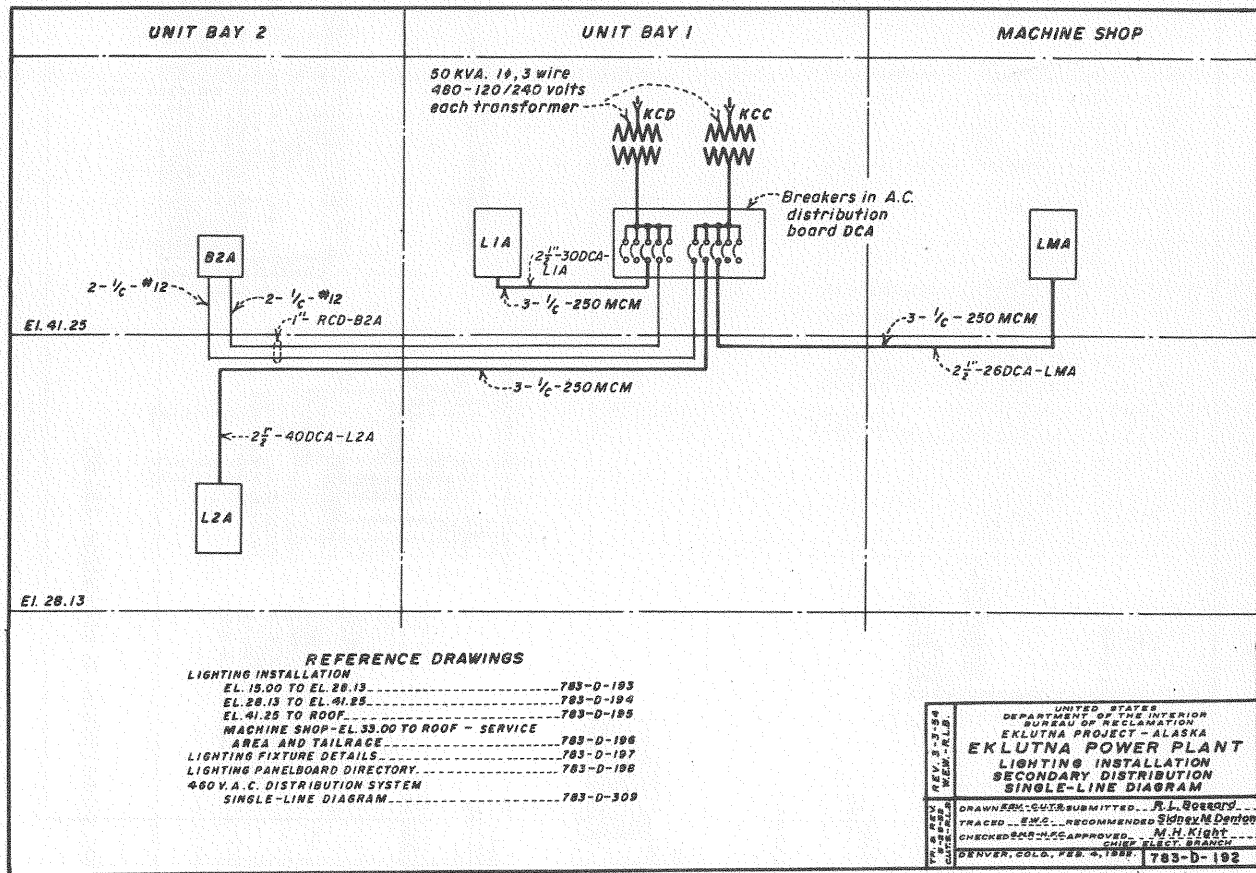


Figure 75.--Lighting installation secondary distribution--Single-line diagram.

(d) *Alternating-Current Lighting Distribution System.*--The 120/240-volt, single-phase, 3-wire, 60-cycle, alternating-current lighting distribution system consists of three secondary distribution panelboards from which branch circuits supply energy to lighting fixtures, plug receptacles, a water cooler, hot water heaters, small ventilating fans, small machine tools, and clock outlets. The panelboards consist of single-pole and double-pole, quick-make, quick-break, thermal and magnetic trip-type circuit breakers which provide overload and short-circuit protection to the branch circuits. The use of wall switches for control of lights has been kept to a minimum. The panelboard circuit breakers are to be used to control lights in the general operating areas.

The areas served from each lighting panelboard (figs. 52 and 76) are as follows:

Panelboard L1A --Rooms 301, 302, 303, 304, draft-tube gate deck, 3-line and C-line exterior lights, switchyard and transformer area, stairway S-3 and stairway S-5.

Panelboard L2A --Rooms 102, 103, 104, 105, 106, 107, 201, 202, 203, 204, 205, 208, and governor cabinets.

Panelboard LMA--Rooms 206, 207, 305, 306, 307, 308, 309, 401, machine shop exterior, and service and tailrace areas.

Branch circuits are connected to provide approximately a balanced load on all panelboard feeder circuits under normal operating conditions. Spare breakers have been provided in the panelboards for other circuits as may be desired.

Estimates of total lighting load were made at successive intervals during the development of the lighting design, the latest of which is shown in the following tabulation:

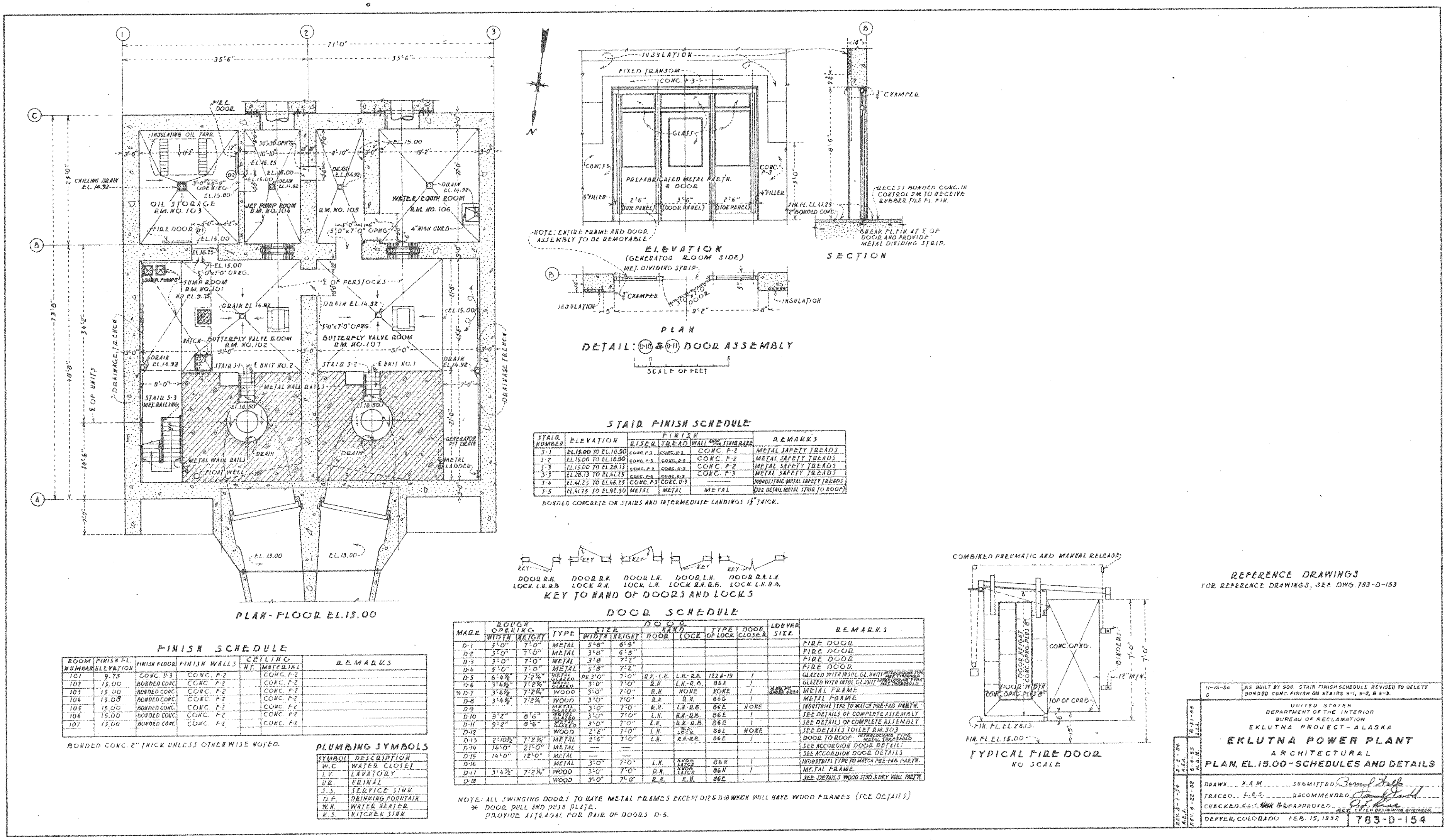


Figure 76. --Architectural plan for powerplant at elevation 15.00.

January 8, 1953	Panelboard L1A	L2A	LMA
Lighting load, kw.	25	14	17
Miscellaneous power, kw.	6.5	3.5	3
20 percent ± lighting load for receptacles, kw.	4.5	8.5*	4
25 percent ± lighting load for future, kw.	7	4	3
Total per panelboard, kw.	43	30	27
Total lighting load, kw.	100		

*A large percent of the light load was used in estimating plug receptacle requirements for panelboard L2A due to the large number of receptacles fed from this panelboard.

The transformers which serve the lighting installation are rated at 50 kilovolt-amperes each. Transformer KCC supplies panelboards L2A and LMA, the sum of the estimated loads for which is 57 kilowatts. Transformer KCC also supplies power to the 3-kilowatt generator-voltage switchgear heaters and the switchgear elevating motors. Although the sum of these loads makes the transformer appear to be overloaded, it should be noted that these are estimated to be the maximum loads which could ultimately be placed on the transformer, and since the transformers are designed to withstand approximately 10 percent overload without damage to the transformer, an additional capacity margin is provided.

Transformer KCD supplies lighting panelboard L1A, with a 43-kilowatt load, and heaters for circuit breakers JY1A and JY2A, with a combined load of 1 kilowatt. Spare capacity is available on transformer KCD for future loads.

A load factor of 100 percent was used to determine the size of panelboards, feeders, and lighting transformers. Feeder and branch circuit wire sizes were fixed to carry design load current with a maximum of 3 percent voltage drop from the lighting transformer to the load. Approximately 1 percent drop was allowed in the feeders from the transformer to the panelboard, and 2 percent drop in the branch wires from the panelboard to the load. The lighting system was designed for 115-volt lamps, and the lighting transformer taps should be set to provide approximately 118 volts.

(e) *125-Volt Direct-Current Emergency Lighting System.*--The purpose of emergency lighting is to assure lighting in vital areas in the event of failure of the normal alternating-current supply. If the intensity of emergency lighting were designed as high as the regular lighting or as extensive in coverage, excessive energy would be required from the station battery. Flashlights should, therefore, always be available for emergency supplementary lighting. Emergency lighting fixtures and plug receptacles are located in vital areas near vital equipment.

The direct-current emergency lighting is supplied by two branch circuits from the emergency lighting panelboard B2A. Panelboard B2A contains a contactor, with normally closed contacts, for each circuit. These contacts are provided with a 125-volt direct-current supply from a breaker in recording board CCB. Control of the emergency lighting is accomplished by these two contactors. The coils of the contactors are supplied from circuit breakers in distribution board DCA. The contactor which controls the emergency lighting circuit for the control room and the electrical equipment room is supplied from transformer KCD, which transformer also provides the normal alternating-current supply to the same areas. The contactor which controls the emergency lighting in various areas of the elevation 15.00 and elevation 28.13 floors is supplied from transformer KCC, which transformer also supplies the normal alternation-current lighting for these

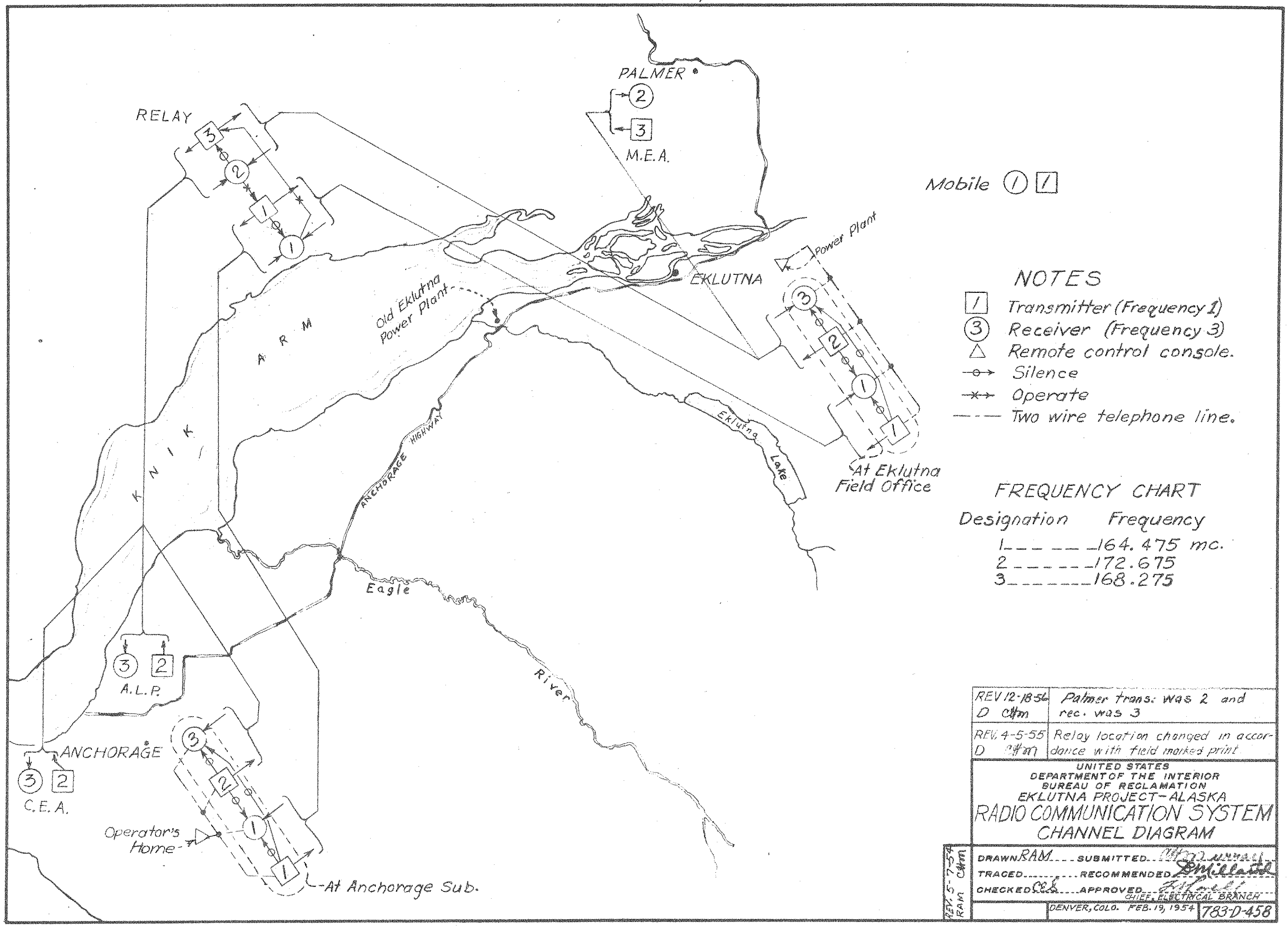


Figure 77. --Radio communication system for Eklutna project--
Channel diagram.

same areas. When the alternating-current supply to the coil of a contactor fails, the contacts close to energize the direct-current emergency lighting circuit in the particular area in which the outage occurred.

When the service is restored to the alternating-current lighting system, the coil of the contactor is energized, opening the contacts and de-energizing the direct-current lighting circuit. The control system may be tested by tripping the contactor coil supply breakers in distribution board DCA.

(f) *Switchyard Lighting Installation.*-- The lighting of the transformer area and switchyard is accomplished by use of incandescent, 300-watt, inverted pendant-type lighting fixtures. Two lighting fixtures are installed in the transformer area. One of these is on the power transformer bus structure, the other on the concrete column supporting one leg of the power transformer bus structure. Both fixtures are mounted at a height of 9 feet. Two fixtures are installed on the tie bus structures (elevation 58.54) and are mounted at a height of approximately 9 feet. Three fixtures are installed in the switchyard (elevation 92).

One single-phase, 120-volt alternating-current duplex convenience plug receptacle is mounted in each power circuit breaker control cabinet, and two such convenience receptacles are located at approximately elevations 58.58 and 41.25.

55. <u>Radio System</u>. - A VHF radio system was furnished for the Eklutna project to provide voice communication between the Eklutna Powerplant, Eklutna field office, Palmer substation, and Anchorage substation. Because of the mountainous terrain, a repeater station was required between Eklutna Powerplant and Anchorage. The channel diagram is shown on figure 77. A remote control console is provided in the powerplant control room for remote operation of the transmitter-receiver sets located in the Eklutna field office. A remote control console is also located in the operator's residence near Anchorage substation. The transmitter-receiver sets are located in the Anchorage substation building. In addition to providing communication between fixed stations, the system permits communication from fixed stations to mobile sets in powerline patrol cars. The radio system between Eklutna Powerplant and Anchorage provides two service channels; one is standby for the other.

D. Major Equipment

56. Turbines. - The generators of the Eklutna Powerplant are driven by two identical vertical-shaft reaction turbines of the Francis type. No provision is made for additional generating units. Each turbine has a nominal rated capacity of 25,000 horsepower when operating at 600 revolutions per minute under a head of 800 feet, with a manufacturer's predicted output of 27,700 horsepower (fig. 79). Satisfactory operation is required for net heads between 700 and 850 feet, and the best efficiency and rated horsepower were called for at a weighted average head of 800 feet. The centerline of the distributor is at elevation 24.0, 6 feet above minimum tailwater (fig. 78). The maximum tailwater elevation of 35.0 will occur only during an extreme flood. In selection of the type of turbine, impulse turbines were rejected because of the lower average efficiency, the higher setting necessitated by the floodwater conditions with its resultant loss of head, and the increased structure costs. Pressure regulators were not included in the installation, as a surge tank limits the pressure rise.

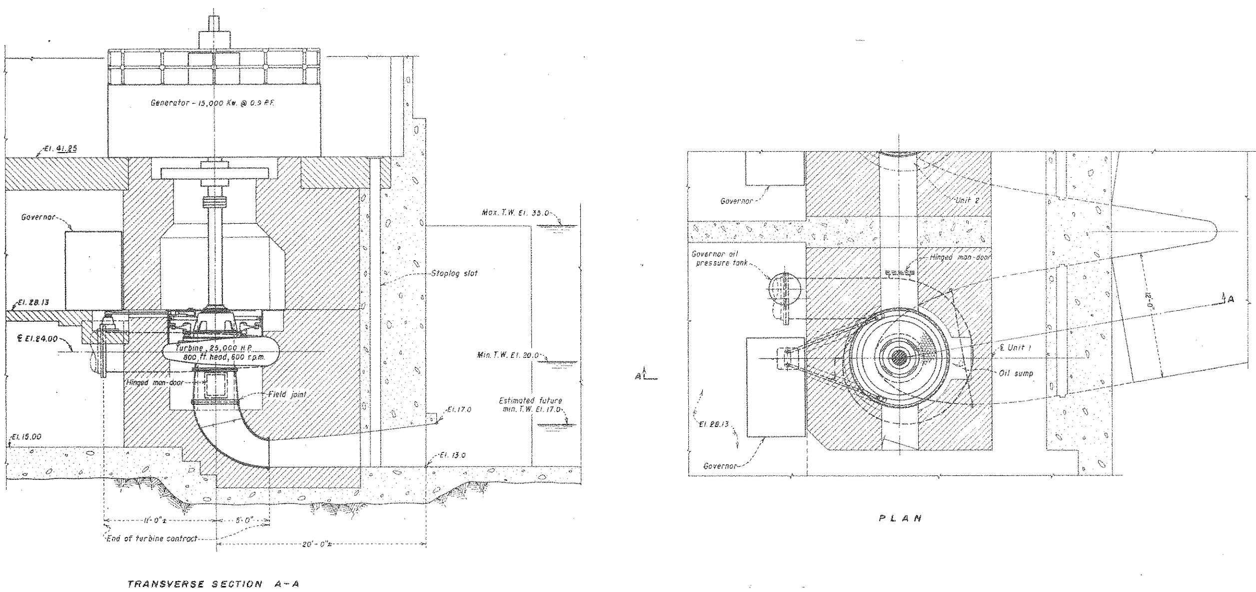


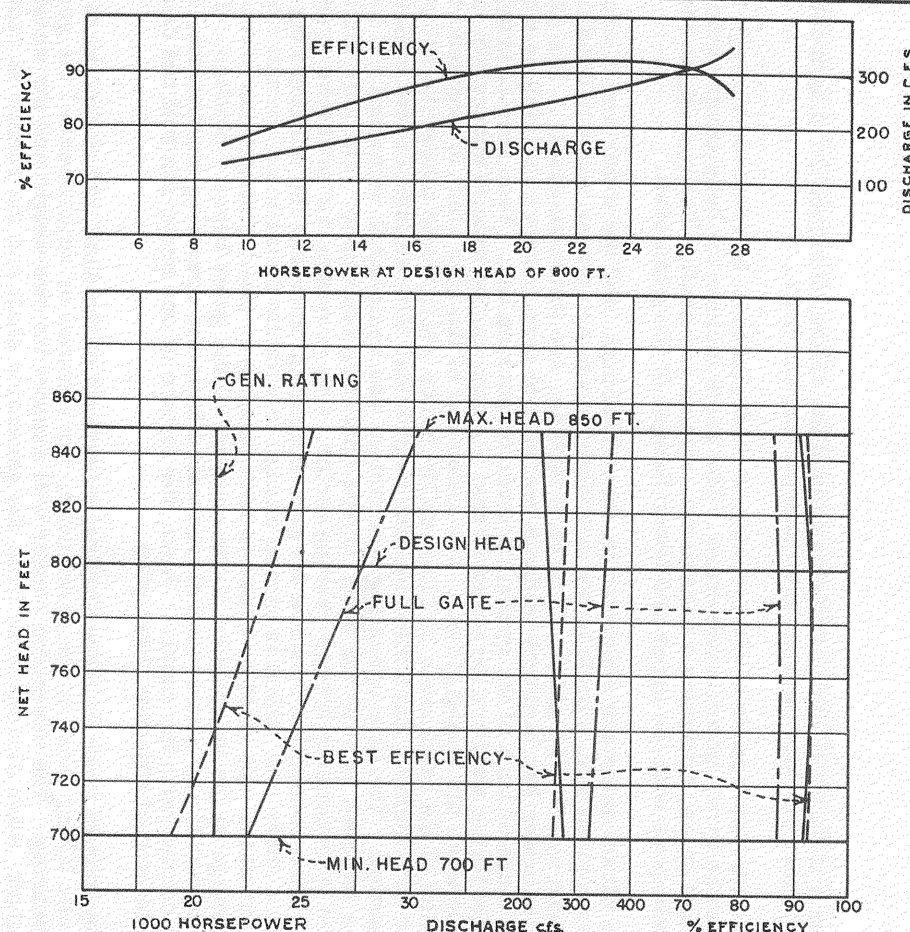
Figure 78. --Preliminary arrangement of turbines, generators, and governors. From drawing 783-D-60.

The spiral cases are of cast steel, designed for an internal pressure of 500 pounds per square inch. They were subjected for 2 hours to a hydrostatic test of 750 pounds per square inch in the manufacturer's shop, and embedded in concrete while under a pressure of 350 pounds per square inch. The water velocity at the inlet section under rated conditions is 27 feet per second. The runners, wicket gates, facing plates, and wearing rings are of stainless steel, because of its resistance to corrosion. The stationary wearing rings are provided with brass inserts to prevent seizing in case of accidental contact with the rotating wearing rings. The glacial flour in suspension in the water is believed to be too fine to cause appreciable damage. The water passages of the runner will pass 1-1/2-inch-diameter solids.

Under 500 pounds per square inch pressure the casing stresses do not exceed 12,000 pounds per square inch, and the stresses of alloy steel parts do not exceed 17 percent of the yield point, or 15,000 pounds per square inch maximum. A stress of two-thirds of the yield point is allowed in the wicket gates and mechanism at the breaking point of the shear pins and in the rotating parts at runaway speed. The elbow-type

EKLUTNA POWER PLANT EKLUTNA PROJECT.
SPECIFICATIONS NO. DS-3506 UNITS 1 AND 2 DATE Sept. 27, 1951
TURBINE RATING IN H.P. 25,000 RATED HEAD 800 FT. SPEED 600 R.P.M.

Generator rating in kv-a. 16,667 Power factor 90 percent.
Turbine mfgr. Newport News Ship Bldg. & D.D. Co. Type Francis
Cost per unit f.o.b. factory $ 167,500 Weight 135,000 lbs.
Cost per h.p. $ 6.70 Weight per h.p. 5.4 lbs.
Type of scroll case SPIRAL-CAST STEEL - 2 Piece
Type of draft tube Elbow
Weight of runner 14,000 lbs.
Weight of turbine parts including hydraulic thrust to be carried by generator thrust bearing 99,500 lbs.
Governor capacity in foot-lbs. 42,000 Pipe size 3 inches.
Gov. mfgr. WOODWARD GOVERNOR CO. Time element 3 seconds.
Cost per unit f.o.b. factory $ 29,343 Weight 19,000 lbs.
Generator mfgr. Pacific Oerlikon
Generator WR^2 450,000 lbs. at one foot radius.
Turbine WR^2 18,500 lbs. at one foot radius.
Regulating constant of unit (R.P.M.^{2} x WR^2 ÷ H.P.) 6,750,000
n_s of runner 21.6 at 800 foot head when delivering 23,500 h.p. (Best eff.).
N_s of runner 23.5 at 800 foot head when delivering 27,700 h.p. (Full gate).
H.P. at 800 ft. (Design head) 27,700; at 100.0 percent of design head; 355 c.f.s.
H.P. at 850 ft. (Max. head) 30,300; at 106.3 percent of design head; 365 c.f.s.
H.P. at 700 ft. (Min. head) 22,500; at 87.5 percent of design head; 325 c.f.s.
H.P. at 800 ft. (Rated head) 25,000; at 100.0 percent of design head; 297 c.f.s.
H.P. at best efficiency equals 84.8 percent of h.p. at full gate.
Runaway speed at 830 ft. hd. 980 r.p.m. equals 163.3 percent of normal speed.
Dimensions of turbine:
Unit spacing 24 ft.
Max. dia. of runner 5.17 ft.
Dia. of gate circle 6.165 ft.
Height of distributor case 0.567 ft.
Dia. of scroll case inlet 3.75 ft.
Dia. of shaft 15 inches.
Dia. of cover plate 7.82 ft.
Number of wicket gates 18
Number of stay vanes 18
Dia. at top of draft tube 3.53 Ft. = D_3.
Outside radii of stay vanes 4.33 to 4.20 ft.
Distance from center line of distributor to top of draft tube 1.50 ft.
Depth of draft tube 11.00 ft. equals 312 percent of dia. D_3.
Length of draft tube 17.08 ft. equals 484 percent of dia. D_3.
Width of draft tube 12.00 ft. equals 340 percent of dia. D_3.
Distance from center line of turbine to center line of scroll case inlet 6.08 ft.
Distance from center line of distributor to minimum tailwater elevation (One unit operating at full load) 4.0 ft.
Pressure regulator mfgr. NONE Type Size inches.
Cost per unit f.o.b. factory Weight lbs.
Remarks:
Placed in operation



PREDICTED CHARACTERISTIC CURVES FROM MANUFACTURER'S DATA CURVE No. H.E. 5631

HYDRAULIC TURBINE DATA
EKLUTNA POWER PLANT
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

J.W.M. 9-9-54

Figure 79. --Hydraulic turbine data for Eklutna powerplant.

draft tube has a plate steel liner extending around the elbow, designed for a hydrostatic pressure of 25 feet of water between the concrete and the liner.

The removable parts of the turbines were designed to be removed through the generator stators by the powerhouse crane. The parts include the head cover, guide bearing, wicket gates, operating mechanisms, runner and shaft. The opening in the head cover will pass both the upper and lower flanges of the main shaft.

The wicket gates are supported by three bearings, and the lower end of each gate stem is provided with a packing box accessible from an annular space around the upper draft tube liner. The gates, 18 in each turbine, are interchangeable. The stem diameter at the lower two bearings is made oversize to permit future refinishing without requiring a change of bore of the operating lever or packing box. Each gate is provided with renewable thrust washers arranged so that the gate can be spaced accurately in midposition between the facing plates. The lower end of the gate stem is exposed, to avoid deflection of the head cover by large uplift forces which would otherwise act on the bottom of the gate stems. Each stem bearing is provided with an independent pressure grease connection. The gate-operating mechanism was designed to withstand the loads which may be imposed on it by the most severe operating conditions. The gate shifting ring is guided by renewable bronze bearing strips, with provision for pressure grease lubrication. Each connection between the gate-operating lever and the shifting ring is provided with a shear pin, which is strong enough to withstand maximum normal operating forces, but which will yield or break in both opening or closing directions of motion to prevent damage to the mechanism if one or more of the gates become blocked. The design is such that if any gate is thus disconnected from the operating mechanism, it cannot make contact with the runner. Also, the failure of one shear pin will not cause progressive failure of adjacent shear pins.

Provision is made to allow vertical movement of the shaft and runner by means of the hydraulic lifting jacks at the generators, for removal or adjustment of the generator thrust bearing. The one-piece runner will support its own weight and the weight of the turbine shaft; when disconnected from the generator shaft and the runner is resting on a shoulder on the discharge (fig. 80) and throat ring. Seal ring leakage is drained to the draft tube through holes in the runner. At the request of the Bureau, air is admitted to the top of the draft tube through a perforated tip extension of the runner, with the flow controlled by a valve operated by the wicket gate shifting ring.

The main shaft has forged flanges on each end, for attachment to a similar flange on the generator shaft, and for bolting to the runner. A renewable stainless steel sleeve is provided where the shaft passes through the packing box.

A single guide bearing mounted in a bearing support consists of a removable cast-iron shell split vertically into two sections to facilitate dismantling. The shell is lined with babbitt, which is suitably grooved to provide for oil circulation. Forced oil lubrication is provided normally by a pumping unit (fig. 81) driven from the station service power supply, and there is also a standby pumping unit powered from the station storage battery. Oil is cooled by a pressure-type cooler with removable coils, with water supplied from the station water supply. The bearing is protected by temperature and pressure alarms.

The packing box is water lubricated, and is provided with a low-flow alarm device in the water supply line, as well as a thermal switch to sound an alarm upon overheating of the packing box metal. There is also a connection for grease supply to packing during shutdown periods.

57. Generators. - (a) *Generator Ratings and Characteristics.*—The generator rating and capacity were selected to match the turbine output of 25,000 horsepower at rated head. The corresponding generator output is 16,667 kilovolt-amperes at 90 percent power factor, 3 phase, 60 cycles, 6,900 volts, 600 revolutions per minute, and an efficiency of about 96 percent.

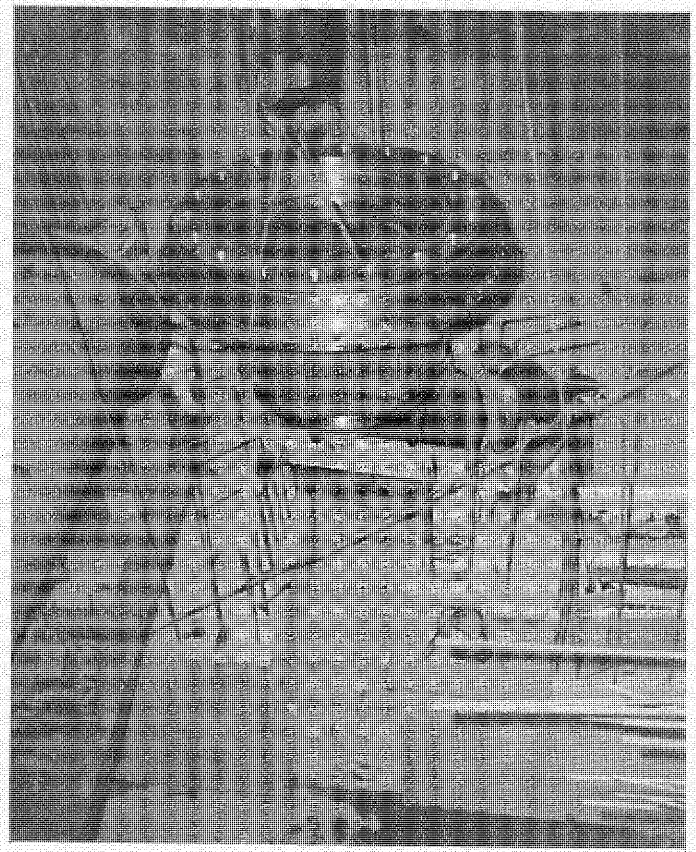


Figure 80. --Discharge ring being set on draft tube liner in unit 1 chamber. P783-908-1602, April 26, 1954.

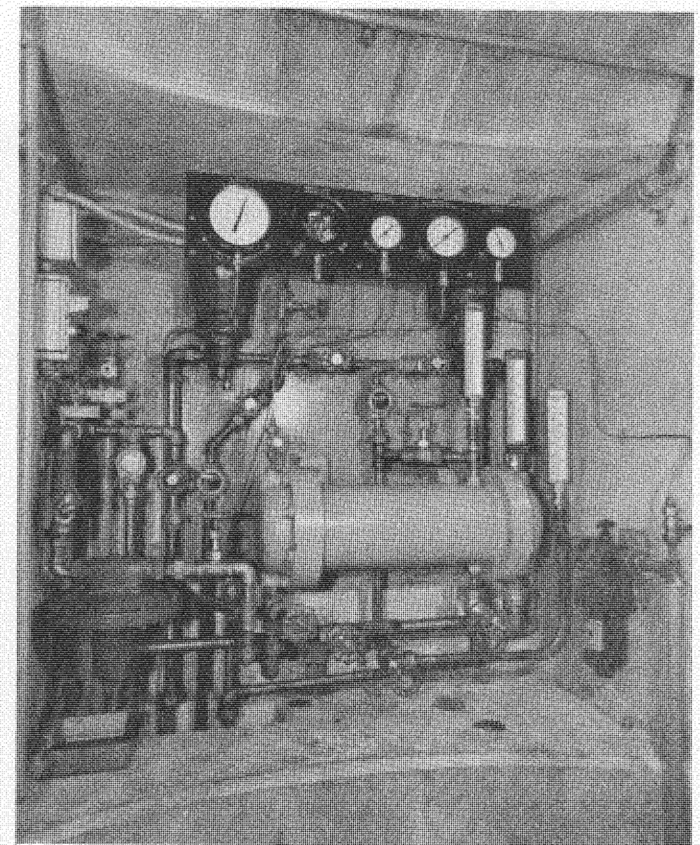


Figure 81. --Interior view of unit 2 turbine pit showing turbine lubricating oil cooler, pump, gage panel and related piping. P783-908-1790, May 5, 1955.

The power factor of the generators was selected on the basis of supplying the required reactive kilovolt-amperes to the system. In selecting the generator voltage of 6,900 volts, several factors were considered, including the availability of standard accessories for the voltage and current chosen, space limitations in the powerplant, and the degree of simplification in design and installation which could be obtained at the lowest cost (fig. 82). Generator costs for a fixed rating and speed, which tend to vary with the voltage, were balanced against accessory costs, which tend to vary with the current, in arriving at the value of generator voltage to be used.

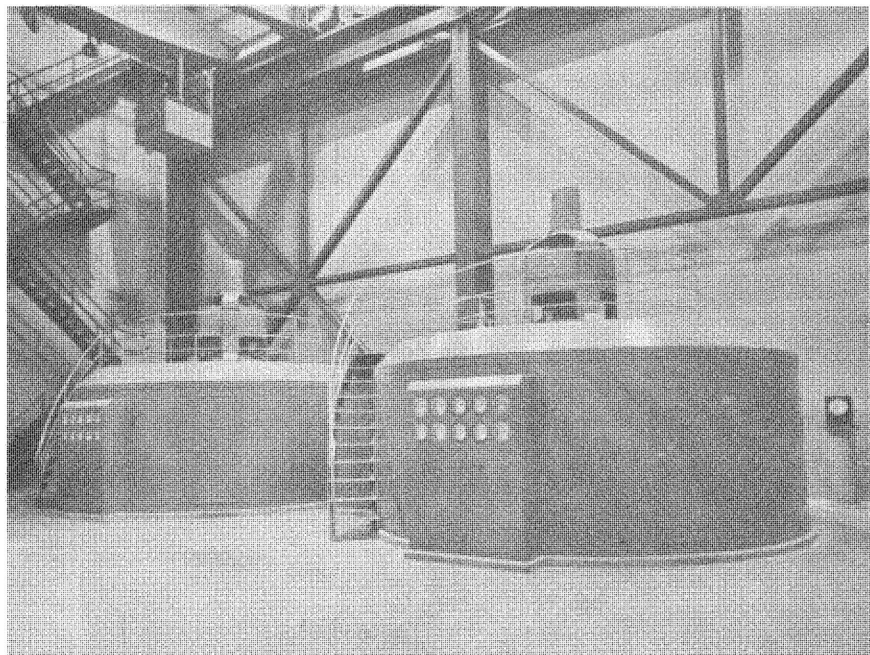


Figure 82.--View from southeast corner of generator room showing units 1 and 2, 15,000-kilowatt (16,667-kv.-a.) synchronous generators. P783-908-1761, May 3, 1955.

Values of short-circuit ratio; WR^2; direct-axis, rated-current, transient reactance; deviation factor of wave form; and balanced and residual telephone interference factors which are normal for generators of this type and rating were specified.

It was specified that generator bids which warranted an efficiency of 96.4 percent (normal for generators of the type specified) with the generators operating under conditions of three-fourths rated load, and rated power factor and voltage, would be considered on an equal basis. It was also specified that in comparison of bids, $500 would be added to bids for each 1/100 of 1 percent less than 96.4 percent efficiency, warranted in the bid, for each of the two generators. It was also specified that should results of field tests (to be performed by the generator contractor under the specifications at the option of the Government) indicate a generator efficiency of less than 96.4 percent, $500 would be subtracted from the generator price for each generator for each 1/100 of 1 percent less than 96.4 percent generator efficiency, as shown by the tests. The $500 figure used for loss valuation was determined by the consideration of such factors as the sale price of power, the estimated daily load on the generators, and the estimated life of the generators.

Amortisseur windings of the low-resistance type were specified for the generator field poles. The benefits of effective amortisseur windings are emphasized in a publication by George and Bessesen[5], which describes the addition of amortisseur windings to an existing generator to limit overvoltages.

Use of amortisseur windings results in decreasing the value of the ratio of the rated voltage quadrature-axis subtransient reactance to the rated voltage direct-axis subtransient reactance (X''_q/X''_d). Benefits of a low ratio of X''_q/X''_d have been emphasized in several references (see footnote 6).

The use of discontinuous amortisseur windings results in a higher ratio of X''_q/X''_d than the continuous type. However, use of the continuous amortisseur winding makes it more difficult to remove a field pole for maintenance or repair. Also, the design of the continuous winding to prevent mechanical hazard or overspeed involves more difficulty and expense on higher speed machines such as specified.

The discontinuous type of amortisseur winding was specified, primarily because of economic reasons, and a value of X''_q/X''_d was specified not to exceed 1.60, which would normally permit use of a discontinuous amortisseur winding. The manufacturer provided a continuous amortisseur winding at no additional cost to the Government, however, which was accepted. No mechanical difficulty with the amortisseur winding was encountered in rotor overspeed tests performed at the factory.

The generators were designed to withstand a runaway speed of 1,030 revolutions per minute, which is the speed (estimated by the turbine manufacturer) that a unit will attain with no load on the generator except friction and windage losses, with the wicket gates open, and an effective head of 830 feet on the turbine.

Originally a runaway speed of 1,000 revolutions per minute, based on turbine information, was specified under the condition that the unit stress for all rotating parts of the generators and exciters should not exceed two-thirds of the yield point. Subsequently, the turbine manufacturer perfected a new turbine runner design which increased the turbine efficiency but also increased the maximum runaway speed to 1,030 revolutions per minute. Since generator construction was already underway, the rotating parts of the generators and exciters could not be altered for the higher overspeed without considerable difficulty unless the above unit stress requirement was raised to 68.5 percent of the yield point.

Rotors designed for a unit stress which would not exceed 68.5 percent instead of 66.66 percent of the yield point were accepted since the manufacturer agreed to guarantee the rotors, and to test them at the maximum overspeed value of 1,030 revolutions per minute at the factory, and since the savings resulting from the more efficient turbine design would be significant.

Provision was made in the specifications for either shipment of the generator shafts to the turbine factory or the turbine shafts to the generator factory for alinement. In order to expedite completion of the generator installation, however, the generator contractor was authorized to aline the generator and turbine shafts in the field. In order to accomplish this, it was necessary for the generator contractor to furnish the turbine contractor with a template for drilling undersized holes in the turbine shaft couplings which would match the generator shaft couplings. The holes in the turbine shaft couplings were reamed out to match the generator shaft couplings in the field. Coupling bolts and coupling bolt covers were furnished by the generator contractor. No difficulty was encountered in alining the shafts in the field.

Several schemes were considered for utilizing the generator losses for heating the powerplant building.

5/ Bessesen, B.B. and George, R.B., "Generator Damper Windings at Wilson Dam," Trans. AIEE, vol. 58, April 1939, pp. 166-172.

6/ Clark, Edith, Weygandt, C.N., and Concordia, C., "Overvoltages Caused by Unbalanced Short Circuits." Trans. AIEE, vol. 57, August 1938, pp. 453-468. Westinghouse Electric Corporation, "Electrical Transmission and Distribution Reference Book," 1950, pp. 177-183. Crary, S.B., "Power System Stability," vol. II, John Wiley and Sons, 1947, pp. 175-185.

A scheme was selected in which the generator and water-cooled heat exchangers are enclosed in a housing which contains two external air ducts controlled by flaps. By means of the flaps, up to 50 percent of the generator losses can be utilized to heat the powerplant building. This scheme was selected for the following reasons:

(1) Objectionable loud noise and strong air currents which would result with an open-type self-cooled machine would not be present.

(2) Carbon dioxide fire protection would be possible on this type of machine but not on an open machine.

(3) There would be less chance of dirt and foreign material getting into this type of machine than an open or semi-open self-cooled type.

(4) The water-cooled heat exchangers would give a degree of temperature control not present with the open-type or semi-open-type self-cooled unit.

It was specified that all insulated control, alarm, and other auxiliary wiring for circuits of not more than 460 volts alternating current or 250 volts direct current consist of tinned, copper conductor with fire and moisture resisting insulation subject to inspection.

The generator contractor requested that a mineral-insulated wire which consisted of a solid copper wire or wires enclosed in seamless copper tubing and insulated with magnesium oxide (not normally used for generator wiring in this country) be permitted. The mineral-insulated type of wiring, which is fireproof and moistureproof, requires no conduits and was accepted. In order to avoid breakage of the solid wires which might occur from connection and disconnection to terminals upon assembly or disassembly of the generator, split terminal blocks with removable flexible jumpers were required where the wiring crossed all generator disassembly joints. With this type of installation, the flexible jumpers only need be removed during assembly or disassembly of the generator.

The following data were calculated by the manufacturer as required by the specifications:

(1) Losses in kilowatts:

	Full load	3/4	1/2	1/4
Friction and windage	140	140	140	140
Core	78	78	78	78
Armature I^2R	64	36	16	4
Stray load	44	25	11	3
Field I^2R at 0.9 P.F. including exciter	84	65	49	37
Total losses	410	344	294	262

(2) Resistance of armature windings at 75° C. is 0.0109 ohms, each phase. Resistance of field winding at 75° C. is 0.587 ohms.

(3) Deviation factor of wave form is not to exceed 5 percent (specified not to exceed 10 percent).

(4) The direct-axis synchronous reactance (X_d) is 100 percent. The quadrature-axis synchronous reactance (X_q) is 63 percent.

(5) The direct-axis, rated-current transient reactance (X'_d) is 32.2 percent (specified not to exceed 35 percent).

(6) The direct-axis, rated-voltage transient reactance (X'_d) is 28.3 percent.

(7) The direct-axis, rated-voltage subtransient reactance (X''_d) is 17.8 percent. The quadrature-axis, rated-voltage subtransient reactance (X''_q) is 20 percent. (As specified, the ratio X''_q/X''_d was not to exceed 1.60.)

(8) The zero sequence reactance (X_o) is 10 percent.

(9) The negative sequence reactance (X_2) is 18.9 percent. The negative sequence resistance r_2 is 4.5 percent.

(10) The short-circuit ratio (K) is 1.1.

(11) The direct-axis, open-circuit time constant (T'_{do}) is 2.67 seconds.

(12) The direct-axis, short-circuit time constant (T'_d) is 0.86 seconds.

(13) The initial, root-mean-square, symmetrical, 3-phase, short-circuit current is 7,850 amperes.

(14) The initial, root-mean-square, symmetrical, single-phase, short-circuit current is 7,450 amperes.

(15) The initial, root-mean-square, symmetrical, phase-to-neutral, short-circuit current is 8,800 amperes.

(16) The sustained, root-mean-square, 3-phase, short-circuit current at full load excitation is 2,600 amperes.

(17) The sustained, root-mean-square, single-phase, short-circuit current at full load excitation is 3,680 amperes.

(18) The sustained, root-mean-square, phase-to-neutral, short-circuit current at full load excitation is 5,950 amperes.

(19) The maximum value of no-load, balanced, telephone-interference factor is 40 (specified not to exceed 50).

(20) The maximum value of no-load residual, telephone-interference factor is 25 (specified not to exceed 30).

(21) The calculated regulation is 34 percent of rated voltage, at 0.9 power factor.

(22) The field current (I_f) and nominal collector-ring voltage (V_f) required for rated kilowatt output at rated voltage and power factor is 362 amperes and 225 volts, respectively.

(23) Characteristic curves listed below are shown on manufacturer's drawing No. M-016032b, (available in the Denver office).

No-load saturation.
Full-load saturation, zero power factor leading.
Full-load saturation, unity power factor.
Full-load saturation, zero power factor lagging.
Short-circuit saturation.

(24) Maximum operating temperatures, in degree centigrade, are:

Armature winding (by embedded detector)	95
Field winding (by resistance)	90
Collector rings (by thermometer)	90
Cores and mechanical parts (by thermometer)	85

(25) The maximum line-charging capacity of the generator is 16,700 kilovolt-amperes.

(26) The moment of inertia of the rotating parts (WR^2) of the generator and exciter at a radius of 1 foot is 450,000 pounds.

(27) The amount that the rotor must be raised to dismantle the bearings is 3/8 inch for the thrust bearing and zero for the guide bearing.

(28) The quantity of oil required to fill:

The thrust bearing and upper guide bearing is 132 gallons.
The lower guide bearing is 21 gallons.

(29) The quantity of water at 25° C., required to cool:

The surface coolers is 245 gallons per minute.
The thrust bearing and upper guide bearings is 40 gallons per minute.
The lower guide bearing is 6.6 gallons per minute.

(30) The pressure loss through each cooler is 7.5 pounds per square inch.

(31) The net volume of air within the housing and ducts, for one generator, for which carbon dioxide for fire protection must be provided is 2,300 cubic feet.

(32) The weight of:

Complete generator, including exciter is 149,000 pounds.
Each exciter is 4,000 pounds.
Rotating parts, including exciter, is 72,000 pounds.
Rotating parts of exciter is 1,500 pounds.
Heaviest individual part as disassembled for shipment (rotor without poles and fans) is 44,000 pounds.
Total weight of heaviest part that must be lifted by crane during assembly or disassembly is 70,000 pounds.

(33) Recommended viscosity of lubricating oil, in seconds, Saybolt, at 100° F. is 300.

The following results were obtained from factory efficiency tests performed by the generator manufacturer. (Copies of complete tests are available for reference in the Denver office.)

(1) Generator No. 878000M01:

Losses in kilowatts:

	Full load	3/4	1/2	1/4
Friction and windage	143.0	143.0	143.0	143.0
Thrust bearing	43.0	43.0	43.0	43.0
Core losses	88.0	88.0	88.0	88.0
Armature I^2R	65.0	36.6	16.2	4.1
Stray load	42.0	23.6	10.5	2.6
Field I^2R	69.7	53.3	40.5	30.5
Slip ring	0.7	0.6	0.5	0.5
Exciter	4.24	3.28	2.6	1.99
Total losses	455.7	391.4	344.3	313.7
Efficiency, percent	97.05	96.64	95.61	92.29

(2) Generator No. 878000M02:

Losses in kilowatts:

	Full load	3/4	1/2	1/4
Friction and windage	134.0	134.0	134.0	134.0
Thrust bearing	34.0	34.0	34.0	34.0
Core losses	87.0	87.0	87.0	87.0
Armature I^2R	64.5	36.3	16.1	4.0

	Full load	3/4	1/2	1/4
Stray load	43.0	24.2	10.7	2.7
Field I^2R	68.8	54.1	40.3	31.1
Slip ring	0.7	0.6	0.5	0.5
Exciter	4.7	3.7	2.8	2.2
Total losses	436.7	373.9	325.4	295.5
Efficiency, percent	97.17	96.78	95.84	92.70

Provision was made in the generator specifications for field tests to be performed which would determine how well the machine performed and would establish conformance of the equipment with warranties and the specifications. The field tests were not performed, however, because of the following reasons:

(1) The generator contractor had performed factory tests which included efficiency tests and rotor overspeed tests, and had furnished certified reports of the results. These tests were performed at no expense to the Government and could be used in establishing conformance of the equipment with the more important warranties and requirements of the specifications.

(2) Considerable hardship and expense would result to power customers during performance of generator field tests.

(3) A considerable savings would result to the Government if the field tests were omitted.

(b) *Equipment Fabrication Details.*-- The two generators in this plant were manufactured by the Pacific Oerlikon Co., of Zurich, Switzerland. Each generator is a vertical-shaft type synchronous machine, designed for clockwise rotation when looking down on the unit. A thrust bearing and an upper guide bearing are provided above the rotor; a lower guide bearing is installed on the shaft near the base of the generator. A common oil reservoir is provided for the thrust bearing and upper guide bearing, and one for the lower guide bearing. As the thrust bearing is supported by a ring mounted on a bracket consisting of a bridge of two channels, supported from the stator frame, the above load is transmitted successively through this bracket to the stator frame, thence to the soleplates and on into the foundation. The upper bearing bracket also supports the main exciter, which is directly coupled to the generator shaft. The lower bracket supports the lower guide bearing and the combination air brakes and hydraulic jacks.

The stator bore (fig. 83) is 7 feet 10-31/64 inches in diameter. This allows clearance for installation or replacement of any part of the generator or turbine located below the stator, including the lower guide bearing bracket of the generator.

The generator frames, bearing brackets, base plates, and covers are built of steel plates, rolled steel joists, and sections welded together. The stator frame, generator foundation, and anchor bolts are designed to adequately withstand a maximum tangential load due to possible generator short-circuit conditions or synchronizing out of phase. The stator frame was made in two sections to conform with limitations in handling and trasportation facilities.

The stator core is built up of stampings with low iron core losses, insulated on one side with paper and assembled in packets from 23 to 28 inches thick, the packets being separated from one another by spacers forming ventilating ducts. The teeth are firmly clamped by strong press fingers arranged between the press plates and outer stampings. The core itself is pressed between the press plates by steel bolts screwed into the frame and welded. The wye-connected stator winding is of the two-bar lattice type, embedded in 144 slots, that is, four slots per pole per phase. The coil ends are insulated with mica silk and compound impregnated. The slot insulation of the coils consists of a pressed-on seamless shellac-micanite sheath. Both insulations are class B. Corona shielding is achieved by a graphite varnish applied to the coils in the slots and by a carborundum varnish supplied to the coil ends.

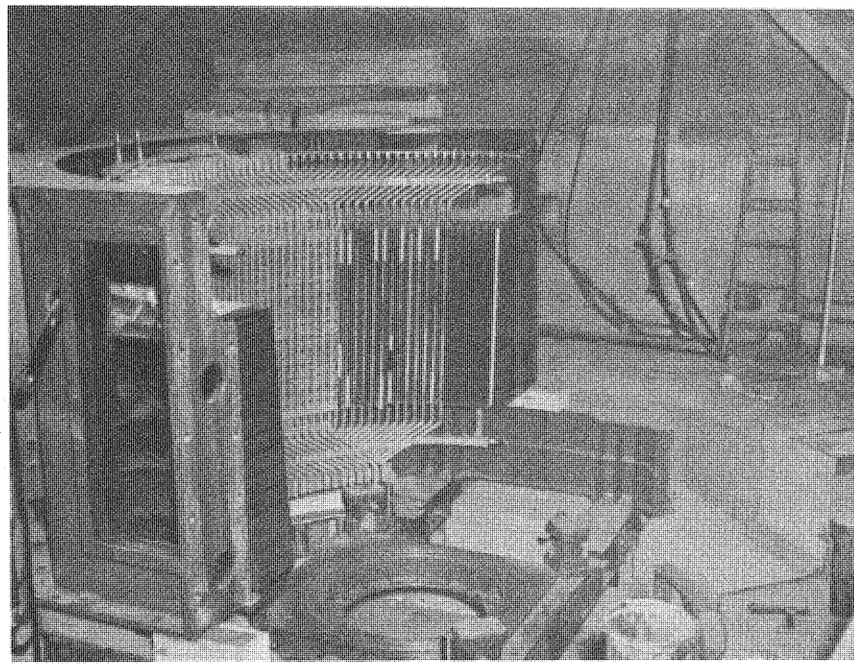


Figure 83. --Half of stator for unit 1 in position over lower bearing bracket support. P783-908-1670, August 9, 1954.

The phase leads, consisting of round copper bars, are connected to power leads through single-phase potheads and also to the generator protective equipment which is located in a separate housing adjacent to the generator. Protective screens are provided around the phase leads in the air housing of the generator. The phase leads are brought out of the stator in such positions that, when looking down on the generator, the electromotive forces reach maximums in the leads in the order of the direction of rotation of the generator. The neutral leads of the stator winding are connected through current transformers to a copper bar, which in turn is connected by means of a cable to the generator neutral grounding transformer. Each generator has three 2,000/5/5-ampere current transformers, one located in each neutral lead of the stator. Three of the transformer secondaries are wye connected and are used with the generator differential relays. Two of the current transformer secondaries are used with the voltage regulator, the third transformer secondary is not used and is short-circuited. The armature windings are designed to withstand the maximum 3-phase, short-circuit current of the generator, but not the maximum line-to-ground short-circuit current. The line-to-ground short-circuit current is limited by the neutral grounding equipment, which is to be discussed later.

The laminated and riveted pole bodies of the generator rotor (fig. 84) are secured to the rotor rings by two rectangular claws. The two-layer type pole coils of 73 turns each are copper strips 2.8 by 3.5 millimeters (0.11 by 0.137 inch) wound on edge and insulated by asbestos. The coils are pressed by steel frames on both sides and secured by thoroughly insulated steel bolts. Thus, the dismounted coils remain compact units. The coils are further insulated against the steel frames by sheets of transformer board; the end windings are covered with stranded asbestos tape in order to increase the creeping distance. The coil fronts are secured by two insulated forged-steel bracings to the rotor end rings. Before assembling of the poles, they are completed with coils and bracings. For this purpose the coil is fixed to the pole shoes through insulated steel bolts. After fastening of a pole, the four coils are tightened. In order to avoid lateral

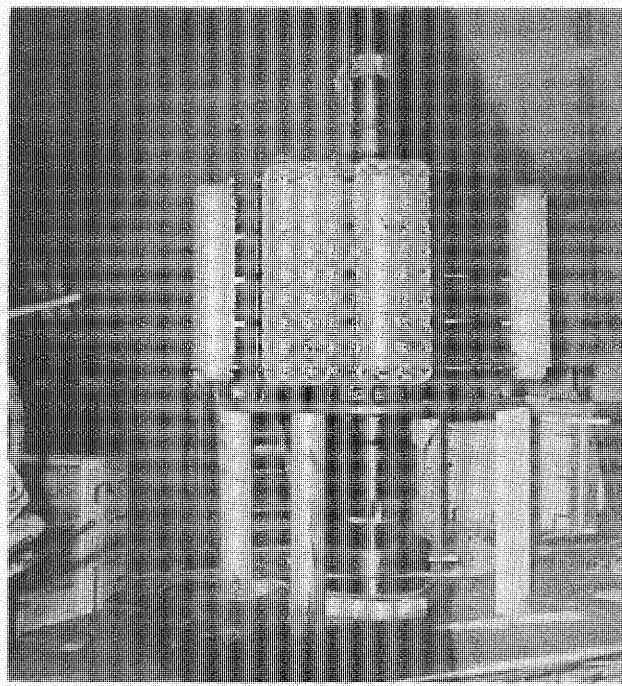


Figure 84. --Unit 1 rotor in place on temporary rotor erection base, with poles being installed. 783-908-1681, August 18, 1954.

deformation during service, the field coils are supported by field coil supports. These V-shaped supports are fixed to the rotor rings by means of special steel bolts. The amortisseur winding is continuous.

The connections between the poles are secured to the rotor rings by special steel bolts. The damper bars, made of round copper, are brazed to the brass damper segments. The latter are fixed to the pole end plates through short steel bolts, which allow axial movement. The connections to the slip rings above the thrust bearing are made of insulated copper bars in the shaft bore. Two insulated brush holders are provided on the slip rings for measuring the field winding temperature by the resistance method. A fan is provided on each side of the rotor for cooling the stator coil ends. The upper fan is fabricated, whereas the lower fan is made of cast steel and is integral with the brake ring. The rotor body consists of four main and two end rings made of forged steel, which are shrunk on the cast-iron spider. Cooling air passes through the openings between the rings. The rings are secured by round wedges, which transmit the rotating torque from the spider.

The generator shaft consists of a steel forging with an integral flanged half coupling which is connected to the turbine shaft. The shaft is of ample size to operate at a runaway speed of 1, 030 revolutions per minute without harmful vibration or distortion. The shaft has a hole bored axially throughout its entire length, the purpose of which is to permit visual inspection of the interior for possible flaws.

The thrust bearing, which is of the flat type, was manufactured by the Escher Wyss Engineering Works, Ltd., of Zurich, Switzerland. The thrust bearing shoes are free to tilt, being supported by members that have spherical lower surfaces which rest on a common resilient ring of soft iron. No adjustment is necessary since a shoe which may momentarily be subject to a greater than normal load is pressed farther into the resilient ring, thereby taking up less load. The wearing surface of the bearing shoe consists of a layer of white metal. The thrust bearing was designed to withstand for 15 minutes a runaway speed of 1, 030 revolutions per minute, carrying the entire weight of the rotating parts of the generator, exciter, and turbine and the unbalanced hydraulic thrust of the turbine runner.

The guide bearings are made of cast iron and are of the babbited type. The upper guide bearing and thrust bearing are adequately insulated to prevent harmful currents from passing through the bearing surface. Suitable test blocks are provided for use in connection with testing the insulation of these bearings.

The upper guide bearing and thrust bearing are located in one oil reservoir and the lower guide bearing in another oil reservoir. Water-cooled cooling coils are provided in both oil reservoirs for cooling the bearings. The circulation of the thrust bearing oil is mainly achieved by a screw pump. The upper guide bearing is self-lubricating. The circulation of the oil is caused by the radially arranged holes in the thrust bearing ring and also by the inclined grooves in the bearing surface. The lower guide bearing is also self-lubricating.

Devices for the following purposes are furnished with the generator:

(1) For indication on the generator gage panel:

Thrust and upper guide bearing oil temperature.
Lower guide bearing oil temperature.
Cooling air temperature for each cooler.
Thrust and upper guide bearing cooling water supply pressure.
Lower guide bearing cooling water supply pressure.
Main cooling water supply header pressure.

(2) For indication at the apparatus:

Cooling water supply temperature located in the main cooling water supply header for bearings and coolers.
Cooling water return temperature located in the water outlet from each surface cooler.
Thrust and upper guide bearing water return temperature located in thrust and upper guide bearing water outlet.
Lower guide bearing water return temperature located in lower guide bearing water outlet.
Oil level sight gage at each oil reservoir.

(3) The following devices are furnished with the generator for remote operation of alarms for excessive temperature or loss of pressure:

Two temperature devices in the thrust bearing metal.
One temperature device in the upper guide bearing metal.
One temperature device in the lower guide bearing metal.
One temperature device at each surface cooler.
One pressure device in the main cooling water supply header.

(4) The following resistance temperature detectors are furnished with the generator for detection at the apparatus and remote indication:

Thrust bearing--two detectors.
Upper guide bearing--one detector.
Lower guide bearing--one detector.
Armature winding--six detectors.

Each generator is equipped with an enclosed cooling system, complete with air ducts, five separate water-cooled heat exchangers located around the generator stator, metal housing, and blades attached to the rotor to act as a blower to circulate air. The housings are practically airtight to insure effective operation of the automatic carbon dioxide fire extinguishing system. A pressure relief door is provided in each generator housing at the top for relief of excessive carbon dioxide gas pressure. Part of the hot exhaust air from the stator may be diverted by means of dampers for the hot air through two vertical air ducts inside the generator housing which exhaust the air into the building, and thus permit up to 50 percent of the generator losses to be utilized in heating the building. The hot air dampers are operated manually from outside the generator housing, and are closed automatically by piston operation upon release of carbon dioxide. Two dampers for fresh air are located in the baffle plates below the generator lower bracket. When one of the hot air dampers is opened, permitting air to escape into the building, a low pressure is created in the generator housing which causes the fresh air dampers to open against gravity, sufficiently to replace the air exhausted into the building.

Four strip heaters, each rated 1 kilowatt at 460 volts, 3 phase, are located below the stator winding within each generator housing. The heaters are intended to prevent condensation within the windings when the temperature approaches the ambient air temperature. The heater contactor is controlled by a differential temperature control device which operates the heaters so as to maintain the temperature inside the generators at a minimum of 6° F. above the outside temperature. The heater control circuit is interlocked with a generator low-speed switch to prevent energization of the heaters when the generator is in operation.

The generator is equipped with two independent ring headers supported near the stator winding and above the rotor, one for the initial discharge and one for the delayed discharge from the high-pressure carbon dioxide gas supply. The header has eight jets. The generator is supplied with a thermoswitch located in the hot air passage ahead of each cooler and a thermoswitch located in each hot air duct for heating the building. The thermoswitches are of the double-pole fixed-temperature fusible-link type, rated at 10 amperes and designed to close 125-volt direct-current ungrounded circuits when the surrounding air reaches a temperature of 185° F. and to effect the release of carbon dioxide. Release of carbon dioxide may also be initiated by a push-button at the control panel mounted on the gage panel.

The generator is equipped with air-operated brakes mounted on the lower bearing bracket. The brake shoes are provided with suitable asbestos metallic friction wearing surfaces which are renewable. The brake shoes are applied to the brake ring on the lower side of the rotor. The brakes are of sufficient capacity to bring the rotating parts of the generator and turbine to a stop from one-half normal operating speed within 7-1/2 minutes after the brakes are applied. The brakes are also designed for use as hydraulic jacks to lift the generator and turbine rotating parts during generator disassembly. A motor-operated high-pressure oil pump is used to operate the jacks.

58. Excitation System. - Direct-connected exciters excited from the station battery and direct-acting rheostatic-type voltage regulators were installed for generator excitation and regulating the generator voltage, respectively.

(a) *Exciters.*— Excitation of the exciter from the station battery instead of a pilot exciter has the advantage that sudden loss of load on the generator and consequent increase in speed would not produce as high an excitation voltage as would be the case with a direct-connected pilot exciter. The station battery has sufficient capacity to supply the excitation for the exciters for a period of about 1 hour should the battery chargers fail.

Direct-connected exciters are well adapted to the unit system of plant operation and eliminate the possibility of loss of excitation on more than one unit at a time. They have high overall efficiency, are not affected by alternating-current voltage disturbances, are adaptable for high-speed excitation, and lend themselves readily to the use of automatic voltage regulators. The most important objections to their use are that failure of an exciter causes shutdown of a generator and the voltage fluctuations are multiplied by speed fluctuations due to speed changes. Exciter failures, however, are very rare and a voltage regulator was specified to stabilize voltage fluctuations.

It was specified that the exciters should have a speed of response, as defined in "Standard Definition of Electrical Terms" (ASA-C42) of the American Standards Association, of not less than 0.5.

The field coils of each alternating-current generator are directly connected to the armature of its direct-current exciter. There is no rheostat or switch in this circuit.

The field current of the alternating-current generator is controlled by varying the field excitation of the exciter. Each main exciter is a direct-connected vertical-shaft, shunt-wound-type, direct-current generator mounted on top of the alternating-current generator. The capacity of the exciter is more than 10 percent in excess of the actual capacity required to supply the field excitation current of the generator when the generator is operating at rated kilovolt-ampere output, 90 percent power factor, and rated voltage. The exciter has one main field (plus auxiliary commutating field), which is excited from the station battery through a field rheostat for manual regulation of the alternating-current voltage. For automatic voltage regulation, the direct-acting regulator inserts and cuts out resistance in this circuit in response to fluctuations in generator voltage.

Provision is made on each exciter bracket and shaft for mounting a permanent magnet generator and housing.

The following data were calculated by the manufacturer as required by the specifications:

(1) Rating of main exciter at normal speed--110 kilowatts and 250 volts.

(2) Field current of main exciter at full-load output--11 amperes.

(3) The speed of response of the main exciter, as defined in the standards of the American Standards Association, is 0.5.

(4) The maximum voltage (ceiling voltage) of the main exciter when delivering full rated current will be not less than 300 volts.

(5) The maximum temperature rise of the main exciter parts, measured in degrees Centigrade by the thermometer method, are as follows:

Armature winding	40
Field winding	40
Commutator	50
Core and mechanical parts	50

Test reports, containing results of factory performed exciter tests, are available in the Denver office of the Bureau.

(b) *Voltage Regulators.*--The generator field current can be adjusted only by varying the induced voltage in the exciter. Since the generator and exciter are direct connected and normally rotate at a fixed speed, the current in the exciter field circuit is varied to adjust the generator voltage.

Consideration was given to both rheostatic-type regulators and rotating magnetic amplifier-type regulators. The rheostatic-type regulator has the advantage of being less complex, cheaper, and easier to maintain than the rotating or magnetic amplifier-type voltage regulator but does not have the high speed of response of the latter. While desirable, the higher speed of response of the amplidyne or magnetic amplifier-type voltage regulator was not considered necessary for the power system to be supplied by the generators. Also, the amplidyne regulator would have required special personnel capable of maintaining such a complex unit, which might be difficult to obtain in Alaska. The simpler rheostatic type was therefore specified.

European practice is to use direct-acting regulators for larger machines than is the practice of American manufacturers. Indirect-acting rheostatic-type regulators were specified originally, since normally American manufacturers furnish indirect-acting regulators for generators of the type and size specified. Since the generator manufacturer, the Pacific Oerlikon Co., had the simpler direct-acting-type regulator, which would require less maintenance, available at less cost to the Government, this type was accepted. The regulator was designated by the manufacturer as type R4.

For manual regulation of the alternating-current voltage, the exciter field is separately excited through the field rheostat and the station battery. For automatic voltage regulation, the direct-acting type R4 regulator is inserted in the control circuit. The measuring system of the regulator is energized from potential transformers connected to the generator leads and is compensated by current from current transformers in the generator leads. The regulator tends to maintain a fixed terminal voltage for the generator.

Each automatic voltage regulator was designed to hold the generator within plus or minus 10 percent during periods of overspeed. Actual tests performed by the manufacturer indicate the direct-acting regulator will allow the generator voltage to rise only 8 percent above normal at an overspeed of 150 percent. The regulator is also capable of regulating the excitation down to zero.

The complete voltage regulating system for a generator consists of the type R4 direct-acting regulator, a regulator transfer switch, a voltage adjusting rheostat, a manually operated exciter field rheostat, an exciter field circuit breaker, a Thyrite discharge resistor, and two generator voltage potential and two current transformers.

The essential parts of the type R4 direct-acting regulator are the measuring element, the regulating element, and the damping device with flexible recall. The measuring element consists of a rotor and a stator. The stator is connected as a 2-phase motor winding and is energized from potential transformers in the generator leads through a voltage adjusting rheostat. The rotor is mounted on jewel pivot bearings and is restrained by two main springs. When the generator voltage rises, the electrical torque produced in the rotor overcomes the restraint of the main springs and turns the rotor spindle in a clockwise direction. When generator voltage lowers, the main springs overcome the torque produced in the rotor and turn the spindle in a counterclockwise direction. The torques produced by the rotor and main springs balance each other when the generator voltage is normal and the rotor spindle remains at rest.

When the rotor spindle is rotated, the contact sector connected to the rotor rolls on the contact path. Each segment of the contact path is connected to a spiral of the regulating resistance. Whenever the sector rolls, a greater or lesser number of the resistance spirals are short-circuited. The regulating resistance is connected in series with the main exciter field and the field rheostat.

The purpose of the damping elements is to hold the regulating system as steady as possible for small voltage variations and to allow the regulating system to overshoot the new regulating position for a short time in cases of large voltage variations, thereby assuring fast response. The recall system returns the regulator from the overregulated position to the correct regulating position. Damping and recall are adjustable so that hunting is eliminated.

The regulators have static adjustment whereby the regulator tends to regulate at a somewhat lower voltage at full load than at no load. This is compensated, however, by a voltage introduced by current transformers connected in the generator leads, which permits the regulator to hold practically constant voltage over the full range of load on the generator. This compensating voltage also forces the regulator to decrease or increase generator excitation to insure proper distribution of reactive load between units. Normally, auxiliary contacts on the exciter field circuit breaker initiates connections of the exciter field discharge resistor across the exciter field circuit. This is necessary in order to prevent damage to the excitation circuit from the high induced voltage due to opening the field circuit.

This method of connecting the discharge resistor is not satisfactory when battery excitation is used for the exciter field since the direct-current supply to the field circuit may be lost for reasons other than opening the exciter field breaker. Tripping of the direct-current breaker for the excitation system or failure of the alternating-current supply to the battery charger when the battery is disconnected from the system, would cause a high induced voltage in the excitation system while the field discharge resistor would remain disconnected from the field circuit.

To avoid this difficulty a Thyrite field discharge resistor which has a relatively high resistance at normal field voltage and a rapidly decreasing resistance with rise of voltage was connected in parallel with the exciter field.

59. Generator Voltage Power and Associated Equipment. - (a) *Generator Surge Protective Equipment.*--The surge protective equipment for each generator is mounted in a metal housing adjacent to each generator. The generator surge protective equipment consists of single-phase 0.5-microfarad capacitors and single-phase 7,500-volt auto-valve station-type lightning arresters. The capacitors and lightning arresters are paralleled and wye connected between the generator leads and ground.

The lightning arresters serve to protect the generator insulation to ground. The capacitors slope the front of a surge so as to decrease turn-to-turn and coil-to-coil voltage stresses in the generator windings. The manufacturer's recommendations in regard to ratings for the lightning arresters and capacitors and the maximum system line-to-ground voltage which might occur were considered in arriving at the ratings selected.

(b) *Generator Neutral Grounding Equipment.*--The neutral of each generator is connected to the station grounding system through the high-voltage winding of a 25-kv.-a., 7,200- to 120/240-volt, single-phase, 60-cycle distribution transformer with a 16-kilowatt, 133-volt, 1.10-ohm grid resistor and a low pickup overvoltage relay connected across the secondary terminals of the distribution transformer.

Distribution transformer and resistor neutral grounding is usually used at stations where the unit system is employed because of lower cost in comparison with reactor grounding and also because it eliminates most of the disadvantages of an ungrounded system.

The sizes of the transformer and resistor were based on the charging current in the case of a line-to-ground fault, which depends on the capacitance to ground of the generator, generator power cables, and the main power transformer low-voltage winding.

The neutral grounding transformers were manufactured by the Erie Electric Co., Inc., and the neutral grounding resistors by the Westinghouse Electric Corp.

(c) *Generator Voltage Switchgear.*-- Generators No. 1 and 2 (fig. 85) are connected to 3-phase power transformers designated KW1A and KW2A, respectively, through air circuit breakers. The distribution transformer, for supplying power to the Government camp, is connected to the main switchgear bus of transformers KW1A and KW2A through two interlocked air circuit breakers. The breakers are interlocked to prevent closing at the same time in order to avoid making a bus tie between the two main buses. The station-service power is supplied from a unit substation, consisting of two transformers, each of which is connected with the main switchgear bus of transformers KW1A and KW2A through a disconnecting switch. The disconnecting switches are components of the unit substation.

Generator voltage breakers rather than high-voltage breakers were selected primarily because, for the currents and voltages involved, the low-voltage breakers were cheaper. Air circuit breakers were selected in preference to the oil-filled type to minimize the fire hazard.

A metal-clad type switchgear assembly is provided for the generators. The assembly consists of the breakers mentioned above, the generator main buses, the Government camp and station-service buses, potheads, instrument transformers connected to these buses, and all necessary wiring and auxiliary devices required to perform the functions of the switchgear. The switchgear assembly is located in the electric equipment room.

Control power for each air circuit breaker (designations UCA1, UCA2, UCA3, and UCA4) is supplied at 125 volts direct current from the main control board.

The generator breaker duty based on system characteristics is:

Interrupting duty (megavolt-amperes)	135
Interrupting current (r.m.s. amperes)	11,300
Momentary current (r.m.s. amperes)	18,000

The Government camp circuit breaker duty based on system characteristics is:

Interrupting duty (megavolt-amperes)	210
Interrupting current (r.m.s. amperes)	17,600
Momentary current (r.m.s. amperes)	18,200

The breakers, furnished by the General Electric Co. mounted in the type M-36 metal-clad switchgear, are type AM-13.8-250-1 magne-blast air circuit breakers, of the 3-pole, single-throw, indoor, vertical-lift withdrawal type, and are rated as follows:

Normal ratings	
Rated voltage (volts)	13,800
Maximum design voltage (volts)	15,000
Minimum voltage (volts) for rated interrupting megavolt-amperes	6,000
Current rating (amperes at 60 cycles)	2,000
Interrupting rating	
3-phase kilovolt-amperes at rated voltage	250,000
Amperes at rated voltage	10,600
Amperes at 6.9 kilovolts	20,940
Maximum amperes	22,000
Short-time current ratings	
Momentary (r.m.s. amperes)	35,000
4 second (r.m.s. amperes)	22,000

The operating mechanism of each breaker is of the solenoid type operated by a 125-volt direct-current source. The closing operation is controlled by the control device, which also permits trip-free operation and prevents solenoid pumping after a trip-free operation. The circuit breakers can be closed by operation of the control switch furnished on the main control board, if the control switch 75CS for breaker raising or lowering is in the normal position and the breaker is in the raised position. The breakers can be opened electrically when the breaker is in the raised position by operation of the control switch furnished on the main control board and by operation of the protective relays detecting faults occurring in the circuits in which the breaker is inserted, and also manually by pushing the tripping pushbutton provided on the control mechanism. The breaker can be operated by the local control switch on the switchgear when the breaker is in the "test" position, and the test jumper plugged in between the stationary and removable elements.

A mechanical interlock is provided for each circuit breaker to prevent the following:

(1) Removing the removable element from, or placing it in, the operating position while the circuit breaker is in the closed position.

(2) Closing the circuit breaker while the removable element is being removed from, or placed in, the operating position.

(3) Closing the circuit breaker unless the primary disconnecting devices are in full contact or separated by a safe distance.

To remove the removable element of the circuit breaker from the operating position for inspection, the breaker is provided with an elevating mechanism and is equipped with trucks having adjustable wheels. The removable element of the breaker inserted in the elevating carriage is lowered by motor operation and is withdrawn from the carriage to the inspection or test position.

Power buses in the powerplant consist of those in the generator voltage switchgear assemblies. The buses are located in compartments formed by metal plates, some of which are removable to provide access to the buses. The insulated bus is designed to withstand magnetic stresses developed by currents equal to the power circuit breaker momentary and interrupting ratings.

One set of three 2,000/5-ampere ratio current transformers is mounted in the generator main power bus section and one set in the bus section between each Government camp circuit breaker and the Government camp tap, for transformer differential relaying protection. Two other sets of three 2,000/5-ampere ratio current transformers are mounted in each generator main power bus section, one set of which is for generator differential relaying protection and the other for generator instrumentation and metering. These transformers were furnished by the General Electric Co. and were designated by the manufacturer as type JS-2. They are of the window-type construction without primary windings, and are mounted around the switchgear bus.

One set of three 75/5-ampere ratio current transformers (General Electric type JS-1) is provided in the bus section between each Government camp circuit breaker and the Government camp tap, for overcurrent protection and metering of the feeder to the Government camp transformer KW3A. The three secondaries of the wound-primary constructed current transformers are connected in wye.

The potential transformers are mounted in fabricated metal compartments of isolated phase construction and on movable supports equipped with primary and secondary disconnecting devices. When the potential transformers are disconnected and drawn out, they are at a safe striking distance from all live parts of the switchgear. A current limiting fuse with high interrupting rating is inserted in each primary circuit. In addition, a grounding device is provided which contacts the fuses when the potential transformer is disconnected, effectively discharging the transformers. In this position the transformer fuses can be safely removed and replaced.

Two sets of two 400-volt-ampere, 7,200/120-volt, 60-cycle, potential transformers (General Electric type JE-42) are mounted in compartments on top of each main generator breaker cubicle and connected to the main generator buses. One set is used to furnish potential for the generator voltage regulator and voltage restrained overcurrent relays and the other set for generator metering, instrumentation, and synchronizing.

One set of two potential transformers, similar to those described above, is connected to the Government camp bus and mounted in a compartment on top of cubicle UCA3 which houses one of the Government camp breakers. These transformers are used for metering of the feeder to the Government camp transformer.

The following auxiliary devices associated with the switchgear equipment are listed with their device designation:

8	Control power switch
52	A-c circuit breaker
52/LC	Latch check switch for 52
52CS	Control switch for 52
52STA	Stationary auxiliary switch to 52
52H, 52H-1	Limit switch for 52
52TS	Test switch for 52
52X	Auxiliary relay for 52 (closing)
75	Position changing mechanism for 52
75CS	Control switch for 75
75M	Motor for 75
75X	Auxiliary relay to 75

(d) *Main Power Cables.*-- Varnished-cambric-insulated cables were selected for connection of the generators, generator voltage switchgear, and main power transformers since this type of cable is satisfactory for the voltage requirement and has a high dielectric strength and is highly resistant to ionization or corona discharge. The cables are provided with lead sheaths which protect against moisture and mechanical injury and are terminated in potheads to protect against moisture.

As a result of a consideration of the generator voltage which may be 5 percent above normal, and the standard voltage ratings supplied by the manufacturer for potheads and power cables, 15-kilovolt grounded neutral power cables and 15-kilovolt potheads were selected. The size of cable, 1,750,000 circular-mils, was selected with the use of the manufacturer's loading tables, considering operating and ambient temperatures, the type of installation, the manufacturer's standard ratings, and future changes in loading.

The generator and generator voltage switchgear assemblies are electrically connected together by six single-conductor 1,750,000-circular-mil, varnished-cambric-insulated, lead-covered cables enclosed in nonmagnetic conduits mounted on racks and terminated in potheads. Power is carried from the potheads at the switchgear assembly to potheads at the power transformers by the type cable described above enclosed in duct banks of nonmagnetic conduits.

Size No. 2 AWG 15-kilovolt single-conductor cable with rubber-like insulation, one cable per phase, was selected for connections between the metalclad switchgear and the Government camp and station-service transformers. The three cables for each transformer are enclosed in a metal conduit.

The size of the cables was based on the transformer capacity and short-circuit conditions, the latter of which proved to be the governing factor. Cable was selected which would not melt under fault conditions during the time required for the power circuit breaker to open the circuit. This was necessary in order to avoid difficulty in replacing cables which had been subject to short-circuit conditions.

Enough of the above cable was ordered in addition to that required for the station-service and Government camp transformers to provide a connection between the generator neutral and the neutral grounding transformer.

60. Governors. - The purpose of each 42,000 foot-pound governor is to maintain constant speed of its generating unit for any load, by controlling the gate opening of the turbine. The gates are normally positioned by an oil-pressured servo-mechanism controlled by a speed-sensitive unit, and a restoring mechanism connected to the gates. The governor is required to start corrective movement of the wicket gates upon a speed change of 0.06 percent or less. Provision is made for automatic shutdown without interfering with normal operating devices.

The servomotors are operated by oil having a viscosity of 300 Saybolt seconds Universal at 100° F., under pressure of 150 pounds per square inch from the governor pressure tank. The force is applied to a lever which turns a vertical shaft connected to the turbine gate linkage. By controlling the oil supplied to the servomotor, the governor controls the gate opening, and has the capacity to effect a complete opening or closing stroke in 3 seconds, with an effective hydraulic head, including water hammer, of 1,150 feet on the turbine. A decelerating device slows the motion near the end of the stroke. The governor is equipped with means for adjusting the rate of gate movement between 3 and 10 seconds, so arranged that any other device cannot cause the rate of movement to exceed the rate for which it is adjusted.

The capacity of the oil pressure tank is adequate to operate the gates through several opening and closing cycles with the oil pump inoperative. The pump has capacity to provide three strokes of the servomotor per minute.

The speed-responsive element is driven by a synchronous motor receiving its power from a permanent magnet generator, used exclusively for this purpose, and direct connected to the shaft of the main generating unit. The design of the permanent magnet generator is compatible with the generating unit in regard to runaway speed, and vertical movement of the shaft. The enclosure for the permanent magnet generator contains direct-connected speed switches and a rectifier-resistor pack for operating the speed indicator.

A new type of dead stop and breakaway indicator for the turbine was furnished with the governor. By varying the air gap as the element rotates, a light is caused to glow intermittently. When it burns or remains off continuously, it indicates that the unit is at a standstill. This type of indicator permits remote indication, which was not possible with the type used in the past.

The basic operating control mechanisms of each governor are as follows:

(1) *Gate limit.*-- Imposes a definite limit of the load without loss of shutdown protection. It is used to control the unit during starting and to prevent overload of the generator.

(2) *Speed changer.*-- This device can vary the speed level called for by the governor from 85 percent to 105 percent of rated speed. It is used during synchronizing with the system frequency, and, in combination with the speed droop control, to adjust the amount of load assumed by the unit.

(3) *Speed droop.*-- This is expressed as the percentage that the normal speed at full load is less than that at no load. The speed droop control adjusts from 0 to 5 percent below the speed level and is used to make each unit take its desired share of the load.

(4) *Partial shutdown.*-- This causes the wicket gates to return to a predetermined speed-at-no-load position through the action of a solenoid-operated switch which is actuated by a number of protective devices. Upon arrival at this position, the control is automatically returned to the speed-responsive element of the governor and the unit is ready to be resynchronized and loaded, provided the trouble has been cleared, or has cleared itself.

(5) *Shutdown.*-- This mechanism disconnects the unit from the line, closes the wicket gates, and intermittently applies the brakes after deceleration to about 20 percent speed, bringing the unit to a stop. The generator brakes are applied under the control of a timer and solenoid-operated air valve. The brakes then remain on for an adjustable period of time unless released manually or by opening the wicket gates. Use of the shutdown mechanism is reserved for serious trouble indicators. The shutdown solenoid must be manually reset at the governor before the unit can be restarted. The brake control can be removed from automatic operation and controlled manually at the governor cabinet by means of the air brake control knob. Manual application of the brakes occurs each time the knob is moved to "Manual" and held, provided that the turbine gates are closed and the speed has decreased to the proper level.

A self-priming rotary-type oil pump, direct-connected to an induction motor, is provided in each governor, and located in the cabinet. Automatic controls cause the pump to start when the oil pressure in the pressure tank drops to a predetermined value and to stop when the pressure rises to a predetermined value. Each governor is provided with a sump tank, located in the base of the governor cabinet. The tank is provided with an oil-level gage, drain and fill connections, and a handhole for access to the interior.

Each governor pressure tank is provided with an oil level sight gage, with both manual and automatic means for shutting off air and oil discharge in the event of breakage of the gage glass. Provision is made for air release, and for charging with air from a portable compressor when required. A device prevents air from entering the oil piping system. A float-operated switch sounds an alarm upon low oil level. A manhole provides access to the interior of the tank.

Inspection doors are provided in the governor cabinets for access to the various equipment. All instruments and controls are self-supporting to permit removal of the cabinet for maximum accessibility for major repairs and maintenance, without interfering with the normal operation of the governor.

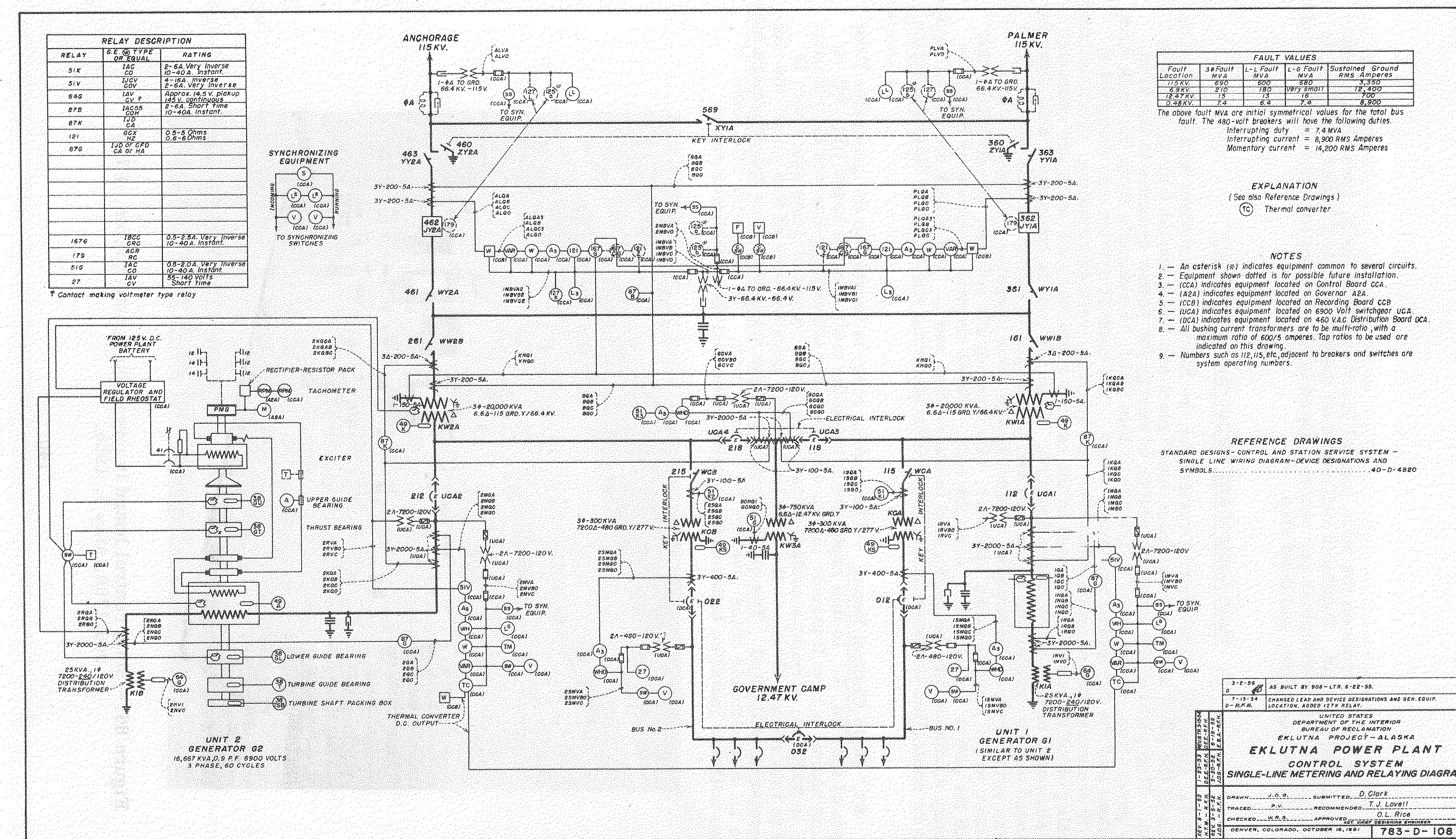


Figure 85. --Eklutna Powerplant control system--Single-line metering and relaying diagram.

Duplicate controls on the main control board are gate limit, speed level, shutdown, and speed-no-load. Duplicate indicators on the main control board include gate position, gate limit, revolutions per minute, speed level, alternating- and direct-current oil pump indicating lights, and dead stop.

E. Main Control and Station-Service System

61. General. - The control system for the Eklutna Powerplant was designed on the basis of the plant serving as a "base load" plant and being attended at all times by two men. This plant is the primary source of energy for power systems in the area. Standby generation, in the event of trouble at this plant, is available from the Knik Arm steam plant and the Air Force and Army bases. The control system was designed so that, with the exception of unit auxiliaries, all starting, voltage adjusting, synchronizing and loading of units can be performed in the control room when the units are restarted after a shutdown of only a few hours duration. When the unit is completely shut down for an extended outage, restarting of the unit and bringing it to approximately synchronous speed are performed at the actuator cabinet by the floor operator. Control is then turned over to the control-room operator, who then adjusts voltage, synchronizes the unit with the power system, and loads the unit. Either normal shutdown or complete emergency shutdown may be performed in the control room. The major electrical equipment to be controlled is shown on the single-line metering and relaying diagram, figure 85.

62. Main Control Room. - The control room is located on the generator floor upstream of unit No. 2. In this room are located the main control board (fig. 86), a recording board, a type B master clock, and the main alternating-current distribution board. In addition, a remote control console for radio communication equipment is located in this room. Owing to the relatively small physical size of this plant, the control room area is limited. The close proximity of the station-service transformers may produce an objectionable noise level in the control room. To minimize this noise, a partition wall was installed between the control room and the switchgear room.

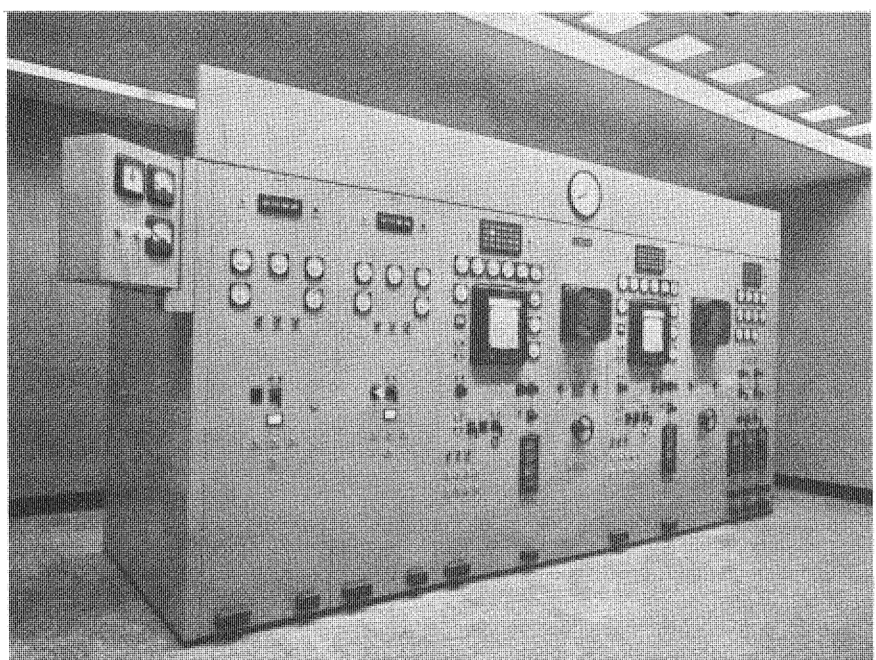


Figure 86.--Main control board in powerplant control room. P783-908-1760, May 3, 1955.

The main control board is of the duplex type with stationary front and rear panels and with doors at each end for access to the interior. All voltage regulating and excitation control equipment, including exciter field rheostats, is mounted on this board. This equipment was located on the main control board for the convenience of the operator and because the equipment used required local manual control rather than remote control. The recording board is of the hinged duplex type of construction, with hinged front panels and stationary rear panels. This type of construction was chosen because of restrictions in available space. All recording equipment, with the exception of unit temperature recorders, was located on this board in order that space would be available on the main control board for excitation equipment.

(a) *Control Equipment.*-- All unit auxiliaries are started and stopped at the equipment either manually or automatically by the use of pressure switches, limit switches, etc. When a unit is shut down by protective relays or by the emergency shut down control switch, it cannot be restarted from the main control board. The floor operator must reset the shutdown solenoid and restart the unit before turning over control to the control room operator. This precaution was taken in design to insure that all trouble would be checked before restarting is attempted.

All unit controls such as turbine gate limits, speed adjustment, voltage adjustment, excitation control and cooling water valve control can be actuated by the operator at the control board. In the event of emergency the operator at the control board can close both butterfly valves and the fixed-wheel penstock gate. Under normal shutdown conditions, the gate limit is returned to the zero position and the shutdown solenoid is not operated. This permits restarting from the control board without resetting the shutdown solenoid. To assist the operator when shutting down or starting up a unit, a flashing red lamp is used to indicate breakaway and dead stop of the unit. Control of all 115-kilovolt and 6.9-kilovolt circuit breakers and the 480-volt supply and tie breakers is provided on the main control board. In the event of complete loss of station-service power due to shutdown of the plant by protective relays, power can be restored to the station-service transformers by closing one of the 115-kilovolt breakers and drawing power from customer's systems until a unit is restarted.

(b) *Protective Relaying.*-- Each generator is protected by differential relays and ground relays with back-up protection for the generator voltage system or high-voltage lines being provided by voltage-restrained overcurrent relays. Operation of the differential relays will shut down the unit completely and also cause discharge of carbon dioxide gas into the generator enclosure. The transformer differential relays provide protection for the transformers and the 6.9-kilovolt switchgear. Overcurrent relays provide protection for each of the station-service and the Government camp feeders. Operation of the transformer differential relays and the 6.9-kilovolt feeder overcurrent relays causes both generator breakers and both high-voltage breakers to trip, to insure clearing of the fault. Since this means that all sources of power for station service are lost, it was necessary to provide for complete shutdown of both units after operation of these relays, since excitation requirements of the generators would cause an excessive drain on the station battery. Operation of these relays, however, does not cause discharge of carbon dioxide gas into the generator housing. Complete shutdown of the unit is also effected when carbon dioxide gas is discharged into the generator housing by action of the thermal links in the generator or operation of the manual break glass stations.

Overspeeding of the units due to sudden reduction of load will not cause shutdown of the units unless mechanical difficulties in the governing system permit the speed to go above the full-load rejection overspeed setting. In this event, an overspeed switch will cause the shutdown solenoid to energize, thereby closing the wicket gates. If the unit is still connected to the power system, the unit "emergency close" switch must be operated to isolate the unit from the system.

Each 115-kilovolt line is protected by distance relays of the reactance type and directional overcurrent ground relays. Although provision is made for installation of carrier relaying equipment and automatic reclosing facilities, including synchronism and potential check relaying equipment, it is unlikely that this equipment will be needed until such time as a major expansion of high-voltage Bureau systems is developed in Alaska. Another factor which influenced the decision to eliminate carrier relaying equipment at this time is the relatively low incidence of lightning disturbance in the area.

(c) *Metering and Indication.*-- The following metering and indication is provided:

(1) Units:

Unit speed at the control board and the actuator.
Main field amperes at the control board.
Temperature recording (recorder automatically selects standard ASA 10-ohm resistance temperature detectors in the stator winding, thrust bearing, upper and lower guide bearings and the main transformer). The recorder is located on the main control board.
Watthours, operating time, amperes, watts, reactive volt-amperes and unit volts, on main control board.
Turbine gate limit and position settings at the main control board and the actuator.
Turbine speed level setting at the main control board and the actuator.
Station total watts and station frequency recording on the recording board.

(2) 115-kilovolt lines:

Line amperes (3-phase) on main control board.
Line megawatts (indicating) on main control board.
Line megavars (indicating) on main control board.
Line megawatts (recording) on recording board.
115-kilovolt bus volts (recording) on recording board.

(3) Station-service equipment:

Line amperes and watthours for each station-service and Government camp feeder on main control board.
Bus volts for each 480-volt bus of board DCA on main control board.

The plant total megawatt recorder was manufactured by the Leeds and Northrup Co. and has space and power to accommodate two retransmitters for totalizing. The station frequency recorder was also manufactured by Leeds and Northrup and is provided with space for future accessories for automatic load and frequency control. When the power systems in the Alaska area develop to a point where automatic tie line load and frequency control becomes economically feasible and necessary, this recording equipment can easily be converted to such service.

(d) *Annunciation.*-- The annunciation system provides individual illuminated indication at the main control board for each trouble source and the sounding of an audible alarm in the generator room. The alarm horn has sufficient intensity so as to be easily heard at any point in the plant. Separate annunciator groups are provided for each generator, for station-service equipment, and for each line. A red group lamp adjacent to each annunciator lamp group lights when trouble occurs and directs the operator's attention immediately to the system in trouble. A horn reset, a lamp reset, and a test pushbutton are provided for each annunciator group. To prevent annunciation for such troubles as low governor oil pressure, generator cooling water trouble and turbine bearing pump trouble, at times when the unit is completely shut down, a latching relay controlled by the governor solenoid reset switch is used to prevent annunciation until the governor solenoid is reset and the unit is ready for starting.

63. Grounding System. - Since the powerplant is supported on closely spaced H-beam steel piles, it was decided not to place a grounding mat under the foundation of the plant, so as to eliminate the possibility of electrolytic interaction of the copper in the mat and the steel piles, with resultant corrosion of the steel. In lieu of a mat under the foundation of the plant, a separate mat was placed at the bottom of the excavation in the service area outside the machine shop prior to backfilling of the area to grade. The ground mat was connected to a ground terminal box in the plant. The grounding system in the plant was then extended from this box to ground all electrical equipment and nonelectrical equipment such as handrails, hatch frames, ladders, steel columns, etc. The grounding mat was designed to carry a sustained ground fault current of 12,400 amperes, root-mean-square, for 14.3 seconds.

64. Station-Service System. - (a) *Alternating-Current System.*-- The station-service system consists of two 300-kv.-a., 7,200-delta to 480-volt grounded wye distribution transformers, two high-side disconnect switches for the transformers, two low-side bus duct interconnections to distribution board DCA, the distribution board DCA, and miscellaneous power cabinets throughout the plant. A bus duct interconnection between the transformers and the distribution board was chosen because of restricted space between the board and the transformers. This eliminated the necessity of routing large cables through oil room spaces below or utilizing an unsightly conduit installation above the floor level. The distribution board DCA is enclosed on top and sides by a partition wall to aid in minimizing noise level in the main control room.

Distribution board DCA is a metal-clad switchgear, containing two supply and one tie breaker of the electrically operated withdrawal type and three distribution panel sections, containing breakers of the molded case type. In addition, the board contains a test panel providing three voltages; namely, 460 volts alternating current, 120/240 volts alternating current, and 125 volts direct current. The distribution panel sections feed power to distribution cabinets and to miscellaneous single loads in the powerplant and at the fixed-wheel gate house. Control of the tie and supply breakers is arranged so that it is impossible to close all three breakers at the same time. Control is also arranged so that on tripping of either supply breaker by any means except overload trip, the tie breaker automatically closes to pick up the load. Control switches at the main control board initiate closing or tripping of the supply breakers and permit closing of or cause tripping of the tie breaker. Distribution cabinets furnished are divided into three classes; namely, dead front recess type, dead front exposed wall-mounted type, and dead front control center type. For a complete listing of loads fed from the various boards and cabinets comprising the low-voltage alternating-current station-service system, refer to the single-line wiring diagram, figure 87.

(b) *Direct-Current System.*-- The 125-volt direct-current station-service system consists of a 125-volt storage battery, two static-type battery chargers, a subdistribution point on the main control board, and a subdistribution point on the recording board. Normal and emergency direct-current feeders were supplied to the main control board from the battery chargers. Selection between these two sources of power was made by an automatic transfer contactor on the main control board.

(1) *Storage battery.*-- The 125-volt battery consists of 60 cells and has a 320-ampere-hour capacity at the 8-hour discharge rate. The battery is mounted on metal racks without side rails (fig. 88). Although this plant is in a major earthquake area, calculations showed that the intensity of known shocks would not be sufficient to cause overturning of the cells. Therefore, earthquake-proof-type of supports for the battery were not provided. The battery size was chosen to provide adequate capacity to carry normal direct-current loads for at least 4 hours, in event of battery-charger alternating-current-feeder failure, before terminal voltage drops below a safe limit. It would be imperative to have the alternate battery charger placed in service during the above time interval, to insure that adequate direct-current voltage would be available for necessary operation of the plant. If battery charger failure is due to complete loss of station service, the plant must be shut down and emergency load requirements on the battery would thereby be reduced to a point where the battery could carry the load for approximately 6 hours before terminal voltage would drop below safe limits. The battery cells were furnished by the Electric Storage Battery Co., and were designated by the company as type EME.

(2) *Battery chargers.*-- The battery charging equipment consists of two dry-disk static-type automatically controlled chargers. One charger is used for normal direct-current service, and the other charger is used as a standby source. Mounted on these chargers are feeder breakers for normal and emergency service to the main control board and normal service to the recording board. A nonautomatic breaker is provided to disconnect the station battery from the system. Alarm relays are provided on the chargers to detect loss of alternating-current supply to the chargers, loss of direct-current supply to the recording board, and low battery voltage. Ground detecting equipment is also supplied on the chargers. Dry-disk static-type chargers were selected for this plant to minimize maintenance requirements. Two chargers are provided because of the necessity of maintaining reliable direct-current power to the excitation systems of the generators.

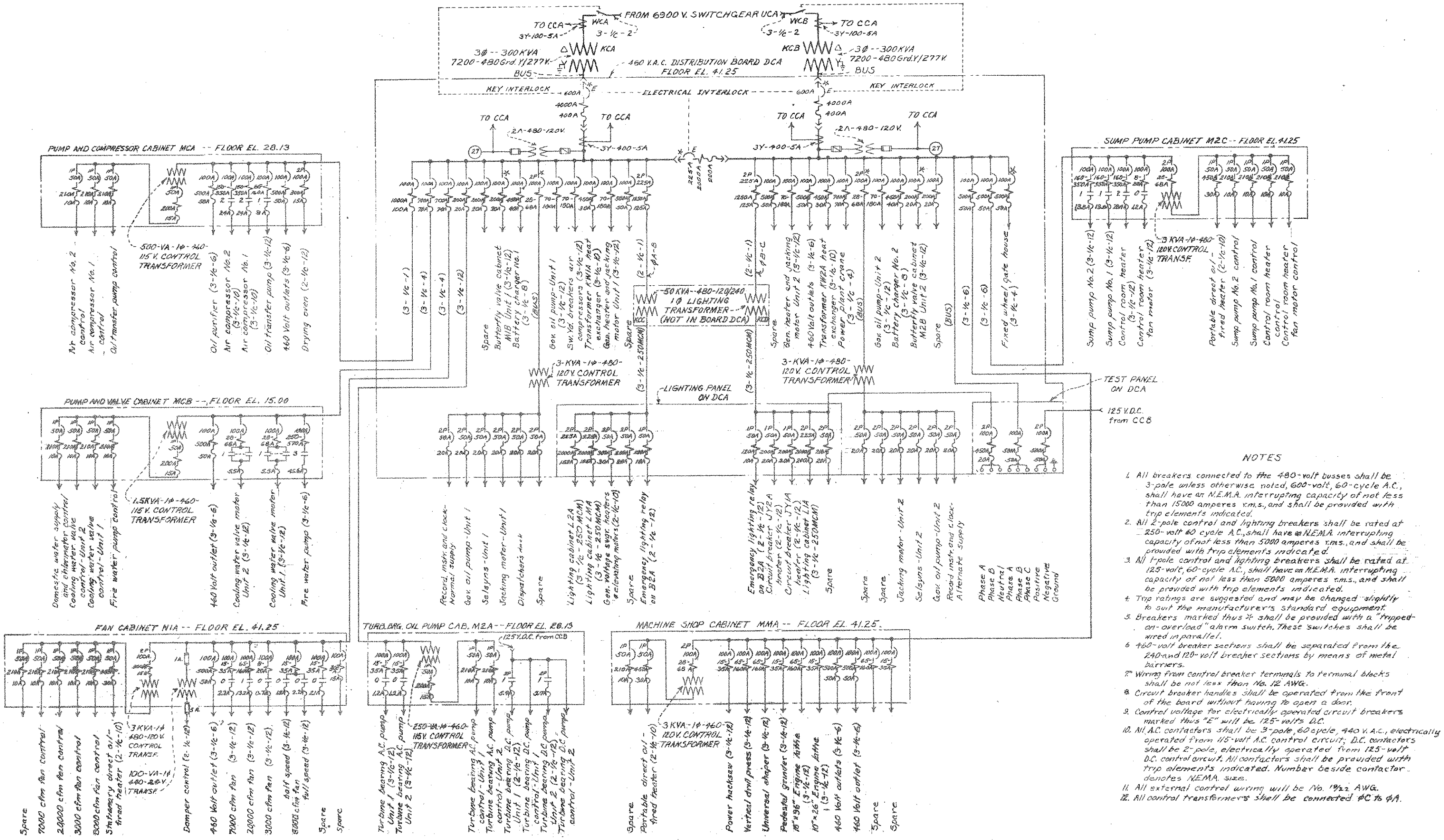


Figure 87.--Single-line wiring diagram for 460-volt alternating-current distribution system. From drawing 783-D-309.

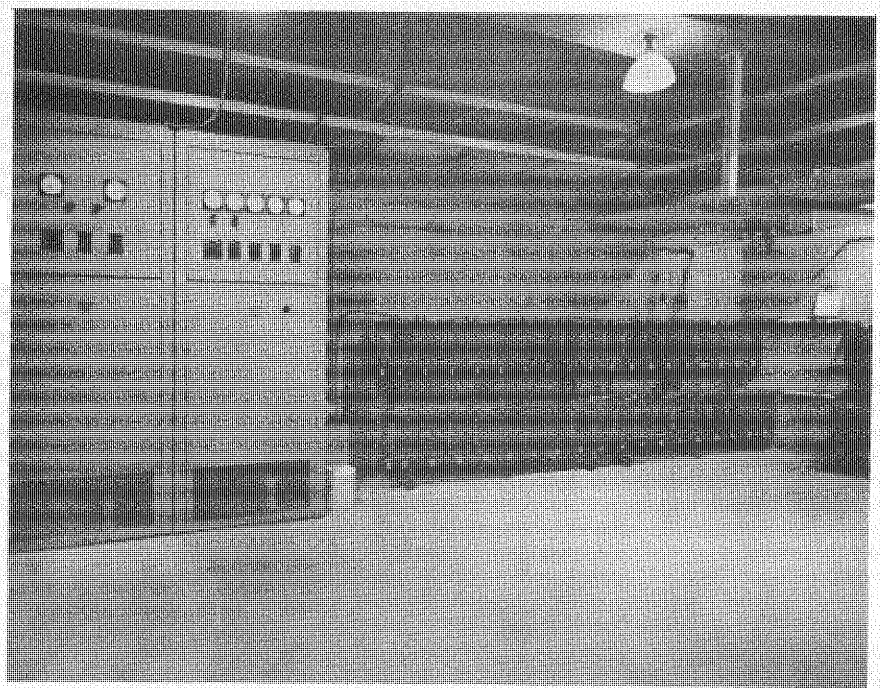


Figure 88.--Battery chargers and batteries for direct-current station-service system. Note cable trays in upper portion of photograph. P783-908-1766, May 3, 1955.

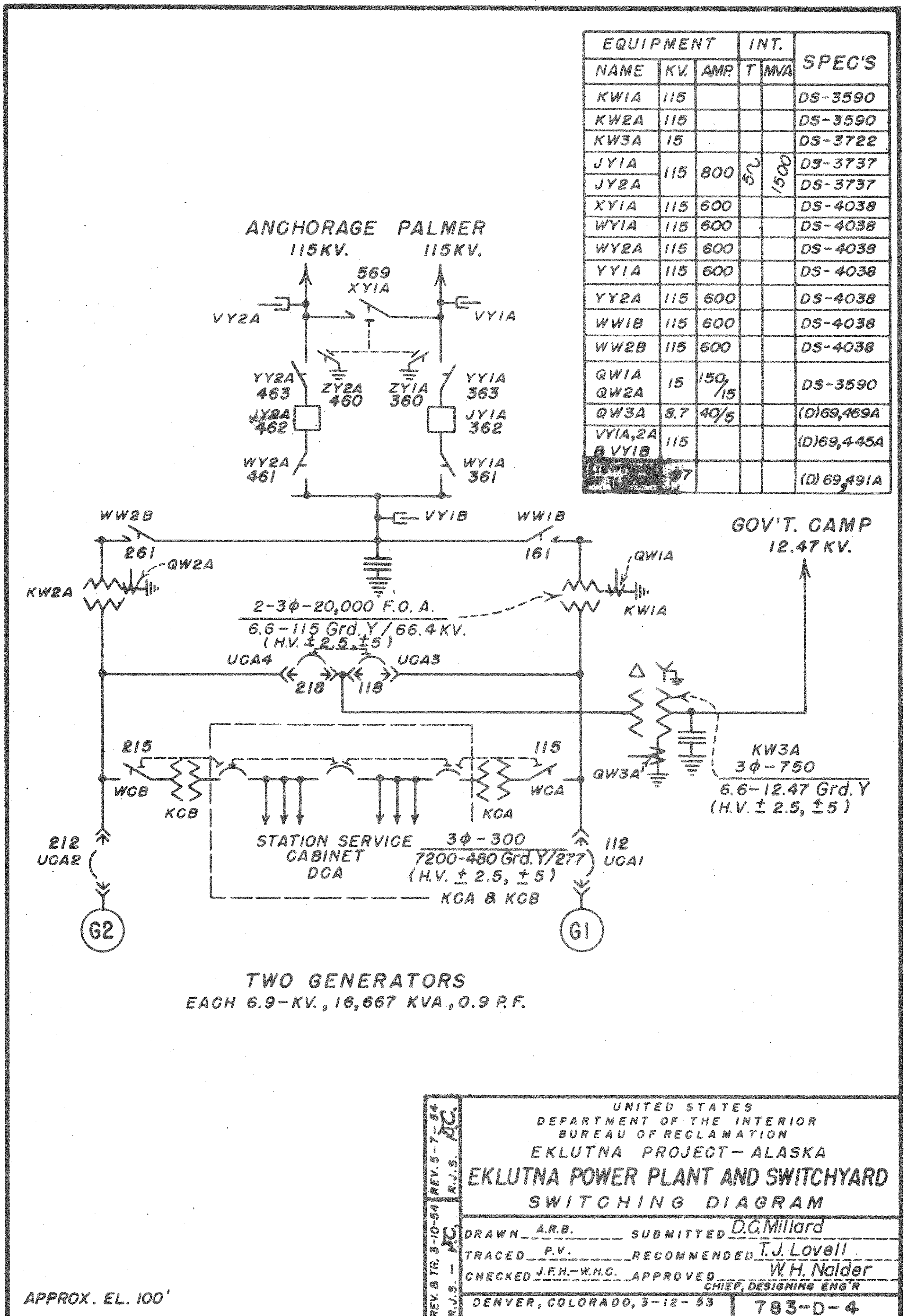
F. Switchyard

65. General Description. - The switchyard and the switching equipment used are located at three different elevations. The switchyard, consisting of the power circuit breakers, disconnecting switches, and main buses, is located on the roof of the powerplant at an elevation of 92 feet above sea level. The main power transformers that "step-up" the generator voltage are located adjacent to and southwest of the powerhouse at elevation 41.25. The high-voltage bushings of these main power transformers are connected to an intermediate or "tie bus" which is located on the roof of the control room at elevation 58.54, and the tie bus extends to the main switching equipment located on the roof at elevation 92.50.

The 115-kilovolt bus structure on the powerplant roof consists of two bays which supply the 115-kilovolt bus structure lines to the cities of Palmer and Anchorage, Alaska. The line to Anchorage leaves the switchyard in a westerly direction, and the line to Palmer leaves the switchyard in an easterly direction. In addition, there is a 12.47-kilovolt line consisting of No. 2/0 AWG aluminum cable steel reinforced which is used to supply the Government camp from a small 3-phase, 750-kv.-a. transformer energized from the low-voltage generator leads. This transformer is designated KW3A, and is located adjacent to and south of the powerhouse at elevation 41.25.

The switching arrangement is shown on figure 89, and the arrangement of the electrical equipment and the bus is shown on figures 90 and 91.

The 115-kilovolt switchyard has only one main bus, and connections are made from it to the circuit breakers by means of a lower or "jack" bus. The buswork is of the conventional strain type, using No. 4/0 AWG copper cable and suspension-type insulators attached to a conventional steel "lattice type" structure. The 115-kilovolt Palmer



EQUIPMENT			INT.		SPEC'S
NAME	KV.	AMP.	T	MVA	
KW1A	115				DS-3590
KW2A	115				DS-3590
KW3A	15				DS-3722
JY1A	115	800	5~	1500	DS-3737
JY2A					DS-3737
XY1A	115	600			DS-4038
WY1A	115	600			DS-4038
WY2A	115	600			DS-4038
YY1A	115	600			DS-4038
YY2A	115	600			DS-4038
WW1B	115	600			DS-4038
WW2B	115	600			DS-4038
QW1A QW2A	15	150/15			DS-3590
QW3A	8.7	40/5			(D)69,469A
VY1A,2A & VY1B	115				(D)69,445A
[redacted]	7				(D)69,491A

Figure 89.--Eklutna Powerplant and switchyard--Switching diagram.

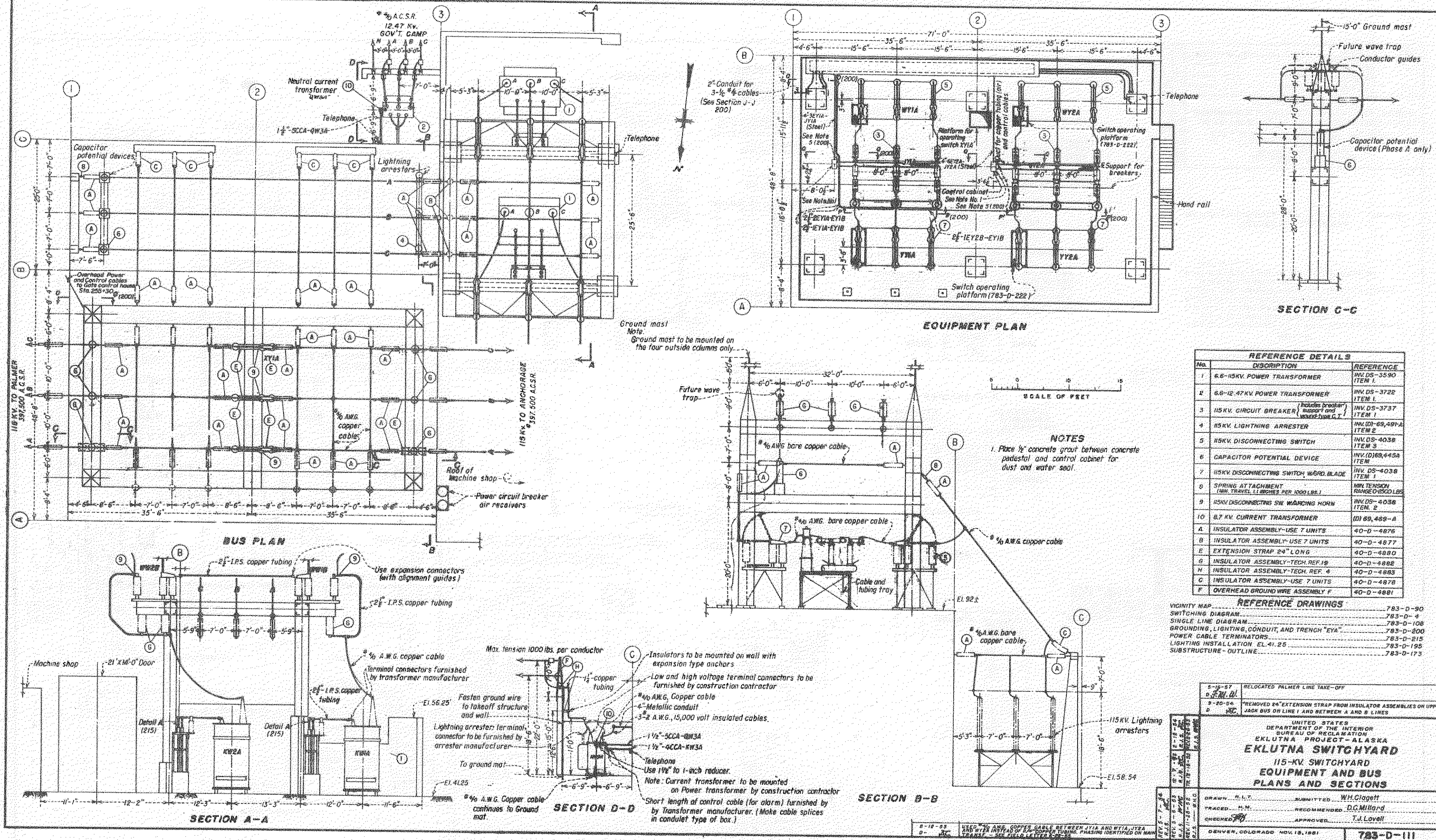


Figure 90.--115-kilovolt switchyard equipment and bus--Plan and sections.

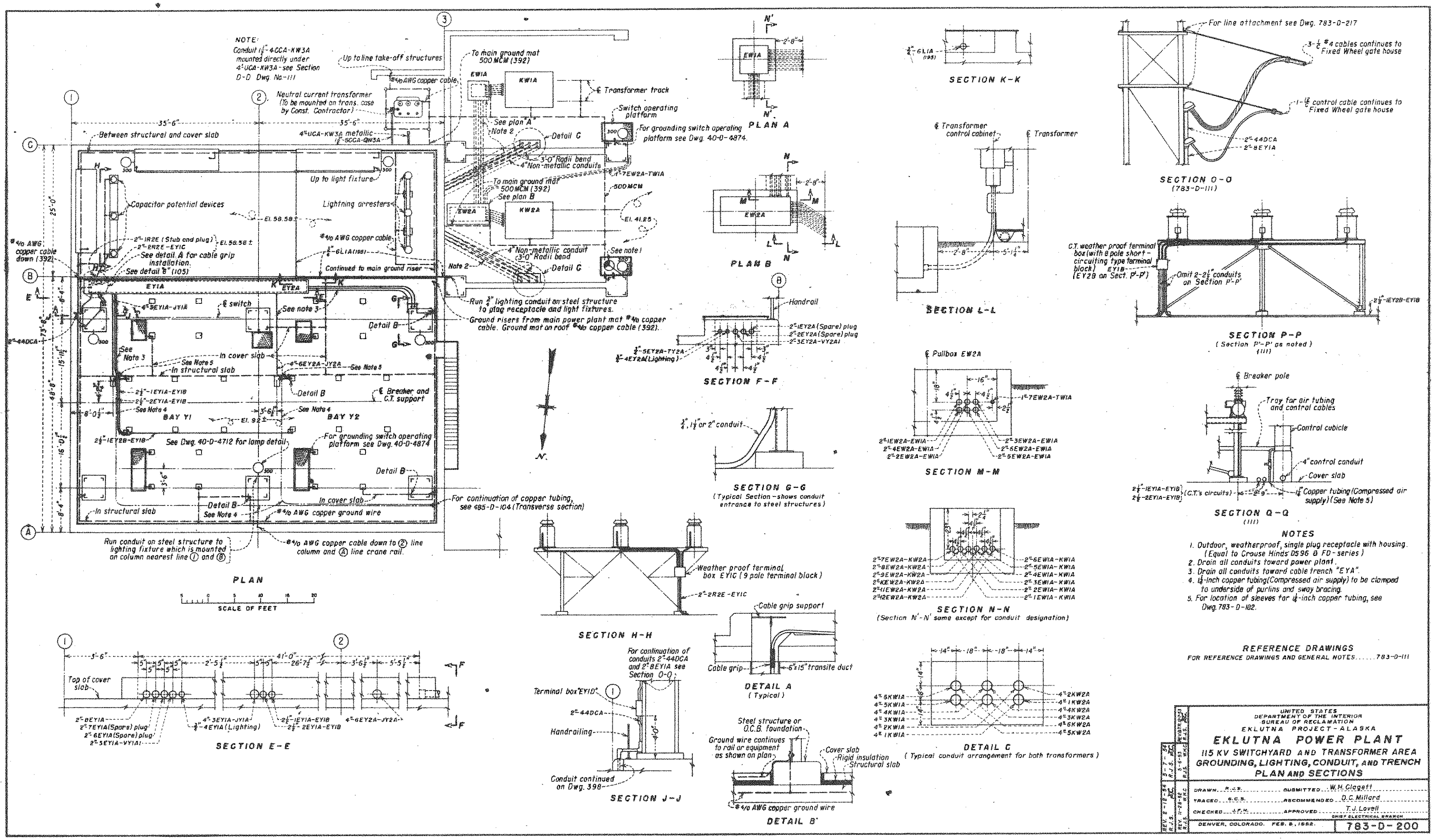


Figure 91. --Grounding, lighting, conduit, and trench for 115-kilovolt switchyard and transformer area--Plan and sections.

and Anchorage lines are each equipped with a 115-kilovolt breaker of the airblast type. Disconnecting switches are placed on either side of the breaker so as to permit its removal from service in case of needed maintenance or repairs. The switches on the line side are equipped with grounding blades, and these are interlocked together and to a bypass switch. The bypass switch is normally in the open position, and is connected between the Palmer and the Anchorage transmission lines. This switch would be closed only under unusual circumstances, such as the Eklutna Powerplant being unable to energize one or both of these transmission lines, or when a 115-kilovolt power circuit breaker is taken out of service for maintenance. In either event the switch would be used to complete and make a closed circuit from Anchorage to Palmer. The circuit from each of the main power transformers (designated KW1A and KW2A) is equipped with 115-kilovolt disconnecting switches of the air-break type, equipped with arching horns and placed on 10-foot phase spacing. These switches are normally closed.

The low-voltage bushings of each of the power transformers are connected to the extended low-voltage generator leads by means of 2-1/2-inch iron-pipe-size copper tubing and flexible braid connectors.

The structure at the Eklutna switchyard is equipped with ground peaks, but no overhead ground wires are provided because of the low lightning incident rate in this area.

One set of lightning arresters is used for protection of both main power transformers and is located at an elevation of 58.54 feet above sea level. These arresters are connected to the tie bus which connects the high-voltage bushings of the power transformers to the main bus. The coupling capacitors with potential devices for supplying the potential for line relaying and synchronizing are also attached to this tie bus at the same elevation as the arresters.

66. Power Circuit Breakers. - (a) *General Description.*-- Two power circuit breakers are installed in the 115-kilovolt switchyard, one is in each of the two bays in positions 362 and 462 (figs. 89 and 92). The two breakers are for normal operation on the 115-kilovolt Palmer and Anchorage lines respectively. These breakers are of the 3-pole, outdoor, full-automatic type, and have the following ratings:

Voltage rating (volts)	115,000
Continuous current rating (amperes)	800
Interrupting capacity (kilovolt-amperes)	1,500,000
Interrupting time rating (cycles)	5
Reclosing time rating (cycles)	20

The 115-kilovolt power circuit breakers have the following accessories:

(b) *Compressor System.*-- The air compressor system is fully automatic and is designed to operate at 426 $\pm$ pounds per square inch. This air pressure is reduced to 225 $\pm$ pounds per square inch through a pressure-reducing valve to provide the required operating air pressure to the breakers. The compressor system is located on the balcony of the machine shop and consists of two compressors, two control racks (one for each breaker), and four compressed air receivers. Two of the four air receivers are mounted directly above the roof of the machine shop on the outside of the west wall of the powerplant. The schematic piping arrangement for the compressor air system is shown on figure 93.

The compressor motors are supplied by a 3-phase, 460-volt alternating-current circuit from board DCA located in the main control room. The direct-current control voltage for the power circuit breakers and compressor system is supplied from the main control board CCA.

(c) *Current Transformers.*-- The current transformers are of the double-primary, double-secondary wound type with bushing type current characteristics. They are housed in a separate shell from the circuit breaker and are mounted (one current transformer on each phase) on the same supporting structure as the circuit breakers. The maximum ratio and accuracy of the current transformers are 600 to 5 amperes and 10L 200 respectively.

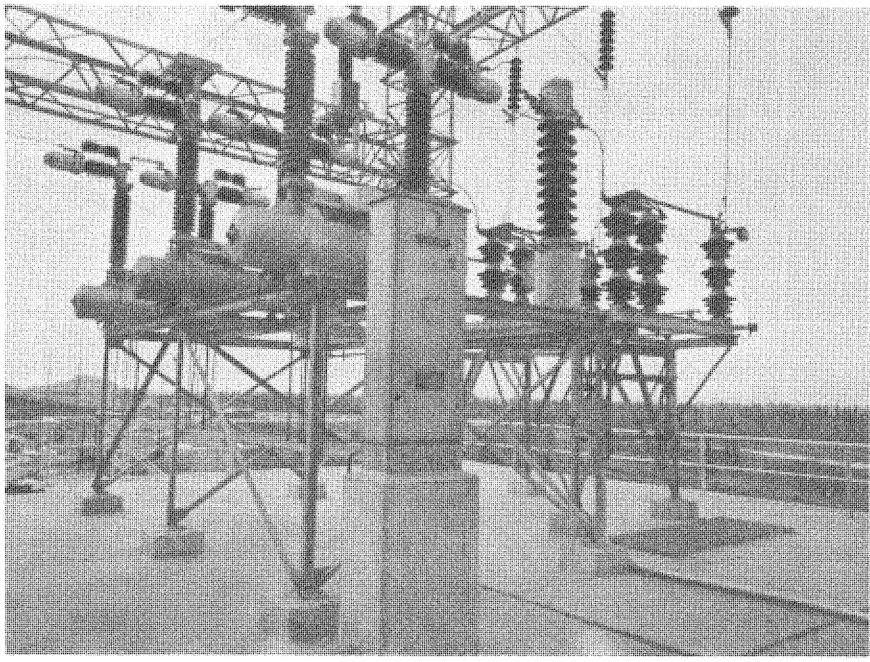
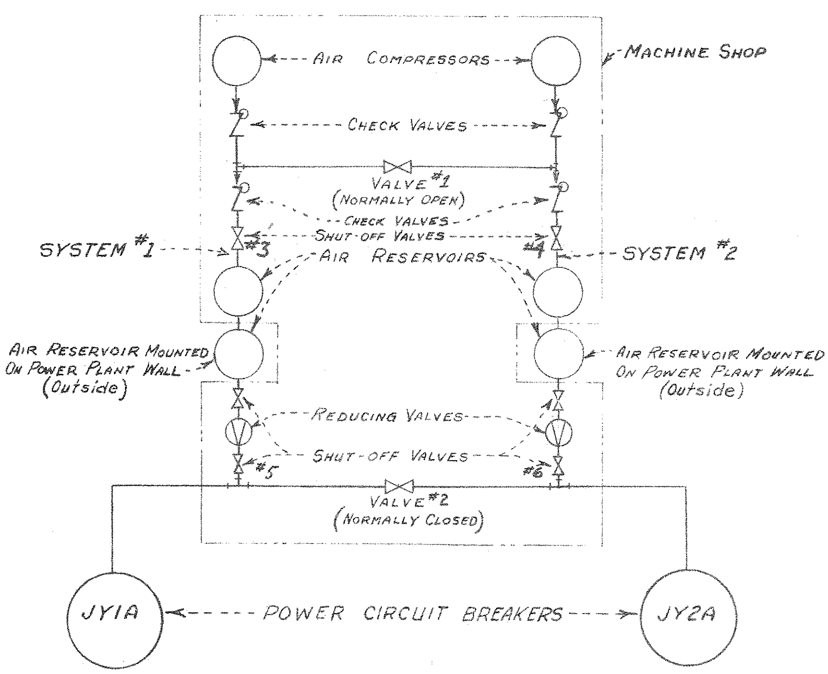


Figure 92.--Air blast breakers and control cabinet. 783-908-1797, May 5, 1955.



EMERGENCY OPERATION

In the event of accidental dumping of air in system designated No. 1, both compressors will then operate to re-establish pressure in the faulty system. Valve No. 1 (Normally Open) should then be Closed permitting System No. 2 to operate in a normal manner isolated from System No. 1. Whenever it is desired to take the air reservoirs out of service, the associated shut-off valves should be closed and the by-pass valve No. 2 opened.

Figure 93.--Schematic piping arrangement of compressed air system for Eklutna switchyard. From drawing 783-D-390.

The current transformers have their secondary leads brought out to accessible short-circuiting-type terminal blocks for connection to external circuits. The current transformers were furnished with the power circuit breakers.

67. Disconnecting Switches. - Four 115-kilovolt, 600-ampere, 3-pole, manually gang-operated disconnecting switches are installed in the switchyard in positions 361, 461, 363 and 463. The switches in the latter two positions are equipped with grounding blades.

Three 115-kilovolt, 600-ampere, 3-pole, manually gang-operated horn-gap disconnecting switches are installed in the transformer area and switchyard. Two of these switches are installed in the transformer area in positions 161 and 261 for breaking transformer magnetizing current. One of these switches is installed as a line to line bypass switch in position 569 in the switchyard. None of the three horn-gap switches is equipped with grounding blades.

68. Lightning Arresters. - Six station-type lightning arresters are installed in switchyard and transformer area as follows:

(1) Three 97-kilovolt rated lightning arresters are mounted on a steel supporting structure on the control room roof at elevation 58.54. The lightning arresters are connected to the tie bus and protect both main power transformers.

(2) Three 9-kilovolt rated lightning arresters are mounted on the high-voltage side of the 6.6- to 12.47-kilovolt transformer.

69. Power Transformers. - The main power transformer installation is located adjacent to the southwest corner of the powerhouse, and consists of two 3-phase power transformers, designated KW1A and KW2A (fig. 94). Each transformer is of the oil-immersed, forced-oil-cooled, forced-air-cooled, outdoor, sealed-tank type, and is rated 20,000 kilovolt-amperes, 6,600 volts to 115,000 volts. The transformers are connected delta on the low-voltage side and solidly grounded-wye on the high-voltage side. The transformers are equipped with two oil coolers and a set of forced-air fans to provide for adequate cooling for loads up to 20,000 kilovolt-amperes. The 3-phase, 220-volt alternating-current supply for the air fans is supplied from an auxiliary transformer mounted on the main power transformer tanks. The transformers are designed for service at rated voltage and capacity at sea level elevation and for a 55° C. rise above a 40° C. ambient temperature. Each transformer has full-capacity taps in the high-voltage winding at 2-1/2 and 5 percent above and below 115,000 volts, with an externally operated tap changer.

Each main power transformer is equipped with the following accessories:

(1) Dial-type thermometer and winding hot-spot temperature indicator.

(2) Winding temperature relay containing three sets of sequence contacts which operate as follows:

For closing second oil cooler circuit. (First oil cooler, located in transformer fan control cabinet, is closed by manual control when transformer is energized.)

For closing a circuit for remote alarm and local lamp indication when the maximum safe operating temperature is approached.

For closing a trip circuit in case the safe operating temperature is exceeded. (This circuit will not be used in the initial installation.)

(3) Liquid level gage.

(4) Pressure relief device. The trigger spring is set at the factory so that tripping will occur at a pressure of 10 to 12 pounds per square inch.

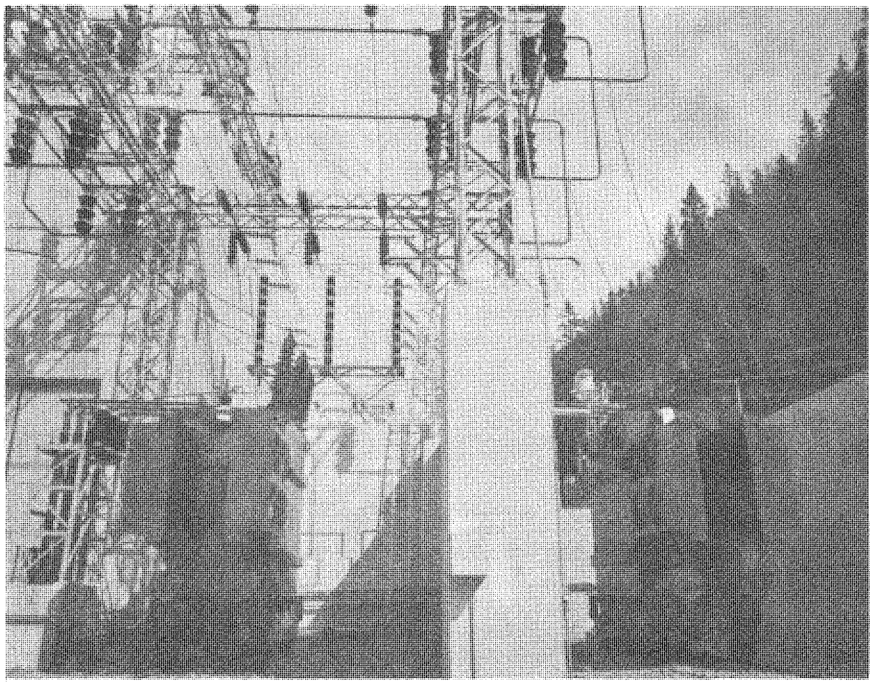


Figure 94.--Transformer structure and two 20,000 kv.-a. transformers. P783-908-1792, May 4, 1955.

(5) Bushing-type current transformers. Two bushing-type current transformers are installed on each high-voltage bushing of each power transformer.

(6) Wound-type current transformers. One wound-type current transformer is mounted on each power transformer case just above the oil coolers. The current transformer is in the high-voltage neutral circuit.

70. Government Camp Service Transformer. - The 3-phase, 6.6- to 12.47-kilovolt transformer is located adjacent to the southwest of the powerplant and is designated KW3A. The transformer is of the oil-immersed, self-cooled, outdoor type, and is rated 750 kilovolt-amperes, 6,600 to 12,470 volts. It is connected delta on the low-voltage side and solidly grounded wye on the high-voltage side. The transformer is equipped with external radiators to provide adequate self-cooling under normal conditions. The transformer was designed for service at rated voltage and capacity at sea level, and for a 55° C. rise above a 40° C. ambient temperature. The transformer has full-capacity taps in the high-voltage winding at 2-1/2 and 5 percent above and below 12,470 volts, with externally operated tap changer. The transformer is of the sealed-tank type, and is equipped with the following accessories:

(1) Dial-type liquid thermometer.

(2) Liquid level gage.

(3) Pressure relief device.

(4) Wound-type current transformer. A wound-type current transformer is mounted on the case of the power transformer, connected in the high-voltage neutral circuit.

71. Gate Control House Electrical Supply. - The gate control house, located at station 255+30, is supplied with 3-phase 460-volt alternating-current power from board DCA located in the main control room of the powerplant. The power and control is fed to the gate control house by two aerial cables (one cable consisting of 3-1/c-4 for power and the other cable 1-12/c-19/22 for control.) These cables take off at the corner of the southeast column of the 115-kilovolt switchyard bus structure at approximately elevation 110.25 and continue to the gate control house.

G. Auxiliary Equipment

72. Cooling Water System. - Conforming to general Bureau practice for high-head plants, cooling water is supplied by jet pumps. Two pumps, each designed to deliver 225 gallons per minute at 40 pounds per square inch pressure are supplied with drive water at about 350 pounds per square inch from a header interconnecting the penstocks. The jet pump suctions are connected to tailwater. Motor-operated valves in the individual drive lines are controlled from the main control board and may also be controlled by local pushbuttons. Each jet pump is intended to supply its own unit only, but interconnection through the emergency supply piping is possible.

The system supplies water to the generator air coolers, generator bearings, lubricating oil cooler for the turbine bearing, and packing box. All cooling water is then discharged to tailwater. Relief valves set at 55 pounds per square inch protect the systems from accidental excess pressure, and a checked bypass from the suction header to one of the relief valves protects this header.

Provision is made for a future supply to the turbine seal rings from this system, in connection with possible future synchronous condenser operation. However, for the synchronous condenser operation contemplated, with water in the spiral case and wicket gates closed, gate leakage would supply ample cooling water and an outside supply would probably not be needed.

An emergency cooling water supply can be obtained from the high-pressure line from unit No. 1 penstock, through a throttle valve and orifice.

73. Domestic and Service Water Systems. - Eklutna Powerplant is attended and it is therefore necessary to provide a reliable source of drinking water. Three sources were considered:

(1) The first source was an existing shallow well used by the construction camp. The water was tested and found to be safe and of good quality, but it would be necessary to trench several hundred feet, below frost depth, and the cost ruled out this scheme.

(2) The powerplant foundation consists of a deep bed of pervious river gravel, from which an adequate supply of water could be pumped. However, it was considered possible that the removal of sand in water from the well over a long period of time might result is some settlement.

(3) The final adopted scheme consists of utilizing penstock water, which passes in sequence through the following equipment at the rate of 6 gallons per minute: strainer, pressure-reducing valve, coagulent feeder, pressure filter, rate of flow indicator, rate of flow controller, hypochlorite feeder, and finally a 525-gallon pressure storage tank. (Fig. 95.) The storage thus provided permitted reducing the instantaneous capacity of the equipment, and acts as a reservoir for filtered backwash water.

A relief valve set at 110 pounds per square inch protects the system from excess pressure. The backwash from the pressure filter is discharged to the station drainage system.

A combination float and pressure switch admits filtered water to the tank and operates a solenoid valve in the station air supply to maintain the water surface at the

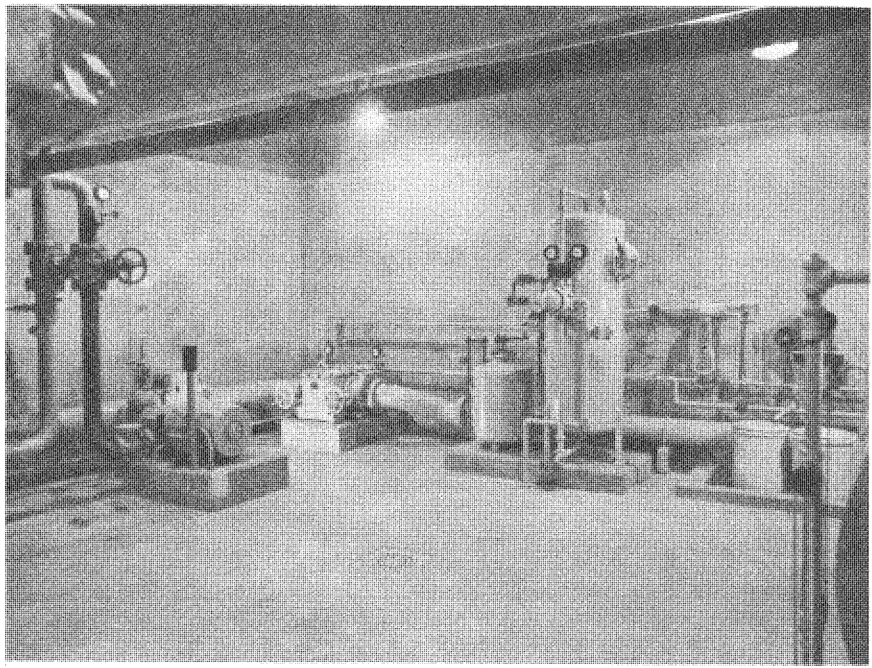


Figure 95.--Interior view of water equipment room showing emergency fire pump, twin strainer, coagulant feeder, pressure water filter, reagent tanks, chlorinator, and related piping. P783-908-1784, May 4, 1955.

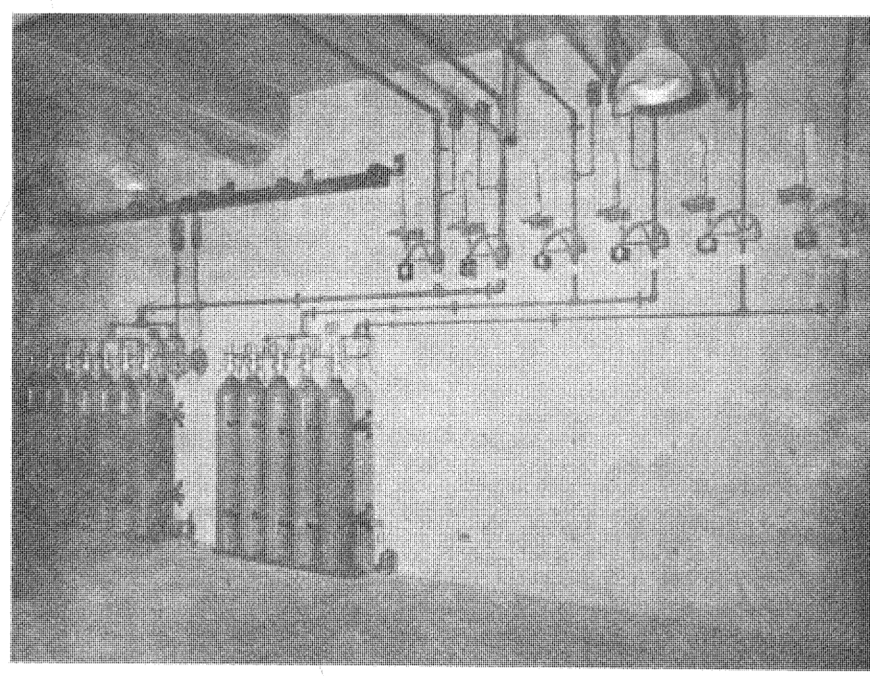


Figure 96.--Carbon dioxide fire protection equipment consisting of tanks, routing valves, and related piping. 783-908-1789, May 16, 1955.

proper level in the pressure tank. A valved bypass permits backwashing the filter with treated water from the pressure tank. The filter may be bypassed for maintenance purposes.

Service water outlets throughout the plant are supplied by this system, which also supplies the domestic water needs.

74. Fire Protection Water System. - High-pressure water in the penstock offered a suitable source for fire protection, and the mains are supplied from this source through a 2-1/2-inch pressure control valve. The penstock will rarely be emptied and the supply to the system is considered quite reliable. However, should the supply from the penstock fail for any reason, a motor-driven emergency pump of 400 gallons per minute capacity is provided, which draws its supply from tailwater through the header which supplies the cooling water jet pumps.

The system supplies 1-1/2-inch fire hoses in cabinets throughout the plant, automatic sprinkler systems in the oil purifier and storage rooms, and manually controlled sprinklers for each of the two main transformers. Because of the extremely low temperatures expected, no 2-1/2-inch outdoor hydrant was provided. A light hose cart with 1-1/2-inch hose, to facilitate handling by one man under adverse weather conditions, is located near the main door. The transformer sprinkler systems are normally dry, and drain automatically after use through a 1/4-inch pipe, or the drainage may be hastened by opening a 3/4-inch valve. Fusible link sprinklers are used on the indoor systems, from which the water is automatically shut off by a weight operated valve if the carbon dioxide gas system is discharged. Flow alarms are provided on the automatic sprinkler systems, and a low-pressure alarm on the main.

For simplicity and economy in piping, tapped connections were made with the fire mains to supply a small sump eductor, manually controlled, and for a temporary connection for cooling water during turbine acceptance tests.

75. Carbon Dioxide Fire Protection. - The generators, being of the enclosed water-cooled type, are adaptable for automatic carbon dioxide fire protection. A common bank of three cylinders for initial discharge and two cylinders for delayed discharge protects either generator through routing valves (fig 96). The initial discharge may be set off by thermoswitches in the generator air ducts, by the differential relays, or by manual operation at the cylinders or at "break glass" control boxes mounted at each generator. The delayed discharge is by manual operation at the cylinders only.

The oil storage and purifier rooms are protected by a common bank of seven cylinders through routing valves. The systems are discharged manually from control boxes outside of each room. They may also be discharged at the cylinders, in which case the routing valves must also be operated manually. Discharge nozzles are located in each room, and one nozzle is located in each of the oil storage tanks. Pneumatic releases are provided for shutting off the exhaust fan, closing fan dampers and fire doors, and shutting off the water sprinkling system. A pressure switch sounds an alarm.

Seven spare carbon dioxide cylinders are provided to serve all the systems.

76. Portable Chemical Fire Protection. - To supplement the water and carbon dioxide fire protection systems, wheeled and hand portable extinguishers using carbon dioxide and carbon tetrachloride are located suitably throughout the plant.

77. Drainage and Unwatering System. - A conventional system of floor drains was provided in the plant, draining to a combined drainage and unwatering sump. Under float switch control, two turbine-type sump pumps (fig. 97) each rated 1,200 gallons per minute at 17 feet of head empty the sump to tailwater. A 25-gpm eductor is also provided to empty the sump completely for maintenance.

The sump is vented outside the plant, and floor drains are trapped. Oil room drains are in gravel-filled pits, to extinguish possible burning oil, and are deeply trapped to prevent escape of carbon dioxide gas discharged by the fire protection system. Generator pit drains have weighted caps on the outlets for the same reason. The outlets are

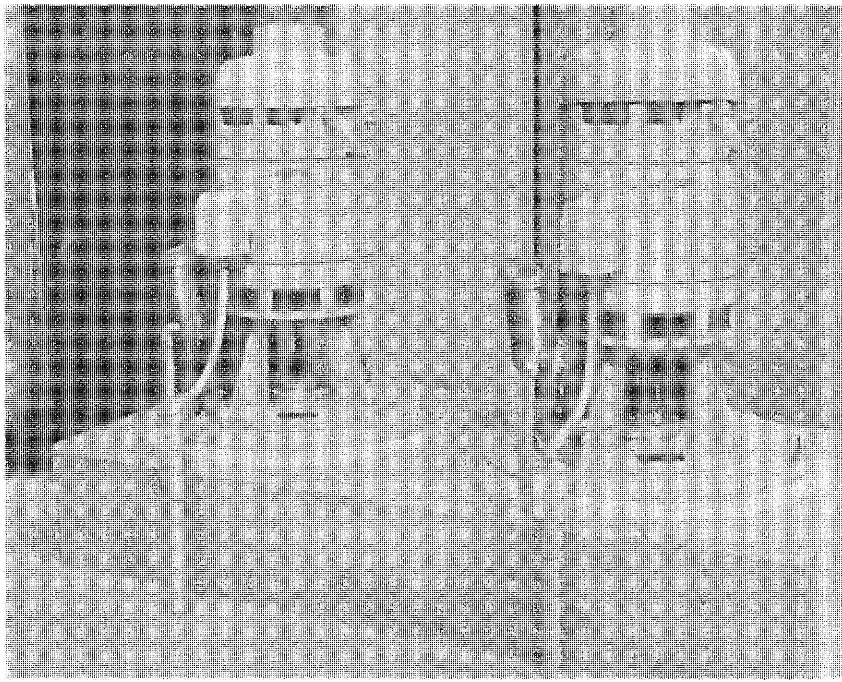


Figure 97.--Sump pump motor installations in southeast corner of generator room. P783-908-1787, May 13, 1955.

visible, in a gallery wall, so that any leakage in the generator pit will be conspicuous. High-pressure relief valve discharges are piped to a large separate drain line to the sump. Turbine packing box cooling water and generator cooler venting bleed lines discharge to the sump, but all other cooling water is piped to tailwater, to reduce sump pumping.

A penstock drain, to remove residual water from the common penstock, is connected to the sump, since afterbay levels will at times be higher than the turbine runner. A gate valve, very difficult to open under high pressure, is used on the drain line to prevent opening it before the penstock has been drained as far as possible through the runner to tailwater. Spiral case drains permit emptying either casing, with the unit butterfly valve closed. The spiral case or penstock drains could flood the plant if opened under high pressure, and a high water alarm is therefore provided in the sump.

78. Oil Handling and Purification System. - A lubricating oil system serves the turbine and generator bearings and the governor oil system. A rotary-type transfer pump, rated 20 gallons per minute at 100 pounds per square inch pressure moves oil between the equipment and two 560-gallon storage tanks in the oil storage room, one for filtered oil the other for unfiltered. Two 60-gallon sump tanks are located in alcoves near the butterfly valves to receive gravity drainage from the turbine bearings.

The insulating oil system serves the two main transformers and a Government camp transformer, all located adjacent to the plant. A single oil storage tank of 3,350-gallon capacity is provided. The same transfer pump is used for both lubricating and insulating oil.

A portable oil purifier with heater, centrifuge and filter press is provided, suitable for operating in the plant or for moving to other areas if needed. The capacity of the purifier is 600 gallons per hour.

To simplify the operation of the oil piping system, flexible hose with self-closing connections is used between the filter, transfer pump, and piping, in lieu of a permanent manifold. In this way, manifold valves are eliminated, and the plant operator makes the connection to the equipment he wishes to use or service.

79. Compressed Air System. - The compressed air system, rated at 100 pounds per square inch, serves the generator air brakes, service outlets in the plant, and a future tailwater depressing system. Air cushions in the domestic water system are maintained by the injection of air from the system as required.

Normal air requirements are supplied by two 50-c.f.m. receiver-mounted, air-cooled units, which operate automatically to maintain pressure in the air receivers. The compressor units are self-contained, and do not have external air intakes.

Make-up air for the turbine governor pressure tanks is supplied by a portable high-pressure compressor unit, rated 8 cubic feet per minute at 300 pounds per square inch pressure. Connection to the tank is made with hose, and no permanent piping is installed.

It is not contemplated that the tailwater depressing system in the draft tube will be installed until possible future system conditions call for motoring.

80. Jib Crane and 2-Ton Hoist for Draft Tube Bulkhead Gates. - A jib crane (fig. 98) with a 2-ton-capacity, twin-lift chain hoist is attached to the powerhouse wall between the draft tube bulk-head gate slots and is used for raising, lowering, and pivoting the draft tube bulkhead gates and for transferring the gates from one slot to the other.

The 2-ton, twin-lift, hand-operated chain hoist is of standard manufacture and is hung from the jib on U-bolts placed on 6-foot centers. The hoist has a lift of 41 feet. A 5/8-inch chain with a swivel shackle is provided on the jib crane to rotate the bulkhead gates 180°.

A factor of safety of not less than 5, based on the ultimate strength of the materials, was used in the design of the jib crane.

81. Three-Ton Capacity Machine Shop Crane. - A 3-ton-capacity, underhung, traveling-type crane is installed on a runway extending the length of the machine shop. The crane is used for handling material and equipment in the shop. The crane is of standard manufacture and is equipped with a 3-ton-capacity, single-hook, low-headroom, chain-operated hoist with a hand-racked trolley. The hoist has a lift of 14 feet. The underhung bridge runs on two wide-flange beams spaced 20 feet between centers. The bridge is hand-racked.

82. Forty-Ton Traveling Crane. - A 40-ton-capacity, indoor, cab-operated, overhead electric traveling crane (fig. 99), with a single trolley supporting a 40-ton-capacity main hoist and a 10-ton-capacity auxiliary hoist, is installed in the powerplant. (Fig. 100.) The crane is used for installing and maintaining the generators and turbines, for untanking the transformers, and for handling miscellaneous equipment and materials.

The main hoist block is suspended from 12 parts of 3/4-inch diameter, 6 by 37, wire rope reeved 6 parts double. The block is equipped with a sister-type hook bored for a horizontal lifting pin, which provides for easy attachment of slings and lifting devices. The hoist has a lift of 47 feet, is powered by a 30-horsepower motor, and operates at varying speeds up to 9.7 feet per minute. The auxiliary hoist block is suspended from four parts of 9/16-inch-diameter, 6 by 37 wire rope, reeved two parts double. The block is equipped with a standard single hook. The hoist has a lift of 60 feet, is powered by a 30-horsepower motor, and operates at varying speeds up to 42.2 feet per minute.

Automatic mechanical load brakes of the friction and screw type are installed on each hoist to prevent the load from lowering until power is applied in the lowering

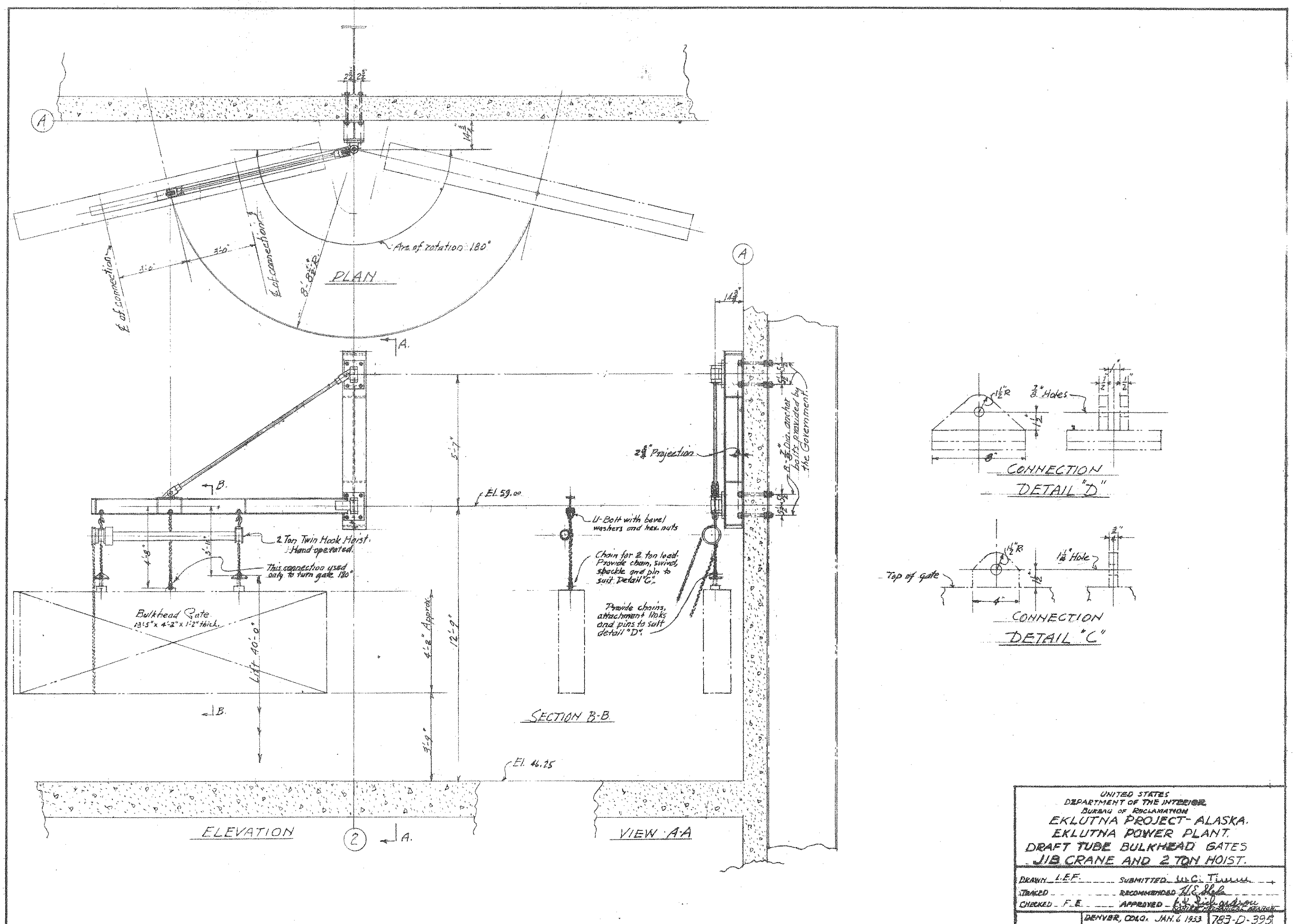


Figure 98. --Jib crane and 2-ton hoist for draft tube bulkhead gates.

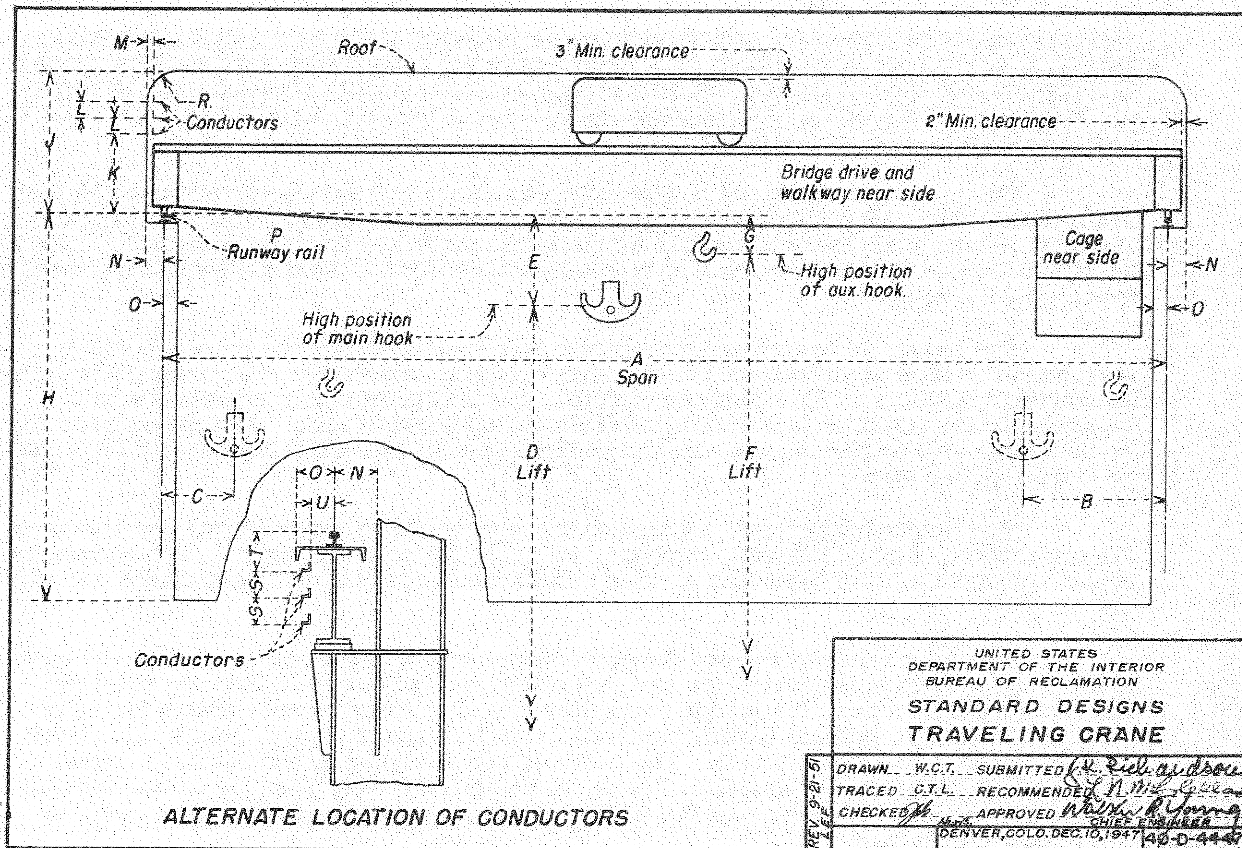


Figure 99.--Standard design for traveling crane.

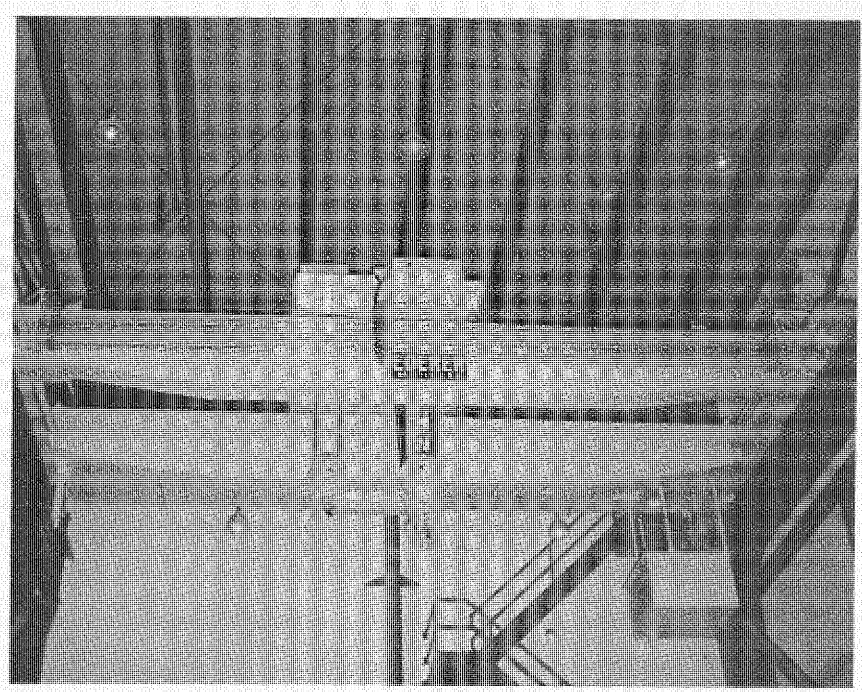


Figure 100.--Interior view of powerplant showing 40-ton overhead traveling crane. 783-908-1762, May 3, 1955.

direction by the hoist motor. Each hoist is also equipped with an electric-solenoid-operated, spring set brake which is released when the hoist motor circuit is energized. The mechanical load brake and electric brake are each capable of holding 1-1/2 times the rated load of the hoist. Block-actuated limit switches are installed on each hoist to limit the upper travel of the hooks.

The trolley is driven by a 5-horsepower motor at varying speeds up to 68 feet per minute. The drive motor is equipped with an electric-solenoid-operated, spring-set brake which sets when the trolley controller is moved to the "Off" position. A drift point is provided on the first point of the trolley controller to hold the brake open without energizing the motor.

The bridge structure consists of two box girders supported by two 2-wheel trucks over a span of 40 feet 10 inches. The bridge is driven by a 10-horsepower motor at varying speeds up to 78.5 feet per minute. The bridge motor is equipped with a hydraulic brake which is foot controlled from the operator's cage. Spring bumpers fixed to the bridge and trolley prevent damage to the crane in case of collision with the runway or bridge girder stops.

Steel angle conductors, located on the web of one of the main runway beams in the powerplant, supply 440-volt, 3-phase, 60-cycle power to the crane. All motors are of the open wound-rotor type with a rated synchronous speed of 900 revolutions per minute.

Full magnetic controllers for each motion of the crane are located in the operator's cage. Each hoist controller has five speed control points in both the hoisting and lowering directions, the bridge controller has four speed control points for each direction of travel, and the trolley controller has four speed control points and a drift point for each direction of travel. The controls are designed to control the vertical movement of the main and auxiliary hooks, when starting from rest, to within one-sixteenth inch, and the movement of the trolley and bridge, when starting from rest, to within one-fourth inch.

The crane is equipped with a 115-volt permanent lighting system. Two 500-watt high-bay lighting units are installed on the crane to illuminate the working area under the crane, and a 110-watt lighting unit and a convenience outlet are installed in the operator's cage. The crane is provided with walkways, platforms and ladders necessary for access to the cage, bridge drive mechanism, trolley, and all parts requiring attention and lubrication.

The crane was designed according to the Navy Department's "Standards of Design for Structural Steel," using a base stress of 14,000 pounds per square inch. Computation of stresses took into account all dead and live loads and loads due to impact, acceleration and retardation. Allowable stresses due to combinations of these stresses were increased according to the Navy Standards noted. A factor of safety of not more than 5, based on the ultimate strength of the material and the rated capacity of the crane, was used in the design of all mechanical parts.

PART III -- CONSTRUCTION

PART III--CONSTRUCTION

CHAPTER VII --*Construction*-- TUNNEL AND DAM

A. Contract Administration

83. Specifications and Contracts. - Construction of the Eklutna Tunnel and alterations to the existing dam were originally planned for performance in accordance with specifications No. DC-3443. Two bids were opened at Palmer, Alaska, on June 25, 1951, but these were rejected on account of the low bid being 90 percent in excess of the engineer's estimate.

The work was readvertised under specifications No. DC-3523 with alternate schedules. Schedule No. 1 provided for construction of a low level tunnel, and Schedule No. 2 provided for construction of a high level tunnel which would require construction, under a future contract, of a new dam to raise the water surface of Eklutna Late to elevation 900. Risk to the contractor was reduced by inclusion of pay items, in both schedules, for handling water and also by provision for escalation payments on labor costs. Four bids were submitted and were opened at Denver, Colo., on September 11, 1951. The three highest bids and the amount of the engineer's estimate are listed below:

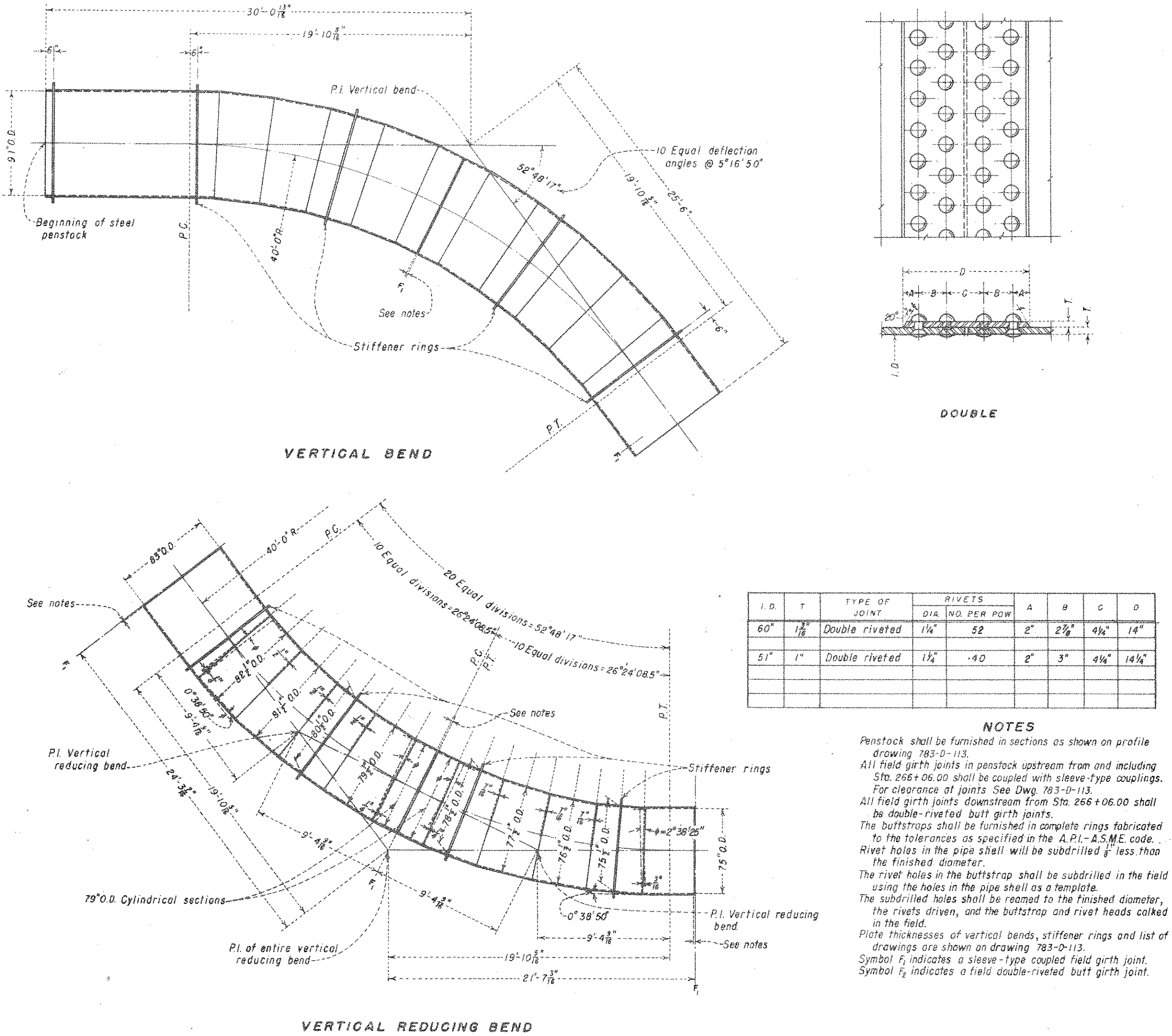
	Schedule No. 1 (Low level tunnel and dam)	Schedule No. 2 (High level tunnel)
(1) Palmer Constructors, Omaha, Nebr., a joint venture consisting of Peter Kiewit Sons' Co., Morrison-Knudsen Co., Inc., and Coker Construction Co.	$17, 348, 865.00	$16, 419, 440.00
(2) Grafe-Callahan Construction Co., Rhoades-Shofner Construction Co., Inc., and D. C. Gordon, Los Angeles, Calif.	$17, 776, 596.50	$16, 391, 192.00
(3) The Utah Construction Co., San Francisco, Calif.	$19, 249, 774.00	$17, 052, 570.00
(4) Engineer's estimate	$18, 175, 568.00	$15, 687, 384.00

The low bid of $17, 348, 865.00 for schedule No. 1 was accepted and contract No. I2r-19609 was awarded to Palmer Constructors on September 17, 1951. The notice to proceed was received by the contractor on October 11, 1951, thereby fixing the contract completion date as August 26, 1954. The completion date for the contract was extended to December 22, 1954, by order for changes No. 4, as amended by an adjustment dated September 21, 1954. Work under the contract was started in October 1951 and completed on December 22, 1954.

A pay item breakdown for work performed under specifications No. DC-3523 is shown as appendix B.

84. Orders for Changes. - (a) *Change Order No. 1.*-- This order, issued January 5, 1952, directed the contractor to furnish type I, low-alkali cement in lieu of type II, low-alkali cement. A price reduction of $0.20 per barrel was provided by the order for changes, resulting in a saving of $12, 529.05 to the Government.

(b) *Change Order No. 2.*-- This order, issued April 25, 1952, directed the contractor to install the penstock with sleeve-type (Dresser) couplings (fig. 17) in lieu of riveted field girth joints (fig. 101). A lump-sum price reduction of $33, 300 was included in the order for changes.



I.D.	T	TYPE OF JOINT	RIVETS		A	B	C	D
			DIA.	NO. PER ROW				
60"	1 3/16"	Double riveted	1¼"	52	2"	2⅞"	4¼"	14"
51"	1"	Double riveted	1¼"	40	2"	3"	4¼"	14¼"

NOTES

Penstock shall be furnished in sections as shown on profile drawing 783-D-113.
All field girth joints in penstock upstream from and including Sta. 266+06.00 shall be coupled with sleeve-type couplings. For clearance at joints See Dwg. 783-D-113.
All field girth joints downstream from Sta. 266+06.00 shall be double-riveted butt girth joints.
The buttstraps shall be furnished in complete rings fabricated to the tolerances as specified in the A.P.I.-A.S.M.E. code.
Rivet holes in the pipe shell will be subdrilled ⅛" less than the finished diameter.
The rivet holes in the buttstrap shall be subdrilled in the field using the holes in the pipe shell as a template.
The subdrilled holes shall be reamed to the finished diameter, the rivets driven, and the buttstrap and rivet heads calked in the field.
Plate thicknesses of vertical bends, stiffener rings and list of drawings are shown on drawing 783-D-113.
Symbol F_1 indicates a sleeve-type coupled field girth joint.
Symbol F_2 indicates a field double-riveted butt girth joint.

Figure 101.--Vertical bends and riveted girth joints for penstock as designed. These riveted joints were replaced with Dresser couplings by an order for changes. From drawing 783-D-115.

(c) *Change Order No. 4.*-- This order, issued January 14, 1953, provided for construction of a drainage channel in the invert to drain the extremely wet sections of the tunnel. An enlarged tunnel section was accordingly excavated from station 207+50 to station 150+13, but without encountering any excessive amount of water; consequently, the enlarged section was discontinued for the remainder of the tunnel. Under the conditions of the order for changes, the contractor assumed responsibility for pumping the drainage water encountered upstream from approximately station 208+00, at no cost to the Government, but was compensated for the additional excavation and support steel required for the enlarged section. The cost to the Government for the additional amount of support steel and excavation was $278, 000; however, it was estimated that payments under the bid items for pumping the drainage water would have exceeded the cost of the additional support steel and excavation by $48, 000. No payment for additional concrete or cement was allowed for the enlarged tunnel section by the terms of the order for changes. A flume steel lining purchased by the contractor for this order for changes was not installed, but was purchased by the Government under order for changes No. 12.

An extension of 118 calendar days was allowed later for completion of the tunnel as a result of work required under order for changes No. 4.

(d) *Change Order No. 5.*-- This order, issued April 21, 1953, provided for payment of $182, 715 to the contractor for increased costs of inlet channel excavation due to conditions encountered which were different from those indicated by the investigations.

During the dredging operations, a hard cemented material was encountered that required blasting for removal. This material had been shown on the logs obtained from churn drill testing as "silty and pea gravel, clean; some boulders, bluish gray." However, the material was actually a very dense cemented till.

(e) *Change Order No. 9.*-- This order, issued September 8, 1953, provided for penstock piezometer piping, penstock footings on piling, and changed the delivery point of the steel penstock from Palmer to Eklutna, Alaska. This order for changes resulted in an estimated increase of $3, 200 in the contract price.

(f) *Change Order No. 10.*-- This order, issued September 16, 1953, directed the contractor to paint the interior of the penstock sections at the site or at the shop, prior to moving them into the tunnel. The contractor chose shop painting and was backcharged $1, 602. 78 for freight of the paint which was originally paid by the Government as freight for the penstock sections.

(g) *Change Order No. 11.*-- This order, issued September 20, 1954, directed the contractor to perform backfill grouting behind the tunnel lining and provided for transfer of the concrete plant to the contractor which had been purchased by the Government under order for changes No. 3. The backfill grouting increased the cost of the contract $296, 754. 95. The concrete plant was transferred to the contractor for $100, 000.

(h) *Change Order No. 12.*-- This order, issued September 21, 1954, directed the contractor to deliver to the Government 811, 471 pounds of steel liner plates and supports, which the contractor had purchased for installation under order for changes No. 4. The contractor was paid his actual cost of $135, 425. 71 for the steel.

(i) *Change Orders No. 3, 4, 5, 6, and 7.*-- These orders for changes were all related, wholly or in part, to a series of actions which were taken to continue construction of Eklutna project under the total $20, 365, 400 project authorization, prior to amended authorization at $33, 000, 000. A series of deletions and reinstatement of contract items in these orders canceled out to "no change" from the original contract with issuance of order for changes No. 8, which was issued on August 13, 1953, after project reauthorization.

Only those portions of orders for changes No. 4 and 5 which were not canceled by order for changes No. 8 have been discussed in subsections (c) and (d) respectively.

85. Extra Work Orders. - (a) *Extra Work Order No. 1.*-- This order, issued June 24, 1952, directed the contractor to remove and replace rotted stringers and sills in both existing and relocated portions of the trestle at Eklutna Dam. Compensation to the contractor amounted to $1, 084. 54.

(b) *Extra Work Order No. 2.*-- This order, issued April 23, 1954, directed the contractor to construct a permanent drainage system in the wet section of the tunnel between station 207+60 and station 226+70. Final cost for this work amounted to $19, 346.

(c) *Extra Work Order No. 3.*-- This order, issued July 22, 1954, directed the contractor to modify the surge tank orifice plate and to furnish and install an access door and frame in the adit plug. This work order increased the cost of the contract $2, 316. 50.

86. Government and Contractor's Camp. - The contractor established a camp and maintenance shop along the Glenn Highway near the North Portal and at Eklutna Lake, including space and utilities for employee's trailer houses. Mess hall and dormitory accommodations were available at both locations.

Government personnel, all or in part, provided their own housing from October 1950 through December 1951. Living quarters were in short supply in the Palmer area, and rent charges were excessive in relation to the Government wage scale which included the 25 percent cost of living allowance. The housing situation during this period made it difficult to recruit and hold qualified personnel.

Six small 2-bedroom prefabricated portable houses in Palmer were completed and occupied in January 1951. Thirty temporary 2-bedroom houses, 10 in Palmer and 20 at the permanent Government camp site near Eklutna Powerplant, were completed and occupied by January 1952 (fig. 102). The 12 permanent houses at the Government camp were completed and occupied in March 1952, and one permanent house at the Anchorage substation site was completed in December 1952. The occupancy rate was 100 percent during most of the major construction period.

Figure 102.--Temporary and permanent houses under construction at Eklutna Government camp. P783-908-459. November 27, 1951.

A laboratory, warehouse, and garage were constructed near the Eklutna Powerplant site. Office space was rented in Palmer until June 1953 when a temporary office addition to the laboratory was completed and occupied.

A Government organization chart for Eklutna project during 1952 is shown as appendix D.

87. Contractor's Forces. - (a) *Personnel.*-- Eight people were responsible for the field supervision, engineering and management for Palmer Constructors. An average of 115 laborers and mechanics were employed by the contractor and subcontractors during construction of Eklutna Tunnel. During the peak of the construction work, a maximum of 343 laborers and mechanics were employed.

(b) *Subcontractors.*-- The prime contractor let four subcontracts for portions of the work required by the specifications. The subcontractors and their work are listed below:

(1) Ben C. Gerwick. - Construction of intake and trashrack sections.

(2) Ben C. Gerwick and Hydraulic Dredging Co. - Excavation and backfill for intake structure.

(3) Alaska Aggregate Corp. - Processing and stockpiling aggregates.

(4) Northern Ready Mix Co. - Processing and stockpiling of additional aggregates.

(c) *Rates of Wages.*-- Adjustments for changes in labor costs for work performed more than 180 calendar days after the date of the contract were made in accordance with the specifications. The adjustments were 85 percent of the difference between the total amount actually paid to all laborers and mechanics and the total amount that would have been paid if computed at the hourly base rates given in the specifications. The total of all escalation paid to the contractor was $385,732.84.

Table 1 shows the basic wage rates and subsequent wage rates which were effective under the contract.

Table 1. - Wage rates in effect for work under specifications No. DC-3523.

Classification	Rate			
	Base	1952	1953	1954
Carpenter	$3.14	$3.34	$3.565	$3.69
Carpenter power saw operator	3.265	3.465	3.690	3.815
Electrician	3.50	3.70	3.85	4.25
Electrician groundman	2.67	3.17	3.245	3.57
Ironworker, reinforcing steel	3.215	3.415	3.64	3.765
Ironworker, structural	3.415	3.615	3.84	3.965
Miner	3.02	3.22	3.345	3.47
Heavy duty mechanic	3.27	3.47	3.595	3.72
Pumpcrete operator	3.27	3.47	3.595	3.72
Batchplant mixer operator	3.27	3.47	3.595	3.72
Bulldozer operator	3.22	3.42	3.545	3.67
Crane operator	3.57	3.77	3.895	4.02
Oiler	2.87	3.07	3.195	3.32
Excavation compressor operator	3.02	3.22	3.345	3.47
Semitruck driver (up to 10 ton)	3.07	3.27	3.395	3.52
Flatbed truck driver	2.87	3.07	3.195	3.32
Mucking machine operator	3.52	3.72	3.845	4.02
Locomotive operator	3.07	3.27	3.395	3.52
Chuck tender	2.82	3.02	3.145	3.27
Monolithic worker	3.02	3.22	3.345	3.47
Laborer	2.735	2.97	3.06	3.185
Tunnel laborer	2.77	3.02	3.145	3.27
Warehouseman	2.77	2.97	3.095	3.22
Powerplant operator	3.27	3.47	3.595	3.72
Hoist operator	3.27	3.47	3.595	3.72
Dump truck driver (5 cu. yd.)	2.87	3.07	3.195	3.32
Heavy duty welder	3.27	3.47	3.595	3.72
Nipper	2.77	3.02	3.145	3.27
Powderman	3.02	3.22	3.445	3.57
Dump truck driver (explosive 5 cu. yd.)	3.02	3.22	3.345	3.47
Jackhammer operator	2.87	3.07	3.195	3.32
Motor patrol power grader operator	3.22	3.42	3.545	3.72
Shaft miner	3.07	3.27	3.395	3.52
Pile driver rigger		3.54	3.66	
Pile driver man		3.385	3.61	
Cement mason	2.985	3.185	3.31	3.435
Dump man	2.77	3.02	3.095	3.22
Lowbed truck driver	3.07	3.27	3.395	3.52
Wagon driller	3.02	3.22	3.345	3.47

	1952
Divers	$40 per 6-hour shift $20 per hour over 6-hour shift $ 1 per foot depth money (60 to 100 feet) $ 2 per foot depth money (100 feet or over)
Diver tenders	$20 per 6-hour shift $ 7 per hour over 6-hour shift

	1954
Divers	\$46 per 6-hour shift \$20 per hour over 6-hour shift \$ 1 per foot depth money (60 to 100 feet) \$ 2 per foot depth money (100 feet or over)
Diver tenders	\$25 per 6-hour shift \$ 7 per hour over 6-hour shift

The contractor's average and maximum employment was as follows:

Year	Maximum	Average
1951	153	104
1952	306	75
1953	343	128
1954	220	153

88. Safety. - With almost 2 million man-hours on the job, there were no fatal accidents and few other accidents involving large numbers of lost-time days. The worst month of record was April 1953, with 13 accidents for 551 days of lost time. The first accident-free month occurred in July 1954. Following is the safety record of Palmer Constructors, including all subcontractors:

Exposure, man-hours worked	1, 884, 598
Number of accidents	128
Lost-time, days	3, 541
Frequency rate	67. 9
Severity rate	1, 879. 51

B. Construction Operations

89. Dam. - The existing dam at Eklutna Lake was considered adequate in height, but minor repairs and alterations were completed by the contractor in conjunction with the installation of the tunnel intake.

A small dike was built on the southeast end of the dam to elevation 875 to assure the required maximum water level of the lake. In accordance with the specifications, riprap was placed along the dike. The riprap was picked out of the river channel below the dam where granite, graywacke, and other types of boulders of suitable size were easily obtainable.

In the course of rehabilitating the existing dam, sheet piling on the southeast end of the control gates was extended to elevation 875.00. An old trestle across the lower side of the dam was replaced by an access bridge constructed on driven timber piling. During construction it was necessary to raise the left abutment of the dam to protect against erosion of the shingle gravel and glacial till around the control works. As similar materials and erosion occurred on the right abutment, and the elevation of these materials became less than the left abutment, remedial measures were also taken on the right abutment.

90. Intake. - The intake structure consists of 225 feet of 9-foot-diameter precast conduit, a bulkhead section, a transition section, and a trashrack section. The entire intake structure was installed by subaqueous operations about 70 feet beneath the level of Eklutna Lake.

The dredging of approximately 410, 000 cubic yards of glacial till and glacial flour for the intake structure posed an unusual and difficult problem of dredge design. Conventional bucket or suction type dredges, large enough to be capable of excavating 70 feet beneath the water surface, would have been extremely difficult to break down to truck load units and reassembly would have been time consuming. Bidders who examined the samples of materials from drill holes were unanimous in the opinion that a suction dredge would be the most efficient. Since conventional type dredges are seldom designed to work lower than ship channel depths, special design would be required, and the increased length of boom, with resultant increase in size of hulk necessary to support a ladder over 70 feet long, seemed to be a formidable economic barrier.

Ben C. Gerwick Inc., in a joint venture with Hydraulic Dredging Inc., as a subcontractor under Palmer Constructors, solved this problem by designing and building a relatively small 14-inch suction dredge that could be broken down to truck loads. The assembled dredge is shown in figures 103 and 105. The size of hulk was reduced by using a floating support for the ladder. Traverse motion of the cutter head was provided by swinging the entire dredge rather than by use of swinging the boom. The stern was used as the pivot point and its position was maintained by two winch-powered "off" lines and a stern line connected to buoys and anchors. Forward motion and swing were gained from quartering aft lines similarly powered and anchored. Mobility was more than ample. Operation revealed no fundamental errors in the design of the dredge and only the usual maintenance problems of replacing worn cutter heads, rock wipers, etc., were experienced.

The subcontractor started work on the access road and launching site on March 18, 1952, and the dredging operations were begun on May 24, 1952, and completed the following November 24. Careful scheduling of operations was required as all the intake work necessarily had to be accomplished during the 5 or 6 ice-free months of summer.

Dredge pumpage ran as high as 400 cubic yards per hour in easily dredged glacial flour and as low as 15 cubic yards per hour in a compact glacial till. This hard cemented glacial till required blasting for removal, and the drilling created a problem that was solved experimentally. The first drilling attempt was made with barge-mounted churn drills, but this method was quickly abandoned in favor of jetting, with the churn drill towers used to handle the jets. Several high-pressure water pumps were connected to a common manifold for the original water supply, but it was soon found that the best progress could be made by connecting the discharge from one high-pressure pump to the intake of the next. This tandem arrangement gave extremely high water pressure which readily cut through the compact glacial till. Blasting results were best when high-percentage dynamite was used, a high-velocity gelatin with 80 percent strength giving the best break in the compact glacial till.

The 225 feet of 9-foot internal-diameter precast concrete conduit was manufactured in California in 16-foot lengths with patented lock-joint rubber gaskets and shipped to Alaska by boat. The bulkhead, transition and intake sections were constructed on the site. All units were placed in shallow water with a two-pier launching gantry mounted on rails as shown in figure 106. A floating "placing gantry" then picked up the individual pieces and placed them in position with the aid of two divers. Plans required that bell ends of the conduit be "leading" for the installation. It was the opinion of the contractor and the divers that assembly would have been greatly facilitated with spigot ends leading.

On December 11, 1952, the subcontractor completed placing and backfilling the first two sections of precast conduit, making the connection to the tunnel which had been previously excavated under the lake shore and lined with concrete. The remainder of the conduit and the bulkhead, transition, and trashrack sections were placed in 1953.

Sand backfill was placed in layers with a minimum of 24 hours settling period between layers. This method was used to avoid a lateral shift of the conduit which might be caused by a heavy settling load if the entire weight of the fill were allowed to consolidate at one time.

The intake portion of the contract was completed in November 1954, when the subcontractor returned with divers and removed the steel dished bulkhead [redacted] from the bulkhead structure in the lake.

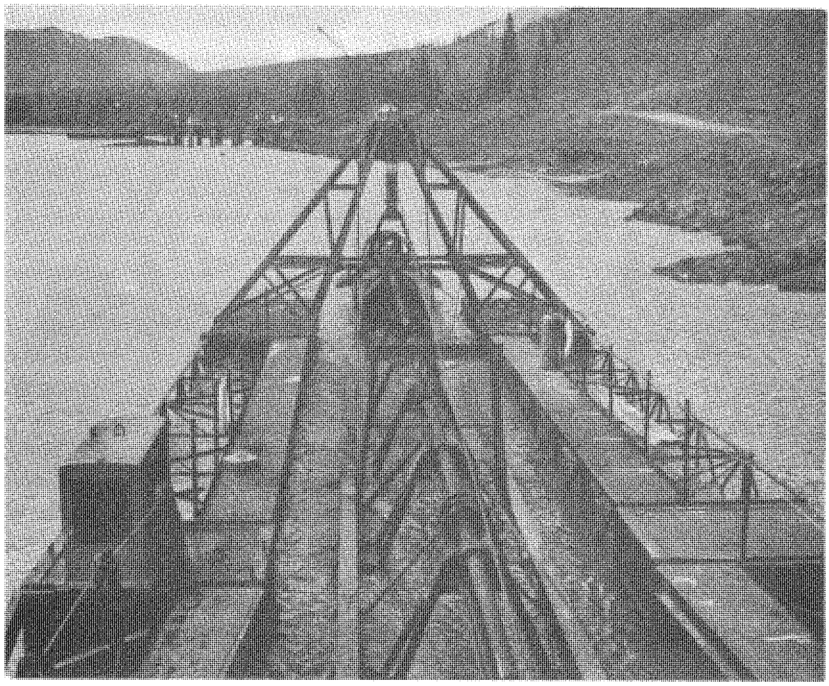


Figure 103. --Dredging equipment used to excavate for the intake structure at Eklutna Lake. View is forward from pilot house of dredge, and shows complete assembly of ladder, A-frame and outriggers. Air tanks at forward end of outriggers, to which A-frame is attached, permit raising and lowering of ladder and cutter head. P783-908-817, May 23, 1952.

Figure 104. --View of assembly area for dredge at Eklutna Lake showing one steel pontoon and steel skids on which assembled dredge will slide into lake. P783-908-788, May 2, 1952.

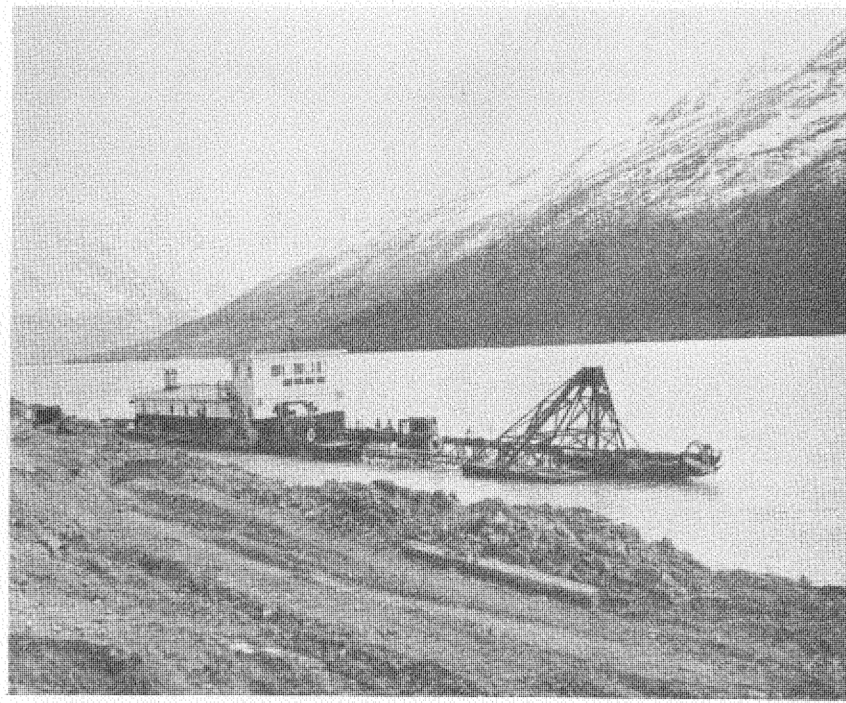


Figure 105.--Dredge being cast off from shore in preparation for intake structure excavation. P783-908-821, May 23, 1952.

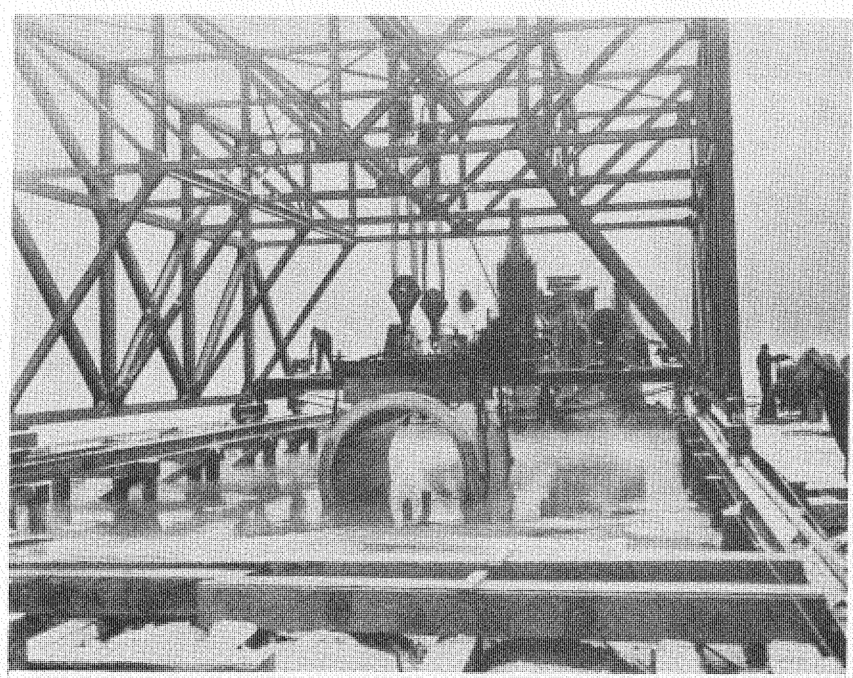


Figure 106.--Launching gantry crane lowering precast pipe to lake bottom. Placing gantry barge in rear is ready to move in and pick up section of pipe from lake bottom. P783-908-1183, December 2, 1952.

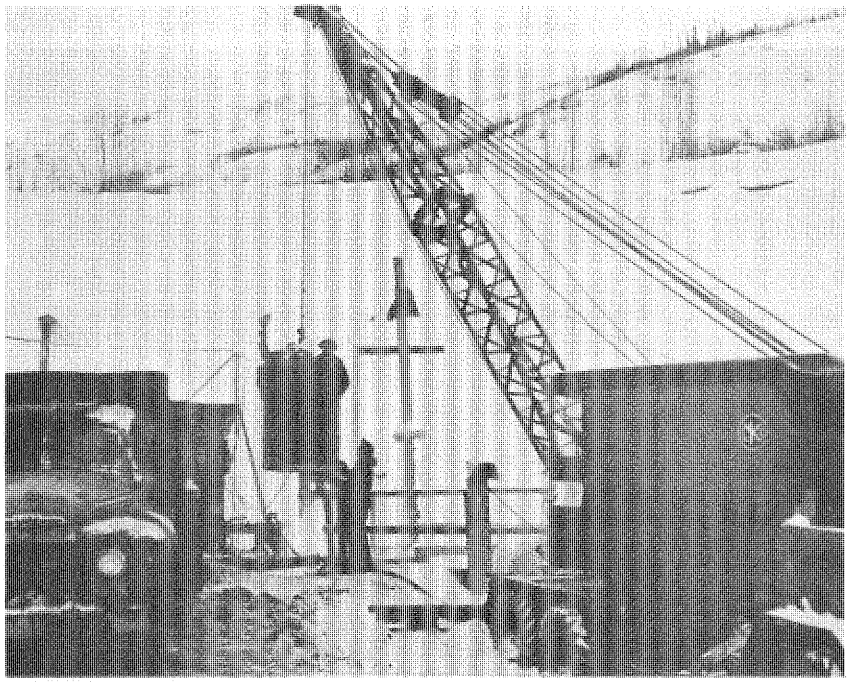


Figure 107. --Constructor's crane in operation at gate shaft near the south or inlet portal of the tunnel. Men are being lowered in the muck bucket. P783-908-604, January 17, 1952.

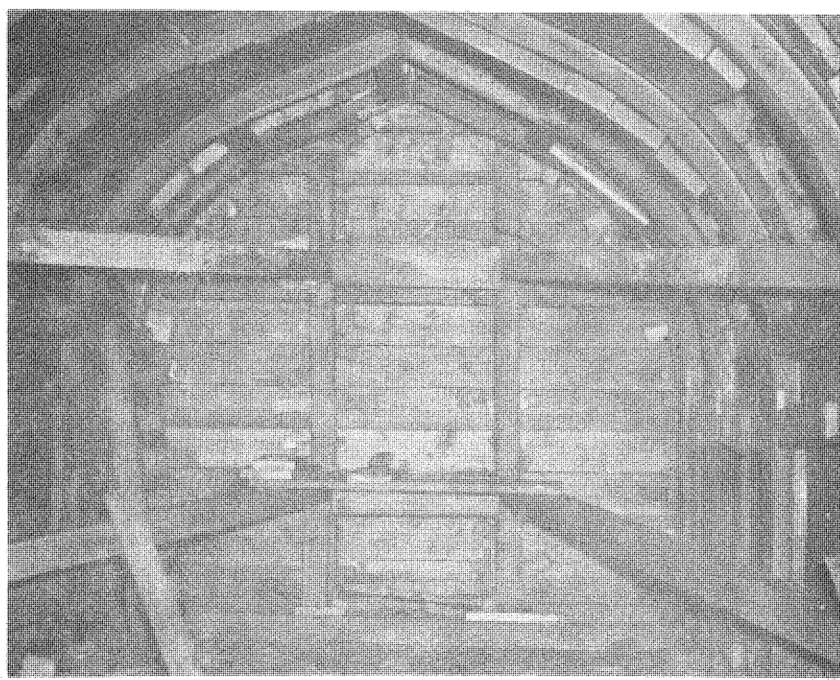


Figure 108. --Bulkhead installed at end of tunnel excavation, station 19+06. Material on opposite side of bulkhead was excavated by dredging. P783-908-770, April 19, 1952.

91. Tunnel and Gate Shaft. - (a) *Excavation.*-- The first work under the contract was started, at both the gate shaft at the Eklutna Lake end of the tunnel and the adit for the north, or downstream end of the tunnel, in October 1951, with the contractor making a hurried effort to get underground before severe winter weather began. The effort was successful at the gate shaft, where the open cut was completed and gate shaft excavation was well underway before the freezeup (fig. 107). The construction of a service road, approximately 2.5 miles long, to reach the north adit at an elevation of 700 feet above the highway, took considerably longer than anticipated due to numerous rock cuts and severe slides. "Portaling in" was delayed until well into the severest part of the winter. Because of the broken and faulted condition of the rock directly overlying the portal, considerable difficulty was experienced in maintaining the portal. The portal was lost twice before it was finally stabilized with a combination of timber and steel supports.

After sinking the gate shaft, the heading was advanced upstream under the lake to station 19+06. The portion of the tunnel upstream from this point was excavated by dredging from the lake. Prior to starting tunnel excavation downstream from the gate shaft, concrete lining was placed in the section under the lake so that steel dished bulkheads could be installed for protection of the workmen and operations. (Figs. 108 and 109.)

Some difficulty was experienced from the sloughing of the glacial till material on the slopes of the open cut excavation for the gate shaft due to runoff from melting snow and ground seepage.

This sloughing was particularly evident in the early summer season. After observing repeated sloughing action on the slopes, a design change was made which increased the height of the gate shaft concrete structure by 12 feet to allow a freeboard for future sloughing. The type of ground encountered in the gate shaft excavation required the use of support steel. Six-inch, 25-pound, structural steel, H-beam rings on 4-foot centers were used the full height of the shaft (fig. 110). The space between rings was lagged solid.

The first mile of tunnel driven from the north portal passed through complexly folded and faulted rock with numerous water bearing channels. Progress was slow as a result of frequent caving and water flows. A major cave-in and loss of the heading occurred November 9, 1952, at station 208+70 at which time the water flow was estimated at 10,000 gallons per minute. (Figs. 111 and 112.) Work was suspended at this heading for 2 months to permit installation of unwatering equipment. Two 22-inch-diameter pipelines, one 10-inch and three 6-inch electric pumps, were installed to pump the water from the tunnel. During the heading shutdown, a change in tunnel design was made to handle the water during driving. The contractor was instructed by order for changes No. 4 (sec. 84(c)) to proceed with an enlarged section that would allow for "under the track drainage" in a steel flume section. Excavation of the enlarged section was started at station 207+50 and discontinued at station 150+13, without encountering further serious water problems. No flume steel was installed. Maximum flow of water from the north portal was approximately 16,000 gallons per minute. Eventually the flow of water stabilized at approximately 1,300 gallons per minute. During this period the contractor was advancing the heading from the gate shaft, and the two headings were "holed through" on October 15, 1953, at station 118+20.

The formation of rock encountered was mostly graywacke and argillite and ranged from shattered and brecciated to somewhat broken but fairly consistent in bedding. Many of the fracture and bedding planes contained graphite and slickensides. Quartz- and calcite-filled seams were present throughout the tunnel.

Drilling of the tunnel was performed on a normal pattern for this type of work, with 26 to 40 holes drilled in each round. Holes were drilled to an average depth of 9 feet and, depending on the type of material, were loaded with 160 to 170 pounds of 40 percent powder to pull an average of 8 feet. Approximately 5-1/2 pounds of powder was used per cubic yard of excavation.

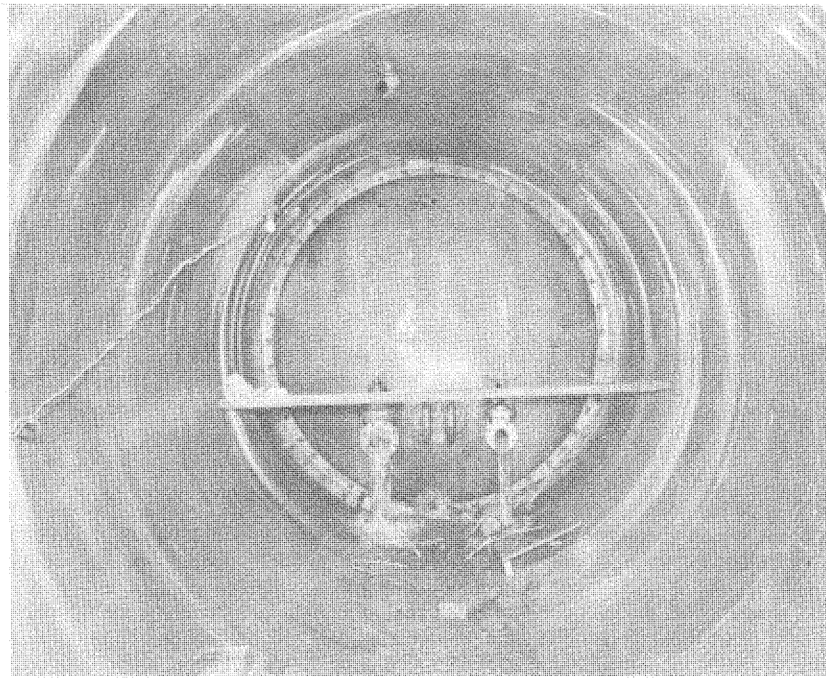


Figure 109. --Steel bulkhead at station 20+00. Valves are open to relieve static pressure of water while blasting for dredging operations on the opposite side upstream from station 19+06. P783-908-1080, September 12, 1952.

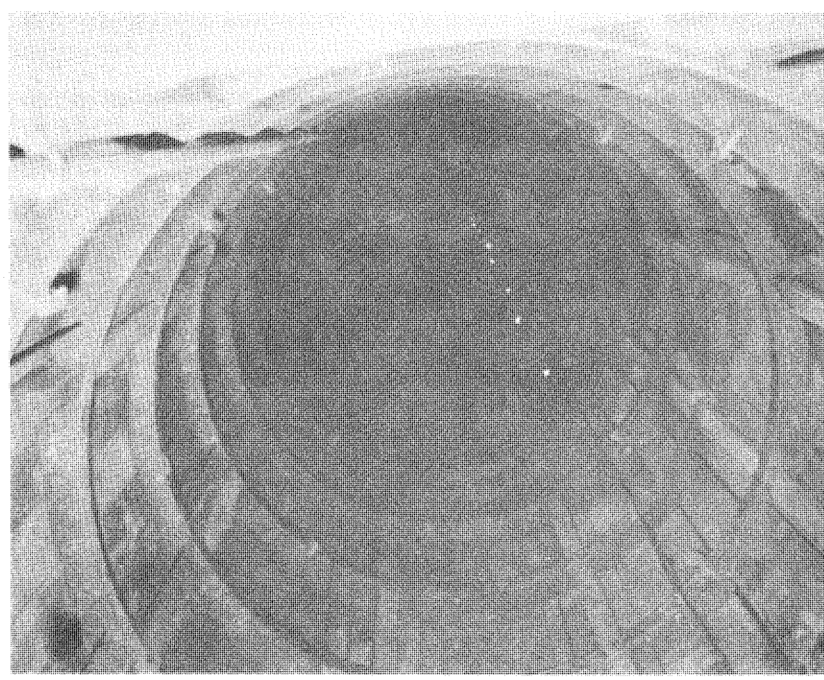


Figure 110. --View of gate shaft, looking down from top, showing structural steel H-beam support rings and lagging. P783-908-446, November 26, 1951.

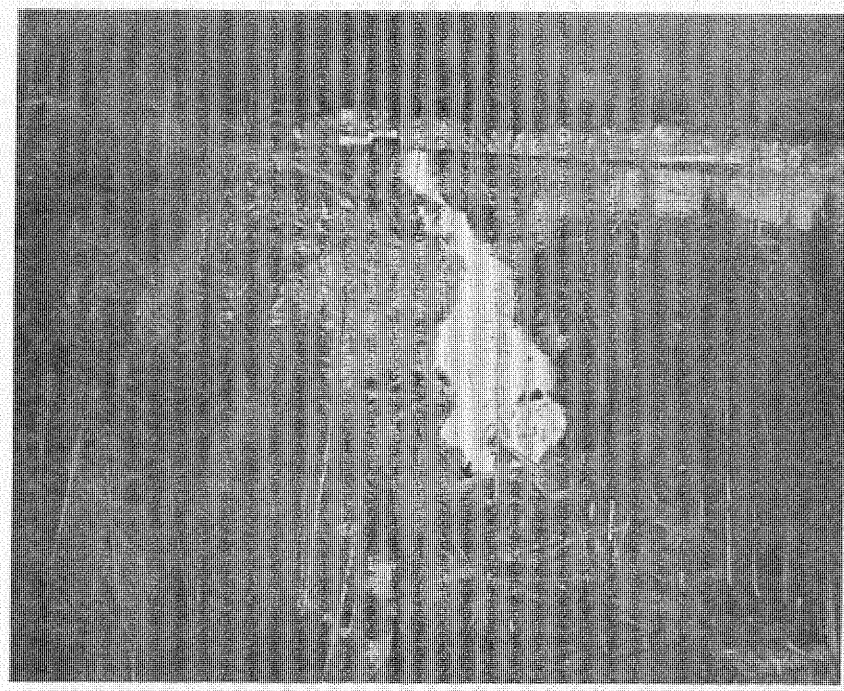


Figure 111. --Tunnel drainage from fault at station 208+70, cascading down slope toward highway. Flow was estimated at 7,800 gallons per minute. P783-908-1153, November 10, 1952.

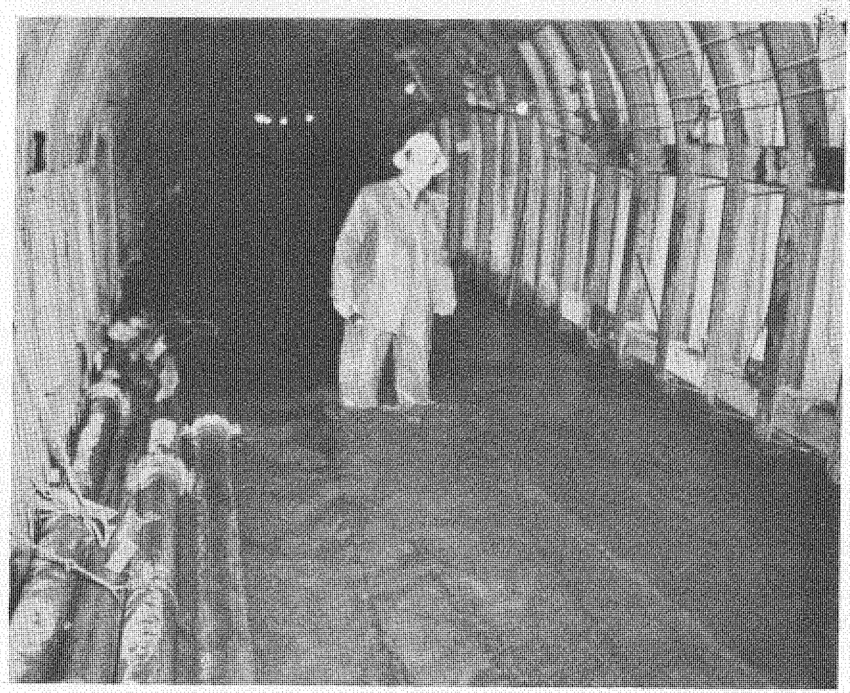


Figure 112. --Water flowing through tunnel from fault at station 208+70. P783-908-1163, November 15, 1952.

Equipment used in this operation consisted of a drill jumbo with four mounted drills, a mucking machine, electric-powered locomotives with 4-cubic-yard dump cars, and associated power equipment. Similar equipment was used at both headings.

The type of rock encountered in the tunnel required steel supports through approximately 70 percent of the tunnel (fig. 113). A total of 1,682,450 pounds of 4-, 5-, and 6-inch steel H-beam supports was used. Most of the support steel consisted of 5-inch H-beams on 4-foot centers; however, the weight and spacing of supports were dependent upon the type of ground encountered. Tunnel roof support bolts were used through several sections of the tunnel during the early stages of excavation, but owing to the numerous seams, thin bedding planes, and poorly cemented joints, they proved to be ineffective and their use was abandoned in favor of steel supports.

Figure 113.--Contractor's men erecting steel support in main tunnel at location of a vertical fault, near station 242+45. Temporary timber lagging is shown inserted in roof of tunnel to protect workmen raising supporting steel. P783-908-752, April 7, 1952.

After holing through, approximately 2 months were spent on invert cleanup, shifting tight support steel, removing fan line, removing collar braces and realining track in preparation for placing concrete tunnel lining.

(b) *Lining Operations.*-- Concrete tunnel lining operations started in January 1954, at station 27+38.5. Concrete placement was on a one shift per day basis initially but was soon changed to three shifts daily six days a week. Pours were continuous beginning on the day shift Monday and ending on the graveyard shift Sunday.

Prior to commencement of concrete operations, the major portion of cleanup work in the tunnel had been done with a mucking machine and laborers using hand tools and compressed air. Final cleanup was done in advance of form setting. Handling the loose material from cleanup presented a problem inasmuch as it all had to be hand carried in buckets down the tunnel past the concrete mixing and placing equipment. Working space was quite limited in this work area. The rate of concrete placing generally depended on the amount of cleanup work that could be accomplished on each shift. Occasionally form setting was the limiting factor as only 240 feet of forms were available (fig. 114). Delays and shutdowns of concrete operations were quite frequent at the beginning, owing primarily to transportation difficulties with aggregate trains. In the cleanup of the tunnel invert, all ballast was removed from underneath the track and the track then supported on blocking. This blocking would work loose because of traffic vibration and, as a result, derailments were numerous.

Three aggregate trains, consisting of five or six cars for each train, were used for hauling aggregate. Passing tracks had been installed at 2,500-foot intervals when the tunnel was excavated, and these were used for passing aggregate trains. In addition to these sidings, a prefabricated portable double track with switches at each end was used for switching loaded and empty trains near the concrete placement. The portable siding was usually moved once a week so that haul distance between the siding and the point of placement did not exceed 2,500 feet. This arrangement worked well, and dry batches of material could be hauled to the mixer so that mixing and placing operations were continuous.

By June 5, 1954, concrete lining had been completed from station 27+38 to station 199+11 at which time concrete operations were suspended until the remainder of the tunnel invert could be cleaned up.

As the tunnel invert in the wet section was cleaned up, the permanent drainage system was installed, and all wet sections of the tunnel were panned. The drainage system consisted of 6-inch steel pipe headers with 1-1/2-inch suction feeders and 6-inch steel pipe risers. The suction end of each 1-1/2-inch feeder was embedded in a gravel filter. The 6-inch risers, which were connected to the headers, were set so as to discharge through a flap valve above tunnel springline. The number of suction feeders required in any given section of the tunnel was dependent upon the amount of water in the particular area being drained. Pumping stations were installed at 1,000-foot intervals and pumps were moved as required.

Operation of the drainage system during concreting was not completely satisfactory. Proper regulation of valves on suction lines was very difficult to attain; consequently, the contractor had to provide additional pipelines and portable pumps for unwatering during tunnel lining operations.

Concrete lining of the tunnel was resumed July 12, 1954, at station 199+11 and by December 18, 1954, the lining was complete all the way to the surge tank. Concrete lining of the gate shaft began June 23, 1954, and was completed September 2, 1954. The concrete was conveyed from the mixer into a hoist bucket by means of a conveyer belt, then lowered down the shaft to the desired locations.

The specifications for the tunnel called for use of reinforcement steel in the entire lining. Because of the good quality of rock encountered in much of the tunnel, it was decided that a major portion of the reinforcing steel could be eliminated from the lining. As a result of this design modification, only 7,901 feet, or 33.6 percent, of the tunnel lining was reinforced, and a saving of about $800,000 was realized.

Backfill grouting to increase the structural stability of the tunnel lining was performed under order for changes No. 11 (sec. 84(g)). Sections to be grouted were selected by reference to records of conditions encountered during excavation and lining operations and from the experience gained in the backfill grouting of a 1,000-foot test section between stations 180+00 and 190+00. The tunnel was backfill grouted from station 50+03 to station 207+00, from station 227+00 to station 229+00, and from station 249+00 to station 254+00; 773 grout holes were drilled and grouted, and 58,865 cubic feet of sand and cement grout were used. The tunnel section from station 227+00 to station 229+00 was pressure grouted in order to seal off ground water outside the tunnel lining. After the tunnel was filled with water, additional grouting was performed from outside the tunnel around the adit plug to seal off ground water seepage.

92. Surge Tank. - The surge tank was excavated between February and August of 1953. A small pilot shaft was raised through the center of the tank and used as a muck chute to the tunnel. The balance of the rock was then drilled in 5-foot lifts and blasted

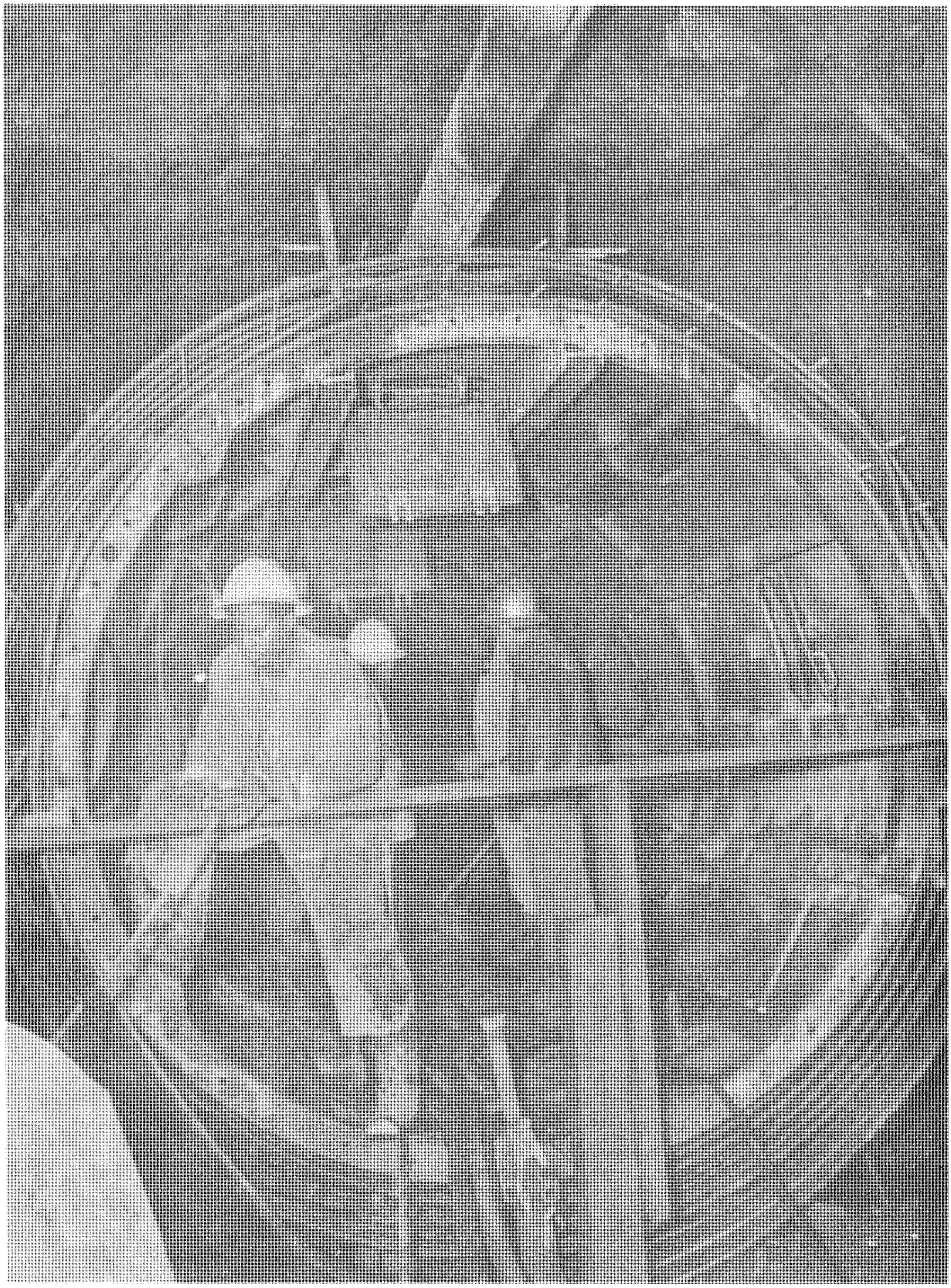


Figure 114. --View of tunnel section showing reinforcement steel, steel forms, and rubber water stop. Pipe at top is pumpcrete slick line. P783-908-1001, July 24, 1952.

on self-cleaning slopes, from the top down. The spoil was taken out through the adit in mine cars and wasted in Waldemar draw.

Although badly fractured, the rock was reasonably stable. Eight-inch, wide-flange H-beam structural steel supports, on 4-foot centers, were used the full height of the tank (fig. 115). Space between supports was lagged solid to within 40 feet of the bottom. A timber crib was constructed on the top downhill side to serve as a "kicker" for the top supports; these supports in turn were angle-tied together with rods and turnbuckles. In spite of these precautions, a movement of 6 inches was observed in the top support ring.

Concrete in the surge tank was placed in the fall of 1954. The concrete was pumped to the base of the surge tank from a mixing plant just outside the adit portal, then placed from a bucket hoisted by a winch mounted on structural steel beams at the top of the surge tank.

93. Penstock. - Open-cut excavation of the penstock started on November 26, 1952. A clamshell was used to excavate between stations 265+60 and 266+06. The ground-water table was at elevation 27, and the open cut was excavated to elevation 18. Continuous pumping was necessary, and sheet steel piling was used to prevent sloughing.

Tunnel excavation for the penstock was started from a portal cut through the upstream wall of the sheet steel piling at station 265+60. Steel liner plates were used as supports for the first 30 feet of tunnel driven, and conventional steel H-beam supports were used for the remainder of the excavation.

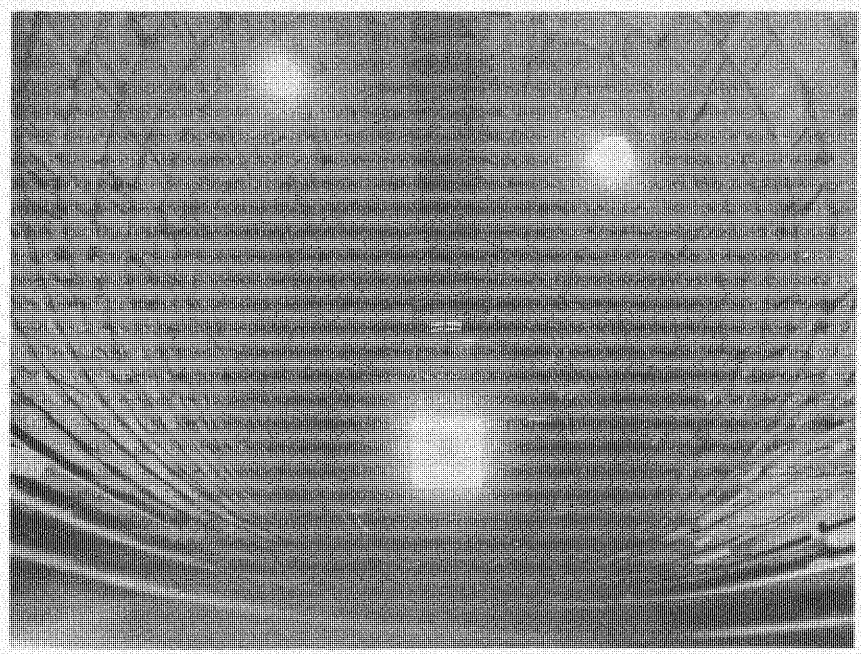


Figure 115.--View of surge tank excavation, looking up. Note structural steel H-beam support rings and lagging. P783-908-1444, August 14, 1953.

The entire length of the inclined penstock was driven from the portal at station 265+60. A miner's shuttle car powered by a hoist located at the lower vertical bend was used to transport men, materials, and equipment to the heading. The track was installed on a solidly lagged deck, supported by structural steel H-beam cross struts with space beneath to serve as a muck chute. The penstock was lagged solidly to minimize the danger of falling rock, and a covered manway and utility line duct was installed on the left side of the penstock excavation. The 53° slope of the penstock tunnel was sufficient to allow muck to flow down the incline without hanging up. The penstock was "holed through" into the previously excavated tunnel at station 255+86 on February 5, 1953.

After holing through, the invert for the entire penstock was cleaned and the track raised in preparation for placing the steel penstock, reinforcing steel, and concrete. The lower steel vertical bends were then moved into the tunnel from the outlet portal on a track-mounted dolly and installed on previously placed concrete saddles. The bends were then embedded in concrete, using pumpcrete equipment for placing. Installation of the horizontal sections was followed with concrete embedment, normally made for two sections at a time. The penstock sections extending downstream from the portal were encased in a concrete anchor block which was supported by steel piles driven to refusal at bedrock.

The inclined steel penstock sections and the two bends at the surge tank junction were transported through the adit and lowered into place with a mine hoist installed at the junction of the north adit and the main tunnel. Concrete encasement was placed for two to three sections at a time using a pumpcrete machine located at the adit portal. The last two bend sections were encased in concrete early in July of 1954, completing all penstock work under specifications No. DC-3523.

94. Concrete Control. - (a) *Aggregates.*-- The source of aggregates for all concrete was the Knik River channel approximately one-fourth mile north of mile 34, Glenn Highway. The processing and stockpiling of concrete aggregates produced in 1952 was subcontracted by the prime contractor to Alaska Aggregate Corp. Processing was started May 16, and was completed July 7, 1952. During this time approximately 65, 400 cubic yards of aggregate was produced.

The aggregate plant equipment used by this subcontractor was practically all new and was especially purchased for this job (figs. 116 and 117). Considerable difficulty was encountered in meeting the specifications on sand because of a deficiency in No. 100, No. 200, and pan sizes. It was necessary to waste a considerable quantity of the coarser sand and blend in fine sand from the adjacent river banks in order to meet the specifications.

The aggregate plant equipment consisted of one 4- by 12-foot 3-deck vibrating screen; one 100-foot conveyor and one 60-foot conveyor; three 30-cubic-yard bunkers; one 9- by 12-foot sand classifier; one 5-inch crusher; one 6-inch high-pressure water pump; one 14-cubic-yard carryall; two tractors; one scoop tractor; and one tractor bulldozer.

In the spring of 1954 it became apparent that the quantity of concrete aggregate originally produced would be insufficient, and the prime contractor subcontracted the production of 4, 250 cubic yards of 1-1/2-inch aggregate and 8, 750 cubic yards of 3/4-inch aggregate to Northern Ready Mix, Inc., of Fairbanks, Alaska.

The processing plant of this subcontractor was an old portable crusher type. A nonvibrating, sloping 2-1/2-inch slotted screen was used to scalp off the oversize. The material then went over a nonvibrating sloping 1/4-inch screen on which a large quantity of water was used to wash off the sand. The material was then dry screened on a double-deck, sloping, vibrating, 4- by 8-foot screen with 1-3/4-inch top and 7/8-inch bottom. The fractions between 1-3/4 inch and 2-1/2 inches were crushed in a roll crusher set 1-1/2 inches. The return from the crusher was washed over a small section of 1/4-inch screen in the chute leading to the dry vibrating screen. After all of the 1-1/2-inch aggregate had been processed, the 2-1/2-inch scalping screen was removed and all material put over the 1-3/4-inch screen. The fraction between 7/8 inch and 1-3/4 inches was crushed with the rolls set at 3/4 inches. A 3/4-cubic-yard dragline was used to excavate from the deposit which was mostly below water level, and two small dozers were used to push the material to the conveyor hopper. Two 8-cubic-yard trucks were used to transport the material to the stockpile at the batching plant.

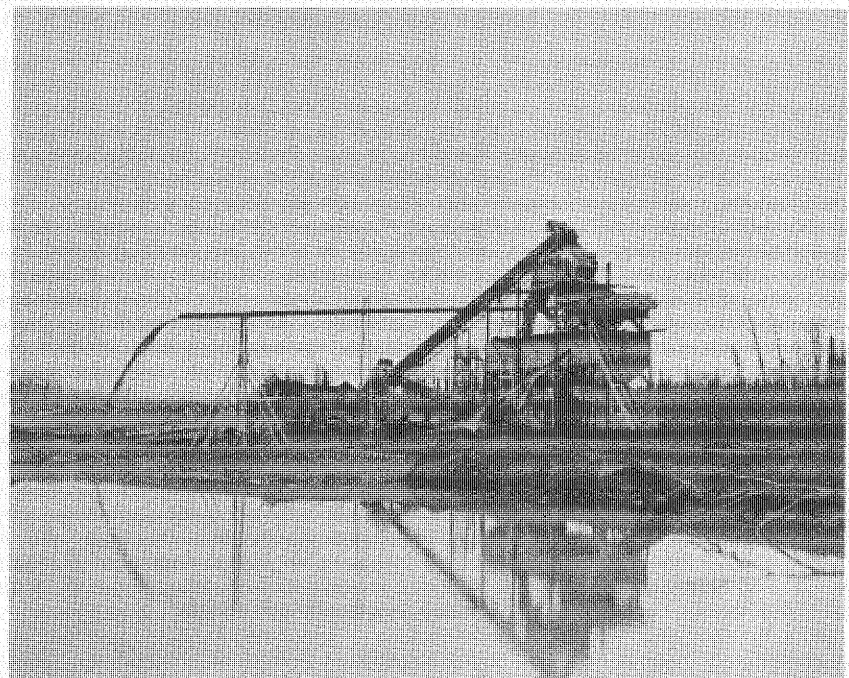


Figure 116.--Alaska Aggregate Corporation's aggregate plant located on the Knik River bed approximately one-fourth mile north of mile 34, Glenn Highway. P783-908-791, May 20, 1952.

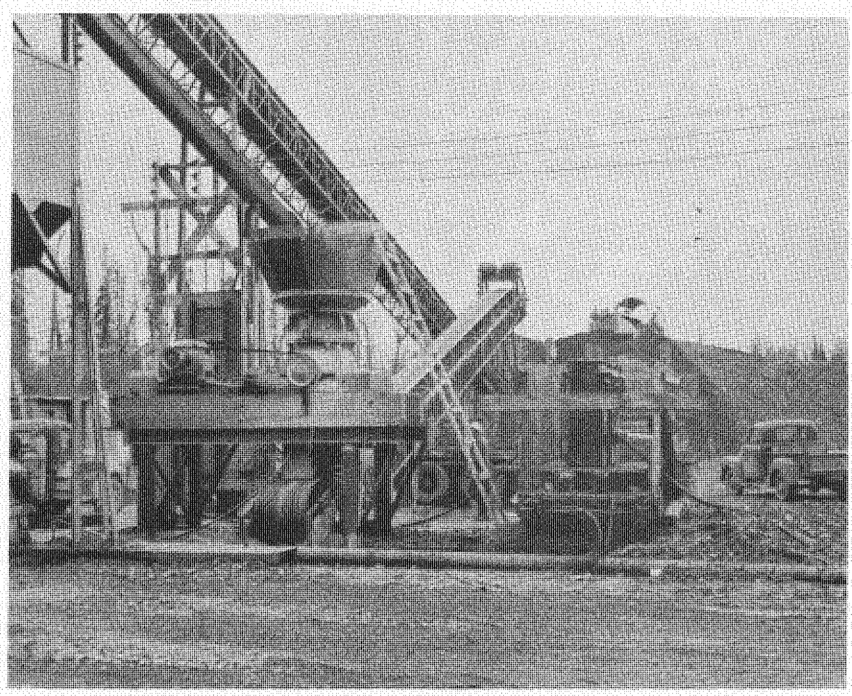


Figure 117.--Rock crusher used by Alaska Aggregate Corporation to crush oversize material. P783-908-792, May 20, 1952.

During production, aggregate was checked for conformance with specification requirements, particular attention being given to graduation and manner of stockpiling.

(b) *Batching, Mixing, and Placing.*-- The batching plant for the tunnel downstream from station 27+38.5, the inclined penstock, and the surge tank was an automatic batching system with a 3-beam scale. The sand and aggregate conveyor loading hoppers were loaded with a dozer. Two 24-inch conveyor belts transported the sand and aggregate from the loading hoppers to 600-cubic-yard storage bunkers. The batch plant and storage bunkers were enclosed with aluminum sheeting, and glass wool insulation was used on the aggregate bunkers (fig. 118). A battery of three hot-air oil burners, each developing 2 million British thermal units and thermostatically controlled at 800° F., was installed to heat the aggregates for cold weather operations. An elevator moved the aggregates from the bunkers to a 3-deck, 3-1/2- by 10-foot finish screen with 1-1/2-inch top, 7/8-inch middle, and 3/16-inch bottom screens mounted over 105-ton-capacity storage bins. To reduce the possibility of scale error from vibration, the scale cabinet was mounted on pedestals separately from the plant in the control room directly below the cumulative weighing hopper, and cable was substituted for the rod linkage from the weighing hopper to the scale cabinet. A 2,400-barrel-capacity cement storage silo was erected at the batch plant.

A double, reversible, aerial tramway, powered by a 125-horsepower, 440-volt electric motor, was installed to transport the aggregates and cement in two 65-cubic-foot buckets to a discharge terminal storage and loading plant near the north portal adit of the tunnel. A 600-barrel-capacity cement storage silo was erected at the discharge terminal (fig. 119).

Dry-batched aggregates for concrete tunnel lining from station 27+38.5 to station 255+02.9 were loaded into 3-cubic-yard 4-compartment cars at the discharge terminal and loading plant near the north portal adit. Each car held two batches of 1-1/2 cubic yards each with a separate covered compartment for the cement in each batch. The bottom-dump batch cars were unloaded onto a conveyor belt which charged a 3-cubic-yard truck-type mixer designed for use in the tunnel. Water for mixing was pumped from various drainage points in the tunnel and did not require heating. A qualitative analysis of the water indicated no objectionable impurities.

Concrete lining of the tunnel was started at station 27+38.5 and progressed downstream, a pumpcrete machine being used to place the concrete. Collapsible full-circle steel forms, oiled with form oil, were used to form the tunnel. Figure 120 shows the collapsible forms used in the tunnel lining operations. The concrete was vibrated with internal vibrators through inspection doors in the forms and by two air vibrators, clamped to the form ribs. The steel forms were collapsed and moved ahead by a hydraulically operated jumbo. Forms were stripped and moved ahead within 12 to 16 hours after placement of concrete.

Concrete for the horizontal penstock was mixed with a 3-cubic-yard truck-type mixer, designed for use in the tunnel and set up at the lower entrance to the penstock tunnel. The mixer discharged into a chute which dropped the concrete directly into the pumpcrete hopper about 15 feet below. Aggregates were trucked from the main batch plant.

The 3-cubic-yard truck-type mixer was again set up outside of the north portal adit for lining the inclined penstock section and the surge tank. Batch cars and a conveyor belt were used to charge the mixer, which discharged directly into a pumpcrete machine. The pumpcrete machine was used to transport the concrete through the adit to the bottom of the surge tank where the concrete was then transferred to a bucket and hoisted for placement in the surge tank walls. Concrete was pumped directly to the point of placement in the inclined penstock sections.

Aggregate was trucked from the stockpiles to the gate shaft where it was finish screened through a 2-deck, 4- by 10-foot vibrating screen. A 1-cubic-yard stationary mixer was set up near the batching bins. The mixer had a magnetic scale and a cumulative weighing batcher on rails which discharged directly into the mixer skip. The mixer

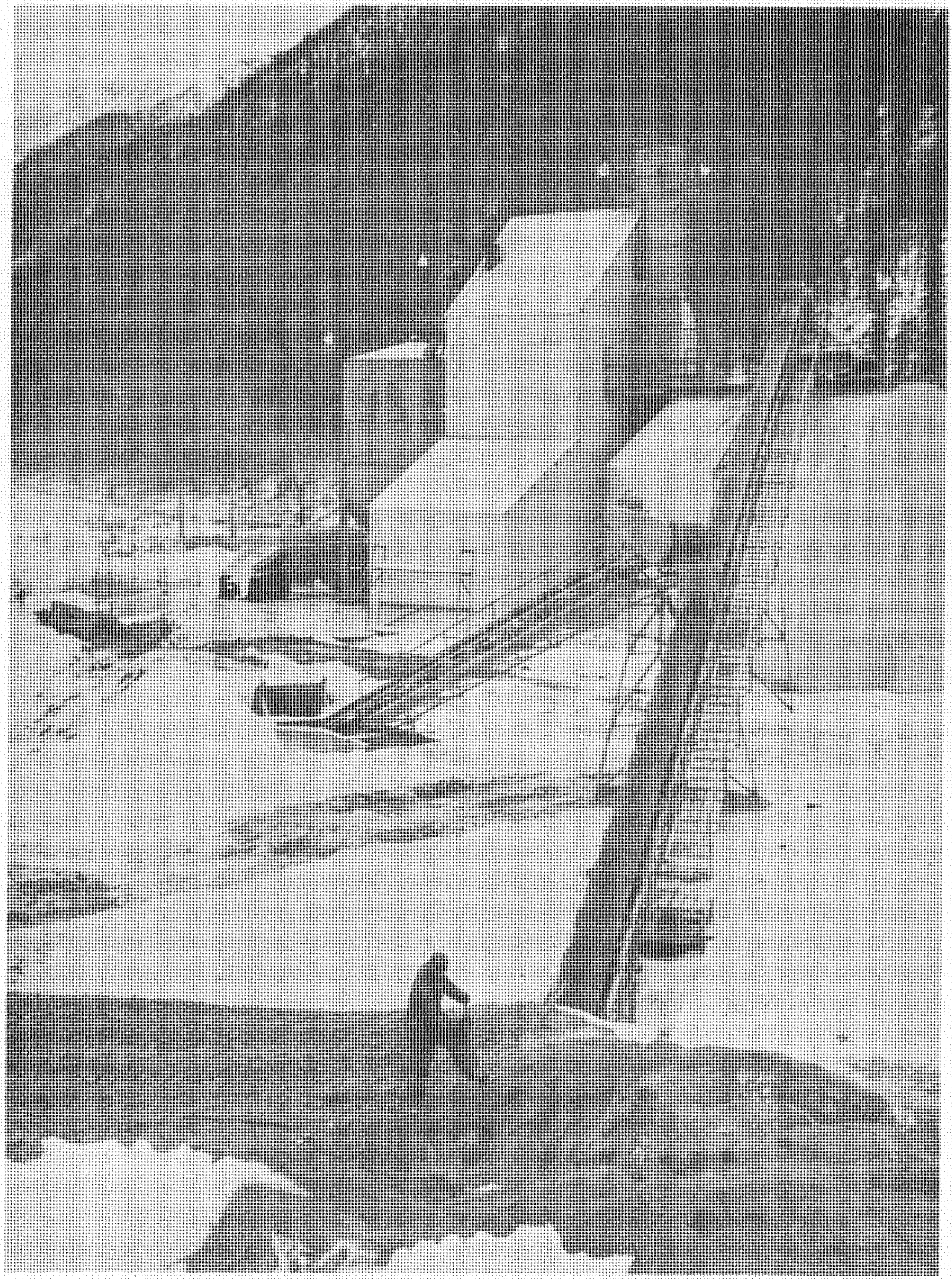


Figure 118.--Batch plant after enclosing to permit heating of aggregates. Aggregate conveyors are in foreground. P783-908-1526, January 9, 1954.

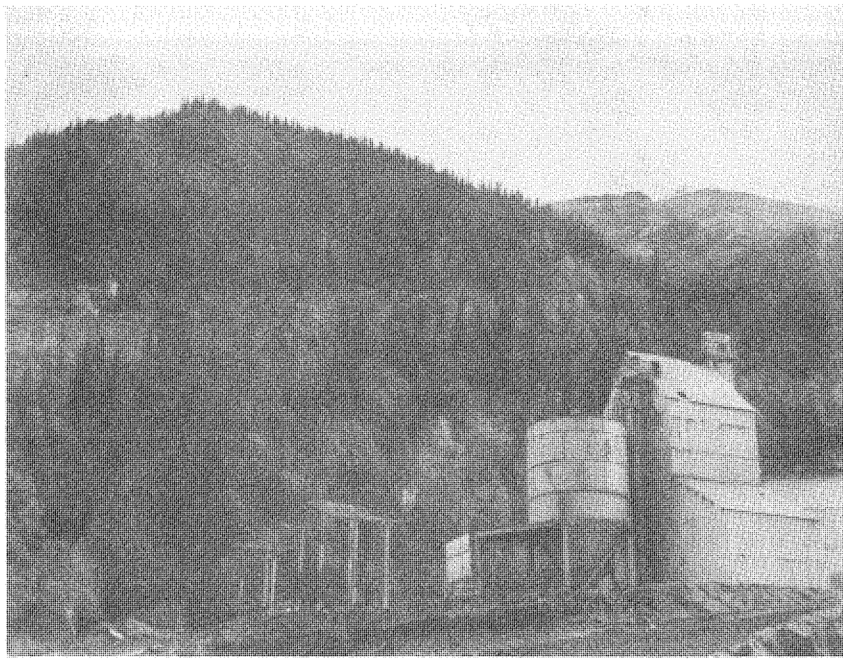


Figure 119. --Overall view of tramway installed to transport concrete materials from batch plant to tunnel adit. P783-908-1690, August 25, 1954.

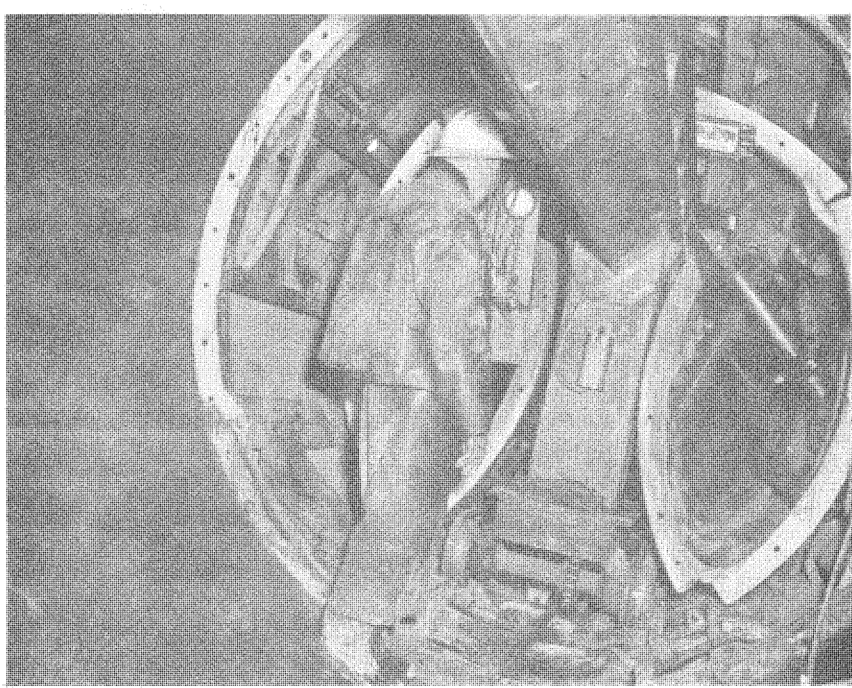


Figure 120. --Collapsible tunnel form being moved ahead through set forms by means of electrically powered jumbo. P783-908-1565, March 17, 1954.

discharged onto a 30-foot conveyor belt which transported the concrete into a 4-cubic-yard hoist bucket in the gate shaft. Only 1-cubic-yard loads were lowered down the shaft to the forms where four or five chutes with baffles were used to drop concrete into the desired locations.

Aggregates for the concrete tunnel lining from the gate shaft to the precast conduit section, station 20+00, and the inlet structure were trucked from the stockpiles at the main batch plant to the gate shaft area. A 3-unit batch plant having a capacity of 4 cubic yards per unit and a 4-beam scale with 3,000-pound capacity on each beam, was used (fig. 121). The aggregates were finish screened through a 2-deck, 4- by 10-foot vibrating screen. The mixer was a 1-cubic-yard nontilting mixer. Concrete was hauled from the mixer by trucks to the gate shaft and precast inlet structure. Concrete for the tunnel lining was discharged into a hopper attached to a 6-inch pipe and dropped 200 feet into a special built car after passing through a baffle box. The car was cylindrical and was rotated while discharging.

The concrete in the tunnel lining was placed by means of a pumpcrete machine. The bottom and sides of the concrete lining were consolidated with immersion-type vibrators through inspection doors in the forms, and the arch and sides down to springline were vibrated from the back of the forms.

Concrete was placed in the joints of the intake structure under 60 feet of water in Eklutna Lake. The 3/4-inch maximum concrete was mixed on a barge in 2-sack batches and discharged into a 4-inch-diameter tremie with foot valve that had been lowered into the form. A diver released the foot valve, and additional concrete was dumped into the tremie until the form overflowed. The pipe was then pulled, and a new foot valve installed before it was lowered into the next joint.

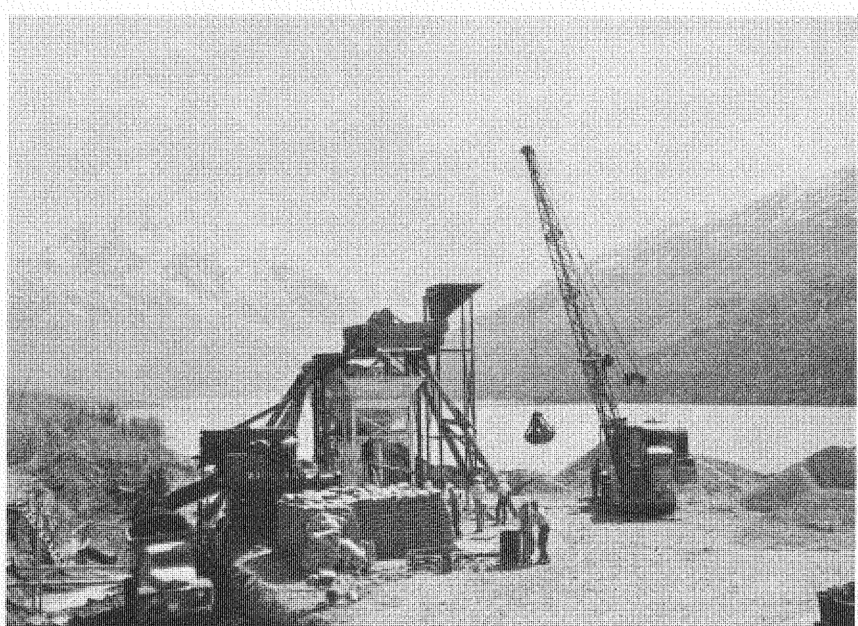


Figure 121.--General view of contractor's batching and mixing plant at gate shaft area, Eklutna Lake. Dumpcrete truck is being loaded with concrete at left for transportation to gate shaft. P783-908-918, June 18, 1952.

(c) *Cement.*-- Considerable difficulty was experienced during the initial stages of concrete placing because of false set in the type I, low alkali cement being furnished. In order to place concrete in which premature stiffening occurred, it was necessary to increase the water-cement ratio to prevent plugging the pumpcrete lines. When the higher water-cement ratio concrete was placed and vibrated in the forms, the false set broke down and the concrete flowed on slopes which were too long and flat to properly maintain until covered with additional concrete. Also, it was very difficult to completely fill the arch with concrete in which false set occurred, as it was not possible to keep the slick line buried and the concrete set up before it could be forced into contact with the rock.

Following several discussions with suppliers, another brand of type I, low-alkali cement was furnished and all placing difficulties due to false set were eliminated.

(d) *Curing.*-- Curing of all concrete was accomplished by application of white-pigmented commercial curing compound.

(e) *Air Entrainment.*-- An effort was made to maintain the amount of air entrained in the concrete at 5 percent, plus or minus 1 percent. This was accomplished by using a commercial air entraining agent introduced into the mixer simultaneously with the mixing water. Frequent tests were made of the freshly mixed concrete with a pressure meter to determine and control the amount of entrained air.

(f) *Concrete Mixes.*-- Routine 6- by 12-inch concrete test cylinders were cast in cans during concrete placing operations. After 7, 28, or 90 days, these cylinders were tested in the Bureau laboratory located at the project. A summary of concrete mixes used and the results of strength tests are included in table 2.

C. Construction Equipment

95. General. - Following is a list of the principal items of special construction equipment used by the contractor under specifications No. DC-3523:

(a) *Intake Construction.*--

1 14-inch suction dredge mounted on steel pontoon barge
1 Gantry crane mounted on rails at the shore of Eklutna Lake
1 Gantry crane mounted on a steel pontoon barge

(b) *Tunnel Construction.*--

1 Centrifugal blower, 12,000 cubic feet per minute
1 Stationary compressor, 1,100 cubic feet per minute
1 Stationary compressor, 900 cubic feet per minute
1 Drill jumbo
16 Drifters
3 Mucking machines
1 Rocker shovel
39 Muck cars
3 Combination trolley and battery-operated locomotives, 8 ton
1 8-ton diesel locomotive

(c) *Batch Plant.*--

1 2,400-barrel cement silo with unloading hopper and bucket elevator
1 3-bin, 105-ton batch plant with 3-beam automatic batching equipment and bucket elevator
1 600-ton, 4-bin aggregate storage bunker with 3,000,000 B.t.u. heaters and two 24-inch conveyors with electric motors
1 3-deck, 3-1/2- by 10-foot vibrating screen

Table 2. - Summary of concrete mix data for work under specifications No. DC-3523

Mix parts	Aggregates, percent clean separation			Concrete, cubic yards	Water-cement ratio, average	Slump, inches, average	Percent of entrained air, average	Cylinder strengths, pounds per square inch			
	Sand, average	Fine gravel, average	Intermediate gravel, average					7-day average	28-day average	90-day average	No. of cylinders
					Tunnel						
1 : 2.31 : 3.91	38.0	32.5	29.5	41,232	0.49	3.9	4.9	2,420	3,710	4,080	251
1 : 2.40 : 3.85	38.8	32.4	28.8	9,938	0.48	4.5	5.3	2,260	3,390	4,240	40
1 : 1.92 : 4.80	37.8	31.8	30.4	108	0.44	4.25	4.8	2,620	3,970	5,450	9
1 : 1.73 : 2.60	42.0	58.0	0	600	0.46	4.5	4.5	3,390	3,750	-	4
1 : 1.82 : 2.54	41.8	58.2	0	60	0.43	4.5	4.5	3,720	4,600	5,380	6
1 : 2.22 : 3.95	36.0	32.0	32.0	-	0.50	3.9	2.5	-	3,840	-	9
1 : 2.25 : 3.37	38.0	31.0	31.0	-	0.50	5.2	3.7	-	3,660	-	10
1 : 2.17 : 3.26	40.0	33.0	27.0	-	0.50	5.1	3.1	-	4,450	-	10
					Intake Structure						
1 : 1.98 : 2.52	44.0	56.0	0	-	0.50	3.5	2.8	-	4,510	-	8
					Gate Shaft						
1 : 2.34 : 4.08	36.5	27.6	35.9	1,067	0.46	3.2	4.7	2,400	3,530	3,960	51
					Surge Tank						
1 : 2.31 : 3.91	37.7	32.1	30.2	1,993	0.50	3.7	5.5	2,340	3,410	4,080	43
1 : 2.40 : 3.85	34.2	33.4	32.4	117	0.47	2.75	4.9	2,680	3,520	-	8
					Penstock						
1 : 2.31 : 3.91	37.7	31.3	31.0	3,773	0.50	4.2	4.9	2,400	3,730	4,510	59
1 : 2.40 : 3.85	40.1	32.4	27.5	190	0.49	3.8	5.4	2,550	3,910	5,040	10
1 : 2.36 : 3.84	38.0	30.5	31.5	418	0.45	5.0	4.6	2,480	4,370	4,880	5
1 : 1.91 : 3.22	38.8	30.0	31.2	431	0.44	4.25	5.0	3,250	3,610	5,540	10

1 Double reversible aerial tram with 65-cubic-foot buckets, located between the batch plant and the north portal of the tunnel
1 Tramway unloading terminal with 600-barrel cement silo, bucket elevator and single automatic cement batching equipment.
1 Tractor
1 Dumpcrete (special concrete dump truck), 3 ton
1 Hough payloader
2 120-barrel utility highway cement tank trailers with tractors

(d) *Concrete Equipment for Tunnel and Surge Tank.*--

18 3-cubic-yard, double-bin, dry-batch cars with separate cement compartment
1 California switch
2 Track-mounted, dry belt conveyors
2 Track-mounted, wet belt conveyors
2 3-cubic-yard truck-type mixers with electric motors
2 Single pumpcrete machines with screw-type agitators
3 Concrete train auxiliary cars with pumpcrete slickline supports
1 Set tunnel forms, 16 feet each, total length 240 feet
1 Set steel surge tank forms, 8-foot lift
1 Hydraulic form jumbo
2 Form vibrators, clamp-on type, air driven
3 Concrete vibrators, air driven, hand operated

(e) *Batch Plant and Concrete Equipment for Gate Shaft.*--

1 3-bin batch plant with 4-beam magnetic batching equipment
1 2-deck vibrating screen
1 1-cubic-yard stationary concrete mixer
1 18-inch by 32-foot wet conveyor belt with electric motor
1 3-cubic-yard rotating drum concrete agitator, track mounted
1 Single pumpcrete machine (also used at north portal)

(f) *Grouting Equipment.*--

1 Pneumatic compressor
1 Grout pump with two agitating mixing tanks
1 Special diesel locomotive, rubber-tire mounted, with 7-ton-capacity rubber-tire-mounted flat car

D. Factors Affecting Construction Progress

96. Weather. - Climatic conditions at Eklutna project, although relatively severe, are more predictable than in most areas in the United States. A review of construction difficulties due to weather usually indicates that lack of preparation is the primary factor causing the difficulty. In the construction of Eklutna Tunnel, cold weather, snow and lack of daylight were all factors which could be expected to have an adverse effect on progress, but through good planning and preparations the weather conditions had little if any effect on progress. Construction of the inlet under Eklutna Lake was accomplished during seasons when the lake was free from ice. The sinking of the gate shaft for the south portal of the tunnel was expedited to get underground before the freeze-up. At the adit for the north portal the attempt to get underground before the freeze-up failed, but a good organization with good equipment accomplished the job after the freeze-up. Concreting operations in subzero weather were accomplished by heating the aggregates and water when required. Weather was a factor in construction progress, but no more so than time, materials, manpower and numerous other factors.

97. Labor. - The labor supply for contract operations was generally adequate in respect to both quantity and quality. Union labor was used exclusively and wage rates were set by master agreements for the Anchorage area. Work stoppages due to labor disputes were minor and had little effect on overall progress.

CHAPTER VIII --*Construction*-- POWERPLANT

A. Contract Administration

98. Specifications and Contracts. - Bids were opened at Denver, Colo., on May 27, 1952, for the construction of Eklutna Powerplant under specifications No. DC-3704. Three bids were received, the lowest of which was submitted by the Rue Contracting Co., Fargo, N. D. The bids received and the engineer's estimate are listed below:

(1)	Rue Contracting Co., Fargo, N. D.	$2, 579, 607.00
(2)	J. H. Pomeroy and Co., Inc. San Francisco, Calif.	$2, 839, 413.35
(3)	Morrison-Knudsen Co., Inc., and Peter Kiewit Sons' Co., Boise, Idaho	$3, 126, 550.00
(4)	Engineer's estimate	$3, 032, 204.00

The contract, No. 14-06-D-162, was awarded to Rue Contracting Co. on June 2, 1952. A period of 830 days was allowed in the specifications for the completion of the contract. The contractor began work under the contract July 2, 1952, 81 days before receipt of notice to proceed. Notice to proceed was received by the contractor on September 22, 1952, fixing the completion date as December 31, 1954. Late delivery of the turbines and butterfly valves to the construction site and late completion of the generator installation by the generator contractor delayed the work in 1954 and 1955. A findings of fact dated April 27, 1955, extended the time for completion of all work to April 8, 1955, on which date the contractor finished all work under the contract.

Several supplemental notices covering minor design changes were issued prior to award of the contract. A pay item breakdown for work performed under specifications No. DC-3704 is shown as appendix C.

99. Orders for Changes. - (a) *Change Orders No. 1, 3, 4, and 5.*-- These orders, issued September 20, 1952, June 23, 1953, July 22, 1953, and August 13, 1953, were all related to the series of actions which were taken to continue construction of Eklutna project under the $20, 365, 400 authorization, prior to the amended authorization of $33, 000, 000. All items of the contract deleted by order for changes No. 1 were reinstated by order for changes No. 5. Orders for changes No. 3 and 4 extended the time during which the Government might reinstate the items deleted by order for change No. 1. This series of orders for changes had no effect on the cost of the contract.

(b) *Change Order No. 2.*-- This order, issued May 4, 1953, substituted type I, low-alkali cement for the original requirement of type II, low-alkali cement. The substitution was made inasmuch as type II, low-alkali cement is not normally available in the contract area. A price reduction of $0. 20 per barrel was effected by the order for change, or a reduction of $8, 197. 13 in the contract cost.

(c) *Change Order No. 6.*-- This order, issued September 16, 1953, directed the contractor to paint the interior of the Government-furnished penstock sections before moving them into place in lieu of painting them after being placed. The contractor chose to paint the sections at the shop rather than at the construction site. No change in the contract cost resulted by reason of this order for changes; however, the contractor was backcharged for the excess cost of transportation resulting from the weight of the coating materials and protective bulkheads.

(d) *Change Order No. 7.*-- This order, issued December 22, 1953, made the following changes:

(1) The contractor was directed to furnish all plug valves, except motor-operated plug valves, and the anchor bars to be embedded in first- and second-stage concrete for erection of draft tube liners and spiral cases in lieu of the Government furnishing them.

(2) Installation of Government-furnished laminated bakelite identification signs on the powerplant switchgear was required.

(3) The requirement for furnishing and installing No. 4 AWG power cable was changed to furnishing and installing No. 2 AWG power cable.

(4) The requirement for furnishing and installing galvanized ladder rungs for the septic tank was added.

This order for changes resulted in an estimated increase of $3, 550 in the contract cost.

(e) *Change Order No. 8.*-- This order, issued May 10, 1954, involved changing the aerial control cable from 7-conductor cable to 12-conductor cable; changing the alinement of the power and control cables at each end of the line, thereby increasing by 103 feet the length of the power and control cables; the addition of three line poles and hardware; and the addition of six double-line guys. The increased cost resulting from this order for changes was $6, 531. 83.

(f) *Change Order No. 9.*-- This order, issued November 19, 1953, provided for minor modifications. The increase in cost due to this order for changes was $1, 367. 01.

(g) *Change Order No. 10.*-- This order, issued February 17, 1954, provided for minor changes. This order for changes decreased the contract cost an estimated $460.

(h) *Change Order No. 11.*-- This order, issued October 25, 1954, was necessitated by the failure of the 10-inch sump pump discharge line originally located along the exterior of the 1-line wall of the powerplant. Failure of the pipe occurred twice due to settlement of fill. The line was relocated along the interior of the 1-line wall and through the A-line wall to the draft tube. Concrete supports were constructed from the exterior of the A-line wall for the 10-inch line, the 4-inch tailwater float-well supply line, and the 8-inch fire protection pump and jet pump supply line to guard against future failure of the lines. Items of work required to accomplish this order for changes included excavation and backfill; unwatering; salvaging materials; cutting a hole in the A-line wall; installing 10-inch sump pump discharge line; covering pipelines with asphalt-saturated felt; and placement of concrete. This order for changes increased the contract cost an estimated $14, 740.

(i) *Change Order No. 12.*-- This order, issued December 2, 1954, provided the following items of construction:

(1) Furnishing and installing copper tubing between the air receivers and air circuit breakers.

(2) Installing current transformer on the 12. 47-kilovolt power transformer.

(3) Furnishing and installing exposed electrical rigid metal conduit 2-1/2 inches in diameter.

(4) Constructing permanent 115-kilovolt transmission line ties to the switchyard.

(5) Applying surface coat to wall insulation.

(6) Mounting and connecting two station-service watthour meters.

(7) Mounting and connecting two start-stop indicating lights.

The estimated increase in cost to the contract due to this order for changes was $8, 700.

(j) *Change Order No. 13.*-- This order, issued January 26, 1954, provided for the following changes:

(1) Repairing 115-kilovolt disconnecting switches which were furnished to the Government in a faulty fabricated condition. The cost of repairing the switches was backcharged to the supplier.

(2) The contractor purchased wire and cable in stock quantities as directed by the Government to avoid possible delay in construction because of unavailability of final drawings. As a result, the unused quantities of wire and cable were purchased by the Government.

(3) Revisions were made to the control board to accommodate design and fabrication corrections. A portion of the cost of the work was backcharged to the fabricator.

(4) Because of the off-color contract with adjacent painted surfaces, the exposed surface of cement-asbestos board on the cable duct on the B-line wall in the generator room was painted.

The increased cost due to this order for changes was $3, 814. 34.

(k) *Change Order No. 14.*-- This order, issued March 18, 1955, contained minor hydraulic equipment changes that increased the cost of this order for change $390. 87.

100. Extra Work Orders. - (a) *Extra Work Order No. 1.*-- This order, issued July 14, 1953, directed the contractor to use a drophammer to drive piles that did not penetrate to the full expected depth by driving with an airhammer. The increased cost to the contract due to this extra work order was $1, 045. 92.

(b) *Extra Work Order No. 2.*-- This order, issued May 10, 1954, directed the contractor to correct oversize butt straps on two penstock joints. This extra work order increased the contract cost $3,719.43.

101. Contractor's Forces. - (a) *Personnel.*-- Eight men were responsible for field supervision, engineering and management for the Rue Contracting Co. In addition, a weekly average of 27 laborers and mechanics was employed during construction by the contractor and subcontractors in executing the contract work. During the height of the construction work, a maximum of 89 laborers and machanics were employed.

(b) *Subcontractors.*-- The prime contractor let seven subcontracts for portions of the work required by the specifications. The subcontractors and their work are listed below:

(1) Munter Construction Co. - Construction of the tailrace conduit and channel; highway relocation; powerplant excavation and backfill; piledriving; aggregate production; and bituminous surfacing of the Government camp streets.

(2) Western Industrial Corp. - Unwatering the powerplant excavation.

(3) City Electric of Anchorage. - Erection of steel switchyard structures and all electrical installation required under the contract.

(4) C. R. Lewis Co. - All plumbing installation required under the contract.

(5) Northern Roofing and Sheet Metal Co. - All roofing installation required under the contract.

(6) Oscar Sundberg and Sons. - All job site painting required under the contract.

(7) Brady Floor Covering Co. - All rubber tile and cove base installation required under the contract.

(c) *Rates of Wages.*-- Adjustments for changes in labor costs for work performed more than 180 calendar days after the date of the contract were made in accordance with supplemental notice No. 2. The adjustments were stipulated to be 85 percent of the difference between the total amount actually paid to all laborers and mechanics and the total amount that would have been paid if computed at the hourly base rates given in the specifications. The total of all adjustments paid to the contractor was $79, 539.52.

Table 3 shows the basic wage rates and subsequent wage rates which were effective under the contract.

Table 3. - Wage rates in effect for work under specifications No. DC-3704

Classification	Base pay	1952	1953	1954 & 1955
Ironworkers, reinforcing steel	$3.215	-	$3.62	$3.765
Ironworker, structural	3.415	-	3.84	3.965
Carpenter, power saw operator	3.265	-	3.69	3.185
Carpenter	3.14	$3.34	3.565	3.69
Millwright	3.34	-	3.765	3.89
Laborer	2.77	2.97	3.06	3.185
Pneumatic tool operator	2.835	-	3.16	3.285
Vibratorman	2.87	-	3.195	3.32
Cement dumper	3.02	3.22	3.345	3.47
Sandblaster	3.02	-	3.345	3.47
Sandblast pot tender	2.77	-	3.095	3.22
Flatbed truckdriver (under 10 ton)	2.87	3.07	3.195	3.32
Crane operator (truck type)	3.57	-	3.895	4.02
Oiler	2.87	-	3.195	3.32
Overhead loader operator (3 cu. yd. and under)	3.22	-	3.545	3.67
Heavy duty mechanic	3.27	3.47	3.595	3.72
Fireman	2.87	-	3.195	3.32
Mixer operator	3.27	-	3.595	3.72
Winch truckdriver (over 5 ton)	3.07	-	3.395	3.52
Elevator bucket loader operator	3.27	-	3.595	3.72
Boilermaker	2.68	-	-	3.05
Cement finisher	3.15	-	-	3.60
Cement truckdriver	3.02	-	3.345	3.47
Compressor operator	3.02	3.34	3.665	3.79
Bulldozer operator	3.22	3.42	3.545	3.67
Motor patrol grader	3.22	3.42	3.545	3.72
Piledriverman	3.185	3.385	3.665	3.735
Shovel operator (3 cu. yd. and under)	3.57	3.77	3.895	4.02
Water pump man	3.12	3.32	3.445	3.57
Turnowagon operator	3.17	3.27	3.495	3.62
Dumptor operator	3.07	3.27	-	-
Lowbed truckdriver	3.07	3.27	3.395	3.52
Electrician	3.50	-	3.85	4.25
Cable splicer	3.80	-	4.34	4.78
Lineman	3.50	-	3.925	4.25
Groundman	2.67	-	3.245	3.57
Plumber	3.50	-	4.10	4.25
Sheet metal worker	3.50	-	4.10	4.25
Brush painter	3.15	-	3.58	3.73
Spray painter	3.65	-	-	3.73
Structural steel painter	3.65	-	-	4.23

Painters were paid an extra $0.25 per hour for swing or stage work, regardless of height, and an additional $0.25 per hour for work over 30 feet above a floor; however, no adjustments were paid to the contractor on the extras.

102. Safety. - No fatal accidents occurred during construction work under this contract. The most serious accident resulted when a carpenter setting forms fell from a scaffold and broke the thumb on his right hand. The lost time from this accident was estimated to be 6 weeks.

The safety record for the contractor, including subcontractors, for the entire construction period is as follows:

Exposure, man-hours worked	252,819
Number of accidents	15
Lost time, days	112
Frequency rate	59.33
Severity rate	443.03

B. Earthwork

103. Highway Relocation. - Because the powerplant and machine shop were to be located on the existing Glenn Highway, it was necessary to relocate the highway over the tailrace conduit (fig. 122). Excavation and placing of embankment material began on July 2, 1952. The material was obtained from a borrow area adjacent to the highway right-of-way and was transported to the point of placement by motorized and tractor-drawn scrapers and spread with bulldozers. Adequate compaction was obtained from equipment travel over the material. Except over the tailrace conduit crossing, embankment construction was completed in August 1952, and selected subsurfacing material was placed the following September. The selected subsurfacing material was obtained from the same source as the embankment material, with the oversized material being removed. Following completion of the backfill about the tailrace conduit, placement of the embankment and selected subsurfacing materials over the conduit crossing was made in May and June of 1953. To complete the highway embankment, 41,437 cubic yards of material were required of which an estimated 9,000 cubic yards settled into the spongy muskeg foundation. Traffic was routed over the relocated highway on June 4, 1953. Frequent grading was required to keep the roadway in passable condition until the crusher-run base was placed in July 1954, and the bituminous surfacing was applied the following September.

The bituminous surfacing required by the specifications was to consist of a prime coat over the crusher-run base, road-mix bituminous surfacing, and a stone-chip seal coat. The Alaskan Road Commissioner objected to use of road-mix surfacing; therefore, the requirement for placing the asphaltic materials, and furnishing and placing mineral aggregate and stone chips for the highway relocation was deleted from the contract. By agreement, the Alaska Road Commission surfaced the relocated highway with plant-mix material and placed crushed rock on the roadway shoulders, but no prime or stone-chip seal coat was applied.

104. Excavation. - (a) *Tailrace Conduit.*-- Excavation for the tailrace conduit began in July 1952 with a dragline. Soon after excavation was begun, ground water was encountered and pumps were installed to unwater the excavation area. Included in the pumping installation were two 10-inch pumps, three 6-inch pumps, and one 4-inch pump. Pump sumps were constructed of timber piling as required. At the downstream end of the conduit excavation area, timber piling was driven to prevent sloughing of material into the area. The conduit excavation area is shown on figure 123.

(b) *Tailrace Channel.*-- The tailrace channel site was cleared and leveled in July 1952. Although most of the channel excavation was accomplished during the 1952 construction season, excavation to grade was completed during the 1954 construction season.

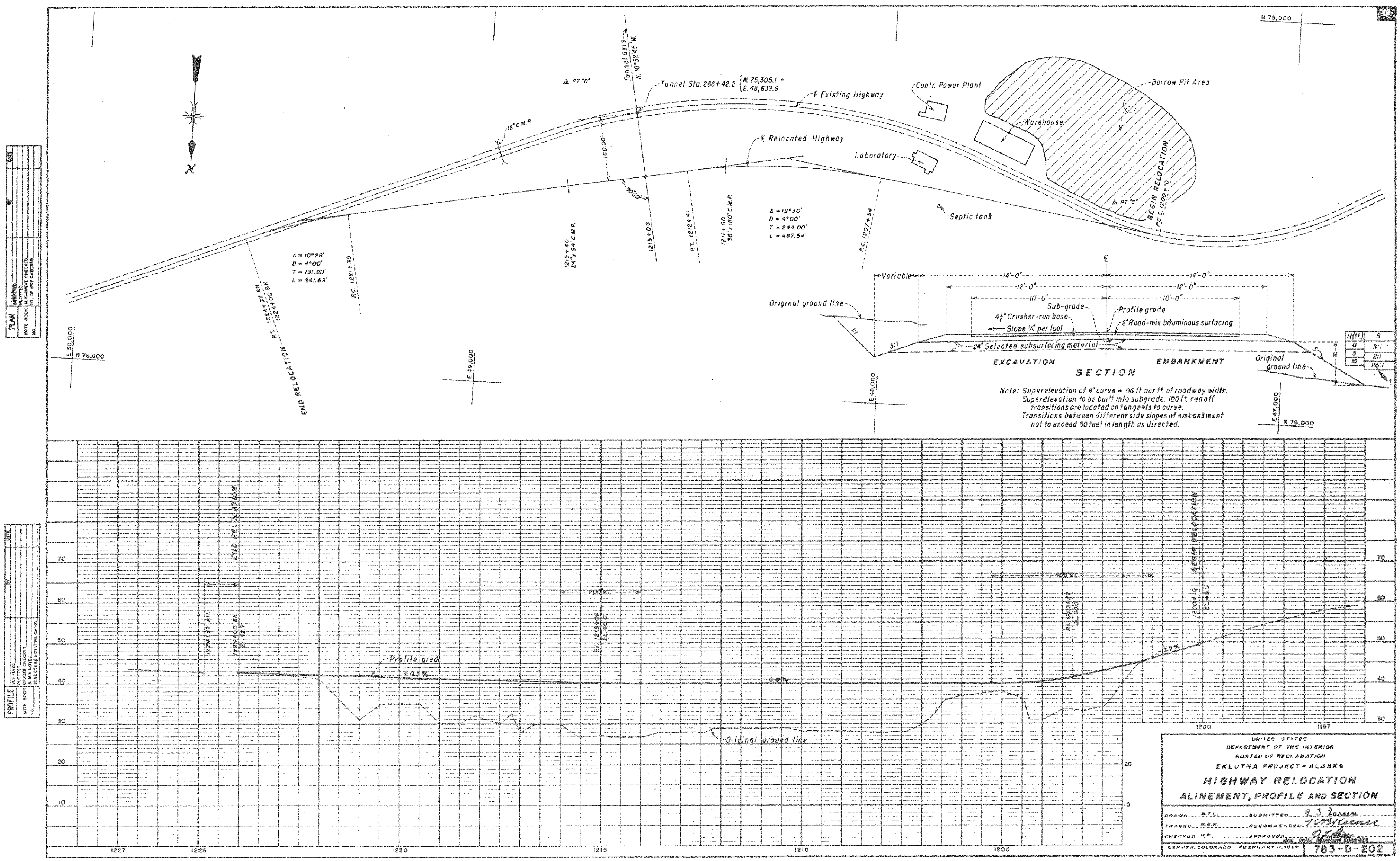


Figure 122.--Highway relocation--Alinement, profile, and section.

Figure 123. --General view of powerhouse and tailrace excavation showing pumps necessary to unwater foundation excavation. Shown are two 10-inch and three 6-inch pumps. P783-908-1084, September 19, 1952.

(c) *Powerplant.*-- Excavation for the powerplant was performed during the 1952 and 1953 construction seasons with a dragline, scraper, and bulldozer. Ground water was encountered at approximate elevation 26, and pumping was required thereafter to keep the excavation area unwatered. Only in one small area was a bulkhead required to retain the side slopes of the excavation.

To facilitate pile driving, excavation and pile driving were performed concurrently. As the excavation progressed, pile-driving equipment was set up at convenient intermediate elevations, and piles were driven in areas already excavated to grade.

105. Backfill. - (a) *Tailrace Conduit and Channel.*-- All backfill material was obtained from the borrow pit shown on figure 122. Backfill was placed and compacted for the tailrace conduit foundation as required by specifications and shown on figure 21. The material was placed in 6-inch layers and compacted by equipment travel and a sheepsfoot roller. Along the right bank of the tailrace channel for a distance of 100 feet downstream from the edge of the riprap, and where possible about the tailrace conduit, compaction was obtained by equipment travel. Backfill placed about the warped walls of the conduit, which was inaccessible to equipment travel, was compacted with an electric compactor.

(b) *Powerplant.*-- Well-graded sand and gravel obtained from the Knik River channel was used for backfill about the powerplant and machine shop. Equipment used for hauling the material included two 15-cubic-yard motorized scrapers and three 8-cubic-yard dump trucks. A dragline and two bulldozers were used for placing and spreading the material. The material was wetted for proper compaction and consolidated by equipment travel. Also, a gasoline-powered immersion-type vibrator and mechanical tampers were used to obtain consolidation in areas inaccessible to equipment travel.

106. Foundation Piling. - Government-furnished, 14-inch, 73-pound steel H-beam bearing piles were driven for the foundations for the powerplant, transformer structure and penstock anchor block by a subcontractor, Munter Construction Co., Seattle, Wash. Pile-driving operations started June 17, 1953, and were completed on August 22 following. A total of 18,139 lineal feet of piling was driven, consisting of 289 vertical and 110 batter piles.

Excavation and pile driving were carried on simultaneously. As the excavation progressed, piles were driven with equipment operating from benches at intermediate elevations adjacent to areas excavated to foundation grade (fig. 15). A dragline with 80-foot boom, airhammer, and 65-foot leads was used to drive the piles.

The specifications required that the piles be jetted as well as driven to elevation -5.00 to prevent damage to the paint coating from abrasion. The jetting operation proved to be impractical as the material encountered would not go into suspension around the pile but would blow back around the jet. Two test piles, one jetted when driven and the other driven without jetting, were pulled for comparison of paint damage. It was found that damage to the paint was greater on the jetted pile, and jetting operations were discontinued.

All piles were driven to refusal in bedrock, the average penetration being approximately 5 feet. Level checks were made to assure that heaving did not occur when driving adjacent piles.

Permanent benchmarks on brass caps were established in the concrete floor at elevation 15.0 for the purpose of checking for settlement of the structure. Levels were run periodically during construction and also since the plant has been in operation, but no settlement has occurred.

C. Mechanical Installations

107. Turbines. - The installation of the turbines was started on April 27, 1954 (fig. 124). This work was performed by the general contractor under specifications No. DC-3704. On May 18, 1954, the first turbine was ready for forming, installing embedded pipe and reinforcing steel and the riveting and welding of butt strap. The only difficulty encountered was in sealing the joint between the gaskets of the spiral case and the upper and lower cover plates. This was caused by trimming the vertical gaskets too close to the spiral case. The first gaskets were replaced and trimmed so that they protruded one-eighth inch into the recess for the gasket under the two head covers. The embedded parts of the first turbine were embedded in concrete on June 7, 1954, and those for the second turbine on July 20. After a satisfactory hydrostatic test of 500 pounds per square inch, a pressure of 350 pounds per square inch was maintained for 7 days and cooling by spray was continued for 7 days. With each turbine, pressure was lost once due to power failure during the testing or curing period, but was restored within 5 minutes in each instance.

The installation of the nonembedded parts was accomplished with only minor difficulties. The main difficulty occured when a shipping crate, having been damaged in shipment, broke open and allowed nine of the gates to drop onto the rails at the railroad siding while the contractor was unloading them. The gates were swung in a lathe at the Alaska Railroad shop for check, and were found to be true. The minor abrasions and scars were filed down and filled with stainless-steel welding rod where necessary and filed smooth to contour. No trouble was encountered in their installation.

All work of installing the nonembedded parts of both turbines, as far as could be done prior to certain work by other contractors, was completed on September 29, 1954, and the manufacturer's turbine erector left the plant the following day. Other than minor pipework and periodic greasing, no additional turbine work was accomplished until November 19, 1954, when the erector returned to the job. The work then continued on the turbines until December 31, when unit 1 was started for the bearing run-in and dry-out. No difficulty was encountered in the operation of the unit. The erector left the

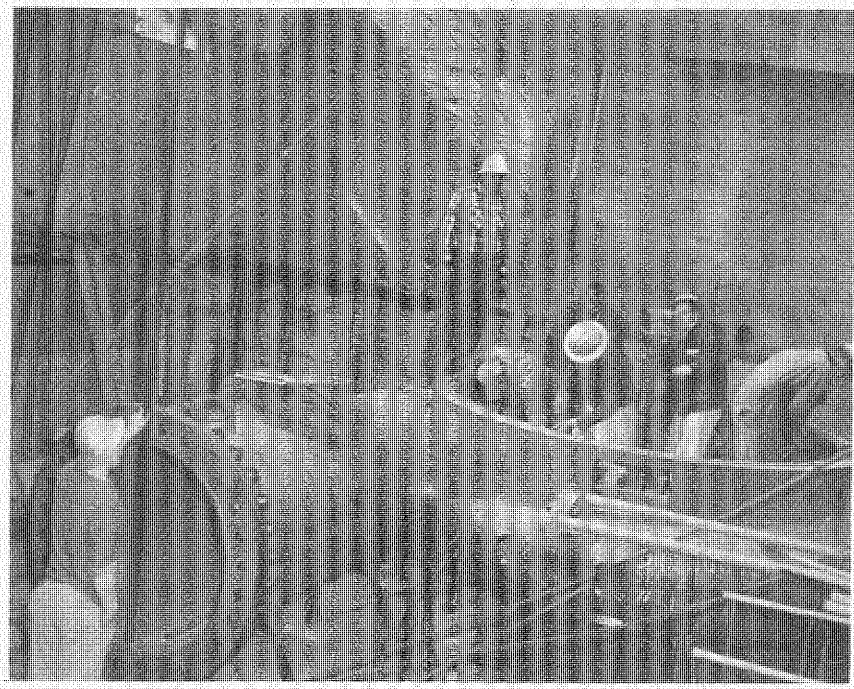


Figure 124.--Setting spiral case for generating Unit 1. P783-908-1609, May 5, 1954.

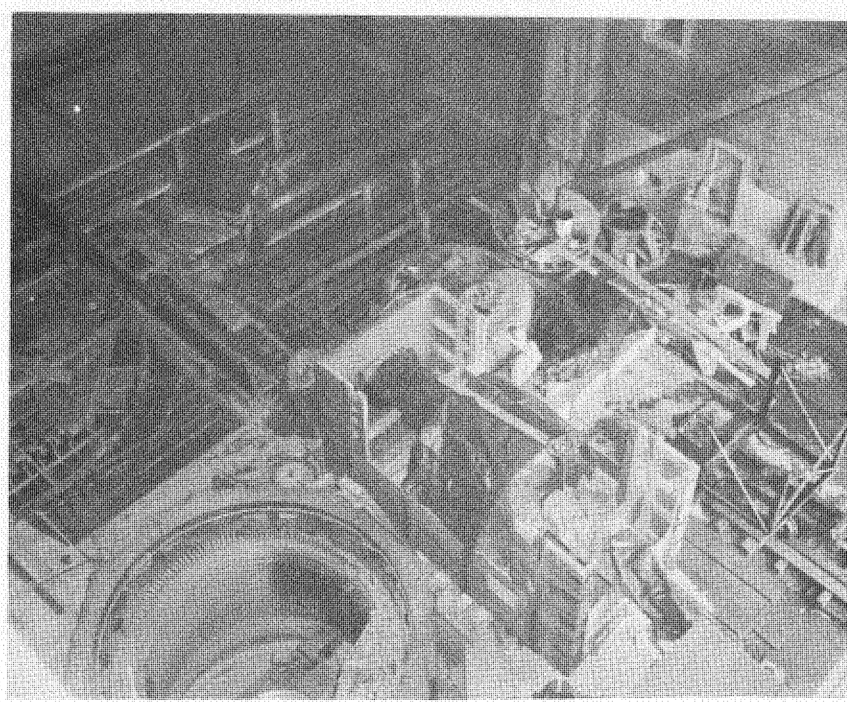


Figure 125.--Overall view during concrete placing operations around unit 2. Unit 1 stator is in place in foreground and rotor for unit 1 is shown being uncrated. Runner for unit 2 is in background. 783-908-1676, August 13, 1954.

job again on January 8, 1955, and returned on March 21. After installation of the stuffing box, packing and guide bearing, unit 2 was started on March 26 for bearing run-in and dry-out. A few troubles were encountered in eliminating air from the lubrication system, but these were corrected without delay.

The contractor performed the installation of the turbines with a crew of millwrights varying between two and five journeymen and one apprentice as the working conditions permitted.

Operation of the units was good except for a slight draft tube surge and power swing at about 10.5 megawatts to 11.5 megawatts load on unit 1 turbine only. The cause has not been satisfactorily determined as yet, but is believed to be due to the change in direction of the draft tube from the horizontal section to the junction with the draft tube of unit 2.

108. Generators. - The first shipment of generator parts which comprised the first unit complete from Pacific Oerlikon Co., of Zurich, Switzerland, arrived on the project June 9, 1954. The two halves of the stator and the rotor were stored out of doors in their respective crates. Heat was provided in each crate to prevent condensation. The rest of the parts were stored in the project warehouse.

The manufacturer's erection engineer arrived on the project July 19, 1954, and began installation of the first generator about July 27. (See figs. 125 through 128.) Progress on the first generator was fair. Some difficulties stemmed from the erection engineer's lack of complete mastery of the English language. However, the first generator was started for bearing run-in and dry-out on December 31, 1954. These tests were completed without difficulty and the high-potential test was completed on January 4, 1955. The stator was given a high-potential test, each phase to ground with the other two phases grounded. Test voltage was 14.8 kilovolts and was held for 1 minute. The field was tested at 1.5 kilovolts for 1 minute. The unit was synchronized at 12:01 p.m. on January 6, 1955. Load rejections were completed the next day, following which the unit was released by the erectors for operation up to full rated load.

Progress on installation of the second generator, which arrived on the project October 7, 1954, was very good. The previous experience of the erection crew resulted in a much shorter erection period. The unit was started up for bearing run-in and dry-out on March 26, 1955. The high-potential tests were completed on March 29, at the same voltage applied to the first unit. The unit was synchronized with the system 2 days later, and load rejections were completed on April 1, 1955, following which the unit was released by the erectors for full load operation.

The work of erection was performed under the direction of Pacific Oerlikon's erection engineer by City Electric of Anchorage on a subcontract. Most of the difficulties encountered in the erection were minor. One problem arose in making up American standard piping flanges to the Swiss standard. The American flanges were larger, and so were the bolt circles. This was overcome by putting all Swiss flanges on unit 1 and all American flanges on unit 2. Interference of metalwork with piping was the cause of a few difficulties of a minor nature.

The thermoswitches supplied by the manufacturer for releasing the carbon dioxide gas were found to be unsatisfactory. The manufacturer supplied a different type of thermoswitch and the necessary relocation of the new thermoswitches was accomplished without further difficulty. It was also found that the copper plate between the two insulation barriers for both thrust bearings was grounded. The bearing was insulated, but by only one barrier. Unit 1 was put in service before this was corrected, but the condition on the second unit thrust bearing was corrected before the unit was started. It was necessary to disassemble unit 1 thrust bearing to correct this condition as well as a few oil leaks at the upper and lower guide bearings. This work was completed on April 22, 1955.

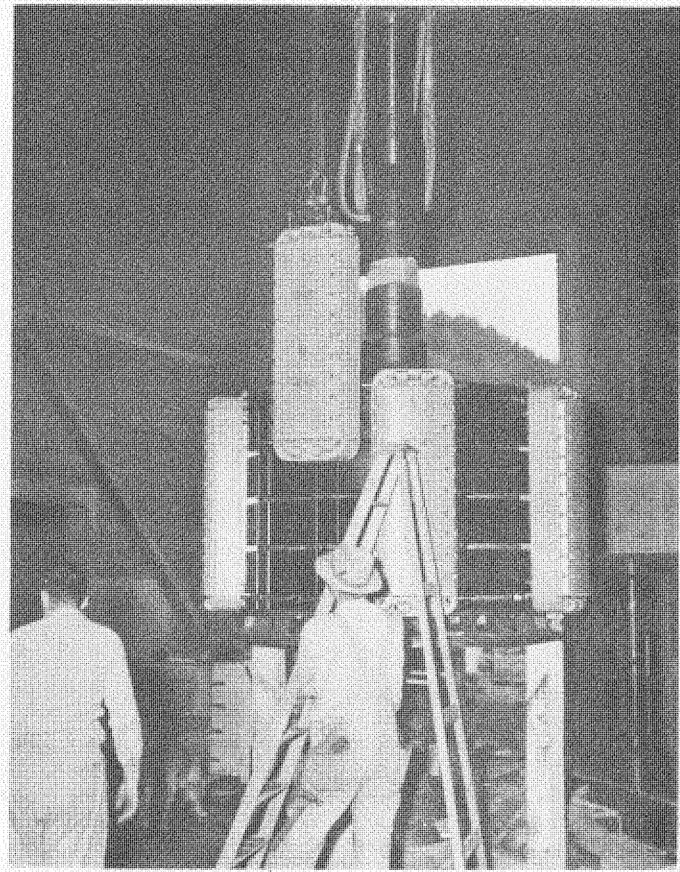


Figure 126.--View of rotor for unit 1 during assembly, showing one of the poles being lowered into place. P783-908-1683, August 18, 1954.

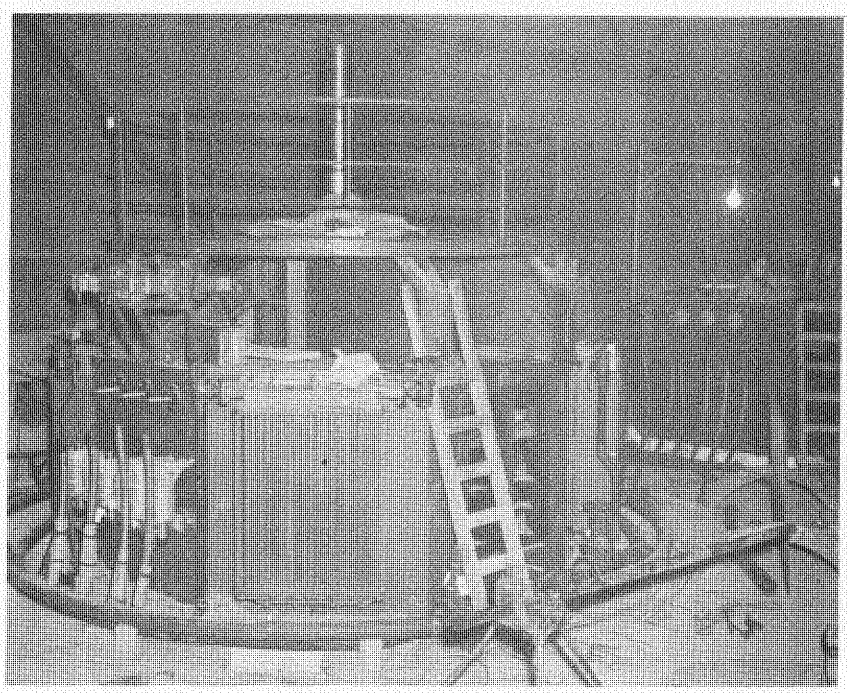


Figure 127.--View of generator No. 1 with cooling water pipes and radiators in place. Generator No. 2 is in background. P783-908-1731, November 3, 1954.

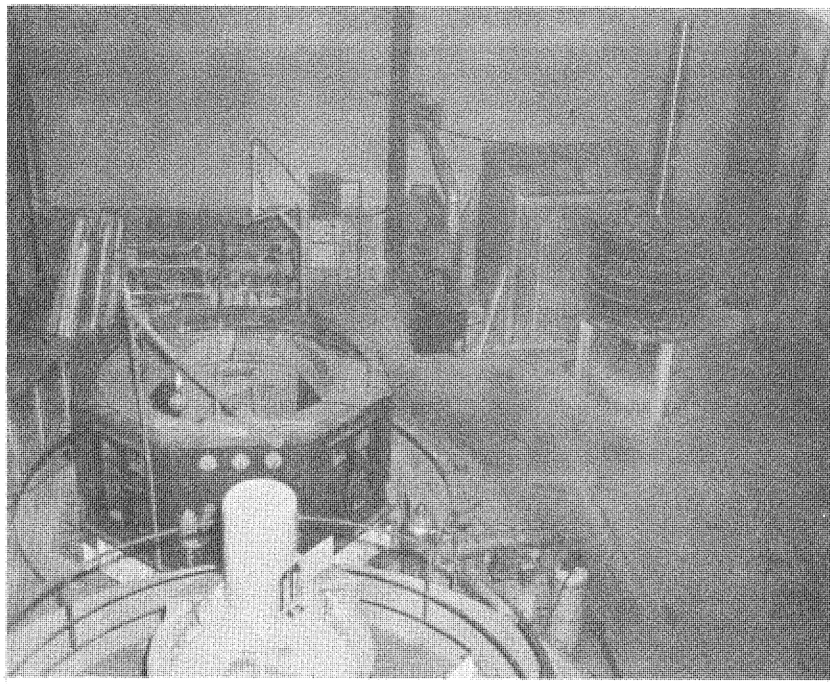


Figure 128. --View of generator floor showing generator No. 1 completed and progress on the installation of generator No. 2. P783-908-1742, December 27, 1954.

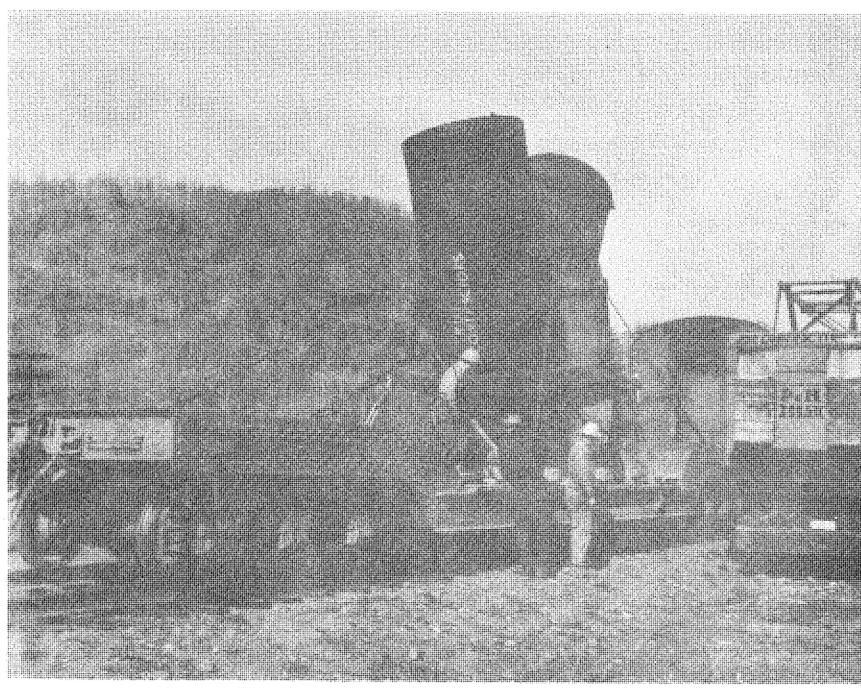


Figure 129. --Penstock wye-branch being unloaded by the contractor, on the main line of the Alaska Railraod, 4.5 miles east of Eklutna siding. P783-908-1590, April 23, 1954.

109. Governors. - The governors for the two units were manufactured by the Woodward Governor Co. under invitation No. DS-3688. Upon arrival of both units on the job site on March 15, 1954, the governors for unit 2 were found to have been extensively damaged during shipment. The casting supporting the ball head motor and flyballs had been broken off and the ball head assembly had fallen backward breaking wiring and tearing instruments loose from the instrument board. Piping and linkage were also damaged. Upon notification of the extent of the damage, the manufacturer requested that the unit be shipped to Rockford, Ill., for repair and testing. This was done and the governor arrived back at the project on August 10, 1954.

Installation of the governors was accomplished by the general contractor under specifications No. DC-3704. Supervision of installations was under the direction of a representative of the governor manufacturer during the periods November 20 to December 23, 1954; December 28, 1954, to January 8, 1955, and March 20 to April 4, 1955.

The governor cabinets and tanks were set in position and grouted in place without difficulty. After grouting the cabinet for unit 1 in place, it was found that, because the floor in the cabinet had been installed approximately 1 inch too low, there was insufficient clearance between the bottom of the floor of the cabinet and the top of the connecting rod pins to permit removal of the pins. This error was corrected by governor manufacturer at its expense, by machining one-half inch from the length of the pins.

110. Penstock. - Installation of the penstock and wye branch was performed during May 1954 (figs. 129 and 130). Considerable difficulty was experienced in the installation of the Government-furnished riveted butt straps. Watertight joints could not be obtained by riveting, because of excessive clearance between the butt straps and the penstock sections.

Field checks indicated that the butt straps were oversize, and upon advice of the fabricator, chevron cuts of approximately three-quarters of the plate depth were made at the third points and the joints bolted up tightly prior to the riveting. After riveting each joint, the chevron cuts were welded and the straps and rivet heads were seal welded.

Hydrostatic tests proved the revised method of connecting the penstock sections to be satisfactory.

111. Butterfly Valves. - The first butterfly valve arrived on the project on November 26, 1954. Installation began the next day and was completed on December 4. The second butterfly valve arrived 2 days later and installation was started immediately. The control cabinets were placed and connected to control wiring and piping by December 13, and checkout of the valves was completed the following day.

No difficulties were encountered in the installations. The work amounted to setting the valves in place and making piping and control connections. The valves were found to have a leakage of 5 to 15 gallons per minute under full head.

112. Cranes. - All three cranes were installed by the general contractor without difficulty. After having been put in service, it was found that the jib crane for handling the draft tube stoplog gate was breaking at the fillet weld where the web of the 10-inch H-beam joined the flange next to the wall. The beam was later altered by welding brackets to the flange at the upper and lower ends and fastening them with cinch anchors to the A-line wall (fig. 131).

Acceptance tests were performed on October 28 and November 19, 1954, on the 40-ton crane.

113. Heating and Ventilating. - This work was performed under subcontract by the C. R. Lewis Plumbing and Heating Co. Only minor difficulties of adjustment and operation were encountered.

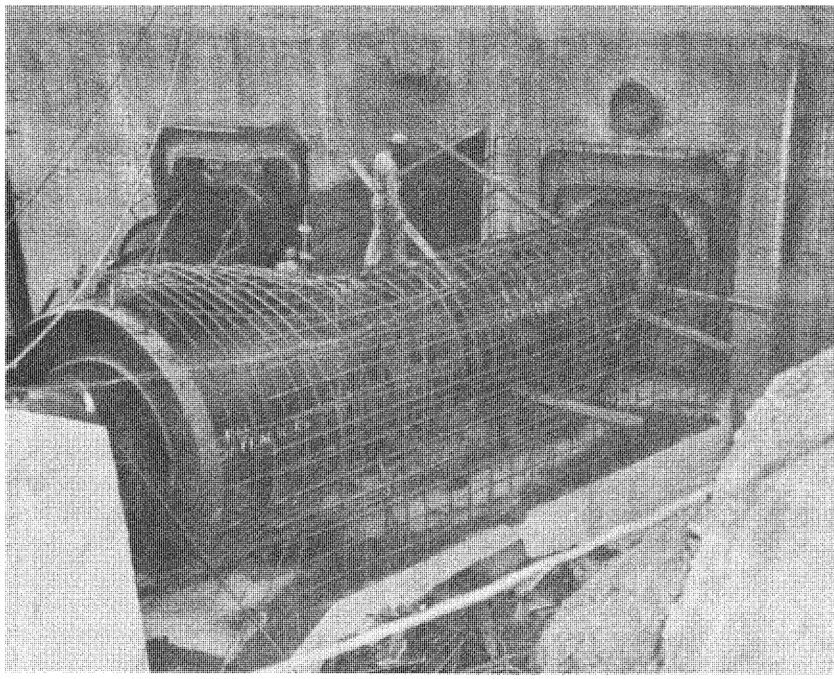


Figure 130. --Penstock wye-branch with reinforcement steel partially in place. P783-908-1635, June 16, 1954.

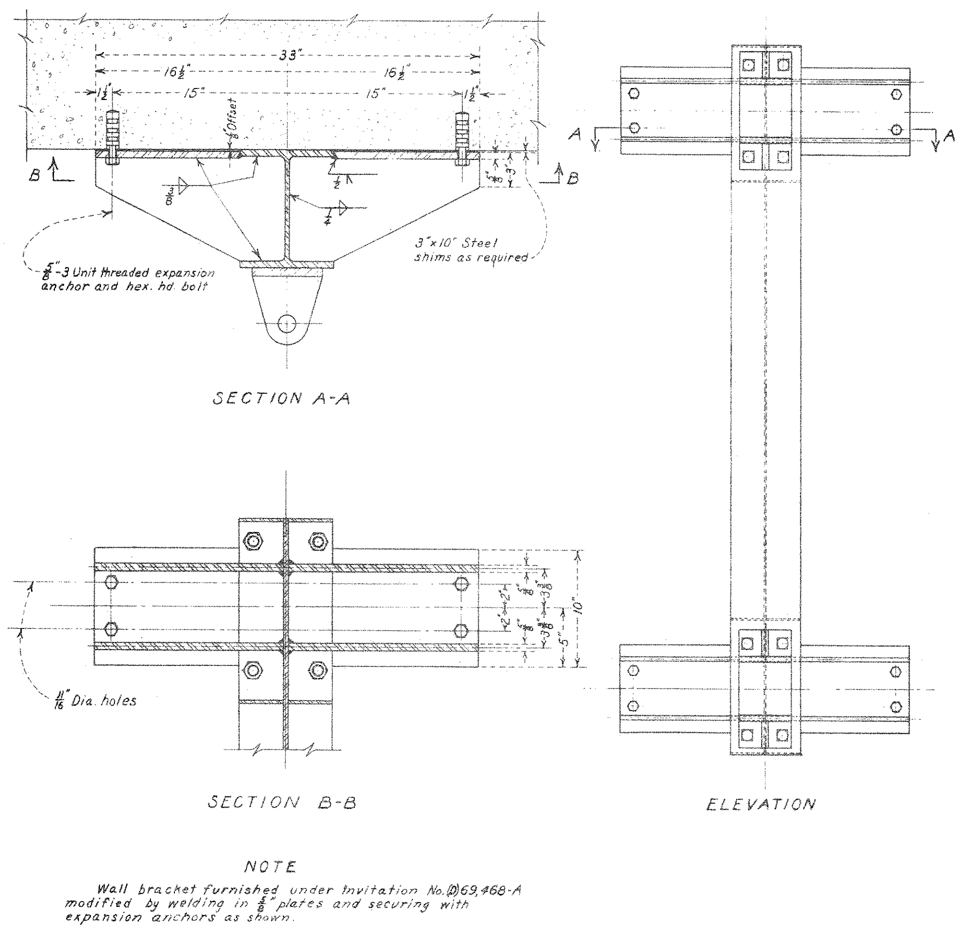


Figure 131. --Modification of wall bracket for draft tube bulkhead gate jib crane. (Reference drawing 783-D-395, jib crane and 2-ton hoist.) From drawing 783-D-558.

114. Miscellaneous. - The installation of miscellaneous metalwork, piping, fire protection equipment, water treatment equipment, pumps and compressors was accomplished without major difficulty. A few minor adjustments and servicing were required, after which the equipment tested out satisfactorily.

Difficulties were experienced with the operation of the tailwater elevation indicator. The original 1/2-inch beaded stainless-steel cable broke while the indicator was in service. The breaks occurred at the points where the beads were crimped on the cable. A new cable was installed, along with a guide sheave and a bracket to move the weight down from the lower sheave block and thus prevent tipping of the block. The new cable broke after a few days' operation, and the condition was subsequently corrected by the manufacturer.

D. Electrical Installation

115. General. - The electrical equipment conduit, cable, and ground wire installations were performed under specifications No. DC-3704 by the City Electric Co., of Anchorage, subcontractor for the Rue Contracting Co. The installation of embedded conduit and ground wire progressed concurrently with the concrete placing operations, and by June 1954, the major portion had been installed.

On June 15, 1954, the electrical subcontractor started a crew on the installation of the 440-volt 3-phase power and control line to the surge tank gate control house. Although this line was constructed on an extremely steep and rugged slope, it was completed except for end terminations by the end of July. Except for the pulling of lighting wire, which was used for construction lighting, no installation of electrical equipment was started in the powerplant until August. At this time, the main floor concrete slab for bay 1 would permit moving equipment into the switchgear room. The generator voltage switchgear was the first item of equipment to be moved in; this was followed a week later with the mounting of the station-service transformers, associated disconnect switches, and the power distribution board. The curing of the main floor slab in bay 2 permitted moving the main control board and the recording boards into the control room on August 27, 1954. The mounting of the smaller miscellaneous power panels and carbon dioxide cabinets was started immediately upon their arrival on the project September 10, 1954. The installation of exposed conduit was made at various times in conjunction with equipment installation in the powerplant.

With the completion of most of the switchyard structural steel about the middle of September, the contractor immediately began installation of the 115-kilovolt insulator and bus. Upon arrival of the 115-kilovolt disconnects on September 16, 1954, assembly of the switches started in conjunction with the other switchyard construction. Erection of the airblast circuit breakers in the switchyard was started late in September; however, due to faulty fabrication of the breaker supporting steel, considerable time was spent in refabrication to match anchor bolts and breaker interrupting units. Erection of the transformers began the first week in October.

As most of the electrical equipment was mounted by the first of October, the contractor immediately proceeded with the pulling of power and control cable. This was followed by the wiring of the boards and panels, the installation of such equipment as the batteries and chargers, and the installation of the main generator cables from the generator through the switchgear to the transformers. During the second week of November, the Government forces started making point-to-point check on internal board wiring in panels which the contractor had completed cable terminations. Then on November 12, 1954, the alternating-current power distribution board was energized from a temporary 440-volt power feeder to supply plant lighting and construction power.

During an outage on the Anchorage-Palmer line on November 26, 1954, the line was restrung through the Eklutna switchyard. As the installation of switchyard breakers and disconnects was not completed, the two lines were tied in through the bypass disconnect 569. The line was then energized to Eklutna switchyard and Palmer at 115 kilovolts through the Anchorage substation.

During the first week of December 1954, all of the electrical equipment was installed at the surge tank gate control house. During the following 2 weeks, operational checks were made first on auxiliary electrical equipment for unit 1 and station-service equipment, followed by a checkout on line breaker operation, relay and control board equipment functioning. The unit 2 bus was energized from the 115-kilovolt switchyard bus through the unit 2 transformer on December 22, 1954. After potential and phasing checks were made on the bus, the Government camp line, which included the contractors construction power, was energized from this bus. A week later and after making numerous operational tests and checks, the supply for the alternating-current power distribution board was cut over from the temporary feed to the unit 2 permanent supply from the generator bus through the station-service transformer.

During the last week of December 1954, all equipment installation and wiring checks were completed. Final operational checks were completed on unit 1 and all associated equipment. On December 31, unit 1 was put in operation for bearing run-in and continued through the stator dry-out phase. On January 4, 1955, the stator windings were showing a good Megger reading and the high-potential test was made. During the following 2 days, numerous tests were made on the unit, including voltage check, phase rotation, synchronizing and voltage regulation. The first unit was synchronized with the system January 6, 1955, and several light load rejections were made.

Except for the remaining completion work on the second generator, essentially all electrical installation was completed by the last of January 1955. During the 2 months following the completion of unit 1, numerous checks, adjustments and revisions were made on this unit and associated equipment, as well as station-service apparatus. By the middle of March, installation and wiring on the second generator had progressed sufficiently to permit point-to-point wire checking. All checks and operational tests on unit 2 were completed March 25, 1955, and the following day the unit was started up for bearing run-in and subsequent stator dry-out. After completion of the stator dry-out and following 2 days of tests and checks, the second generator was put in service on March 31, 1955.

The installation of electrical equipment met with the usual troubles such as wiring changes, improper fabrication of equipment, and the unfavorable working conditions always present when installation is concurrent with other plant construction. In addition, delays occurred because on some installations the proper tools, equipment or trained workmen were not readily available in this area. During the first 5 months of plant operation, no equipment failure or major troubles developed, and with proper attention the equipment should continue to give satisfactory service for many years.

116. Generator Voltage Switchgear. - The voltage switchgear was furnished under invitation No. DS-3694 by the General Electric Co. The switchgear was shipped in three sections, the breakers and auxiliary panels being crated separately. After the sections were assembled and mounted on the floor channels, the interconnecting bus bars were installed and splices were insulated with compound-filled boxes. Considerable construction time was required for the makeup of the 24 single-phase potheads in the switchgear and also for the additional 24 potheads on the transformers and generators. The magneblast circuit breakers were shipped completely assembled and a test operation indicated that no further adjustment was required. The equipment was first energized December 22, 1954, through the unit 2 transformer from the switchyard bus.

117. Distribution, Control, and Recording Boards. - The distribution boards were furnished under various schedules of invitation No. DS-4026. The main control board was supplied under schedule No. 1 by the Nelson Electric Manufacturing Co. This board was shipped in two sections, which were readily assembled and wired. The relays, instruments, and control equipment came mounted and wired, except for the instruments and voltage regulating equipment which was furnished by other suppliers. All instruments were easily accessible from the rear of the panel except the instruments on the two generator control panels; these were obstructed by the annunciator auxiliary relay panels. Numerous wire changes were made on the main board internal wiring. Some of these changes were the result of circuit revisions by design, but most of them

were made to correct manufacturer's wiring. The recording board also was furnished by the Nelson Electric Manufacturing Co. as item 2 of the same schedule. This board, consisting of only two panels, was shipped as one unit with all equipment mounted and wired. The inside of the board is accessible through two hinged doors in front or removable panels on the rear. The recorders for this board were manufactured by Leeds and Northrup and by Esterline-Angus.

The alternating-current power distribution board was furnished under schedule No. 3 of invitation No. DS-4026 by the Electric Service Engineering Co. This board is a compact, double-ended-type, low-voltage, packaged substation, supplied by one of two 440-volt, 3-phase feeders or, under normal conditions, each half of the substation is supplied by a feeder and has self-contained feeder and supply breakers, current and potential transformers, as well as undervoltage and auxiliary relays. The board was shipped as a single unit; however, the associated bus ducts and main feeder breakers were crated separately. Following a thorough checkout, the power distribution board was energized from a temporary supply on November 12, 1954.

The smaller miscellaneous power panels and board were supplied by Zinsco Electrical Products, under purchase order No. D-69, 490-A. These panels were located at various convenient locations throughout the plant and varied from the recessed wall type to floor mounting. The control panels for the carbon dioxide gas release were also supplied under this order and were located convenient to the generators and oil rooms for their fire protection.

118. Power, Station-Service, and Government Camp Transformers. - The transformers were supplied under three separate invitations. Westinghouse was the manufacturer for the 20, 000-kv.-a., 115, 000-6, 600-volt, 3-phase power transformers and the 750-kv.-a., 12, 470-6, 600-volt, 3-phase camp line transformer. The station-service transformers were supplied by the Stockwell Transformer Corp. The camp line transformer was received filled with oil and ready for operation; however, the larger power transformers were shipped without oil, under nitrogen gas pressure, and minus the bushings, heat exchangers, control panel and other fittings. The installation and testing of the power transformers was supervised by the manufacturer's erection engineer. The settings of temperature relays on the power transformer were checked to start the additional cooling fans when the temperature reached 70° C.; the annunciator alarm sounds at 90° C. and the trip circuit is set at 100° C. The unit 2 transformer and camp transformer were energized from the swtichyard bus on December 22, 1954; however, the unit 1 transformer was not energized until voltage was built up from the generator.

The 300-kv.-a., 7, 200-480-volt, 3-phase station-service transformers were shipped filled with noninflammable transformer oil and ready for service except for installation of the gas absorber. Stockwell furnished with each transformer a load-break disconnect switch manufactured by the Brown Boveri Corp. These transformers were first energized December 28, 1954.

119. Station Batteries and Chargers. - The station-service batteries and chargers were furnished under two separate orders. The 320-ampere-hour batteries are type EME 17 Exide supplied by the Electric Storage Battery Co. The cells were shipped fully charged and included a prefabricated 60-cell rack. The specific gravity of some of the cells was checked when they arrived and found to be satisfactory. However, as the plant was not planned to be ready for the battery installations for several months, the batteries were given a freshening charge after the chargers arrived. Both chargers are a voltage-regulated, transformer-reactor-rectifier type using selenium rectifiers. The chargers were manufactured by the Lee Electric and Manufacturing Co. and have self-contained meters, relays, and supply breakers.

120. Exposed Conduit, Wire, and Cable. - All exposed conduit, wire, and cable installed in the powerplant, except main power cables, were furnished by the construction contractor under specifications No. DC-3704. The 1, 750, 000-circular-mil,

single-conductor, 15-kilovolt, lead-covered main generator cables were manufactured by the General Electric Co. and supplied under purchase order No. D-69, 472-A. Quantities for determining payment to the contractor for installation of wire and cable were determined by actual measurement by a Government inspector, concurrent with installation of each run. Lengths of exposed conduit runs were measured when one phase or section in the plant was complete. As only one conductor size, No. 19/22, was used for control cable, considerable time was saved over the usual shifting from one cable reel to another. Essentially, all multiconductor control cable had been pulled by November 15, 1954.

121. Powerplant Lighting Equipment. - All lighting equipment was furnished by the construction contractor except the two 50-kv.-a., dry-type, 480-120/240-volt transformers manufactured by the R. E. Uptegraff Manufacturing Co. and supplied under purchase order No. D-69, 455-A-1. The three lighting panels are of the wall-recessed type and contain a 120/240-volt bus which feeds through breakers to various lighting, plug, and miscellaneous equipment circuits. The emergency lighting contactor is also the wall-recessed type with normally closed contacts to energize the emergency direct-current lights in the event of an alternating-current power failure. Some of the lighting fixtures were used to supplement temporary lighting during plant construction and equipment installation. The contractor used reasonable precaution in the care of this lighting equipment and replaced any that was damage.

122. Switchyard Equipment. - The switchyard equipment was furnished by the Government under several supply contracts. The No. 4/0 AWG switchyard bus, copper tubing, and insulators were furnished by the construction contractor. The 1, 500-kv.-a, 115-kilovolt, airblast circuit breakers were manufactured in Switzerland by the Brown Boveri Co. The breaker air compressors, receivers, air control racks, and breaker supporting frames were subcontracted by Brown Boveri to firms in the United States. As installation instructions were not available and installation experience on this type of breaker was limited, the final stage of erection was delayed until arrival of the company erection engineer. The refabrication of the breaker supporting frame to match anchor bolts and breaker interrupters was done prior to arrival of the company representative; however, the corrective action was approved and the cost assumed by the company. Following operational checks, the breakers were first energized December 22, 1954.

The 115-kilovolt, 600-ampere disconnect switches were furnished by the Schwager-Wood Corp. under invitation No. DS-4038. Although the individual pole units were adjusted at the factory, additional adjustments were required after assembly to obtain synchronism between the individual pole assemblies. As the result of improper fabrication of some of the operating linkage at the factory, considerable delay in the assembly of the two-line disconnects was necessary while a replacement casting was being fabricated and delivered. Some alterations were necessary on the switchyard steel to permit mounting of the disconnect operating mechanism and linkage.

The lightning arresters and the coupling capacitor potential devices were both furnished by the General Electric Co. The capacitors are equipped with carrier-current accessories, which will be used for future carrier installation. The capacitors are connected to the A-phase of each line and on all three phases of the main bus. The arresters are also connected to each phase of the main bus.

123. Control House Electrical Equipment and Power Control Line. - The electrical equipment for the control house was purchased by the Government under purchase order No. D-69, 486-A from the Graybar Electric Co. Although the contractor had some trouble in getting this equipment up the steep, icy slope between the tunnel adit and the gate control house, the installation was completed in 1 week. The construction of the 3-phase, 440-volt power and 12-conductor control line met with considerable difficulty, in spite of the fact that the work was done during early summer. Owing to the extremely steep, rugged slope of the line right-of-way, access was possible only on foot and then footing was uncertain due to loose ground. Locations of poles and guys had to be changed to better suit the terrain. All poles, cables, and and other line material were furnished

by the construction contractor. However, to prevent the cables from "inching" down the hill on the messenger, Kellem-type clamps were purchased by the Government for installation at each pole.

E. Miscellaneous

124. Insulation. - Supplemental notice No. 1 required the use of 2-inch structural insulated slabs for insulation of the powerhouse walls in lieu of corkboard. The slabs were fastened to the concrete forms prior to placement of the concrete.

Difficulties were encountered in fastening the slabs to the forms, preventing grout leakage through the insulation during concrete placement, and painting the insulation. The most satisfactory method found for fastening the insulated slabs to the forms was by nailing with 8-penny finishing nails, the nails being driven through the slabs into the form sheathing. When the forms were stripped, the nails were left protruding from the insulated slab and were snipped off. However, many nails pulled through the insulation leaving a ragged surface.

Although considerable care was exercised in handling and installing the insulated slabs, the edges of some slabs were damaged. Consequently, grout leaks were frequent at concrete facings, joints, and joint intersections. To curb the grout leakage effectively, application of mortar or dry-pack material was necessary around the edges of the slabs.

Painting with gloss paint as required by the specifications was unsatisfactory because the gloss paint magnified every filled joint, she-bolt hole, and imperfection in the insulated slabs. By order for changes No. 12 (sec. 84(h)), the requirement for painting with gloss paint was changed to troweling on the insulation surfaces a mixture of approximately 25 pounds of powdered joint cement and about 5 pounds of asbestos fibers to 5 gallons of gloss paint. This mixture made a heavy paste, which after being troweled on the insulation, left a flat texture and effectively hid the joints and imperfections.

F. Concrete Control

125. Aggregates for Tailrace Conduit. - Aggregates for concrete for the tailrace conduit were purchased by M. P. Munter Construction Co., a subcontractor. Sand and 3/4-inch gravel were obtained from Palmer Constructors, the tunnel contractor, and processed under Bureau inspection. The 1-1/2-inch aggregate was obtained from the Valley Concrete Co., located at approximately mile 43, Glenn Highway. The aggregates were stockpiled at the construction site and, during freezing weather, covered with tarpaulins and heated with steam points charged by a 15-horsepower boiler (fig. 132). A crane, equipped with a clamshell bucket, conveyed the aggregates from the stockpiles onto stationary screens set on a slope of approximately 35° over the batch plant storage hoppers.

126. Aggregates for Powerplant. - Aggregates for concrete in the powerplant and related structures were obtained from the Knik River channel approximately one-half mile northwest of the powerplant. The processing and stockpiling of aggregates was subcontracted by the prime contractor to M. P. Munter Construction Co. Approximately 8,000 cubic yards of aggregates were processed during May and June of 1953.

Fine sand was hauled in as required by a track-type tractor with a 14-cubic-yard scraper from a shallow deposit approximately 350 yards downstream, and was mixed with pit-run material by a dozer which pushed the material to within reach of a 3/4-cubic-yard dragline. The dragline fed the material onto a grizzly used to remove the oversize; and a conveyor belt was used to transport the aggregates to a 4- by 10-foot, vibrating, 3-deck screen with openings of 1-1/2 inches, 3/4 inch, and 3/16 inch, respectively. A small spiral classifier was used for dewatering the sand.

Aggregate was stockpiled on the south bank of the Knik River and trucked from the stockpiles to small, open, partitioned bins near the batching plant. During freezing

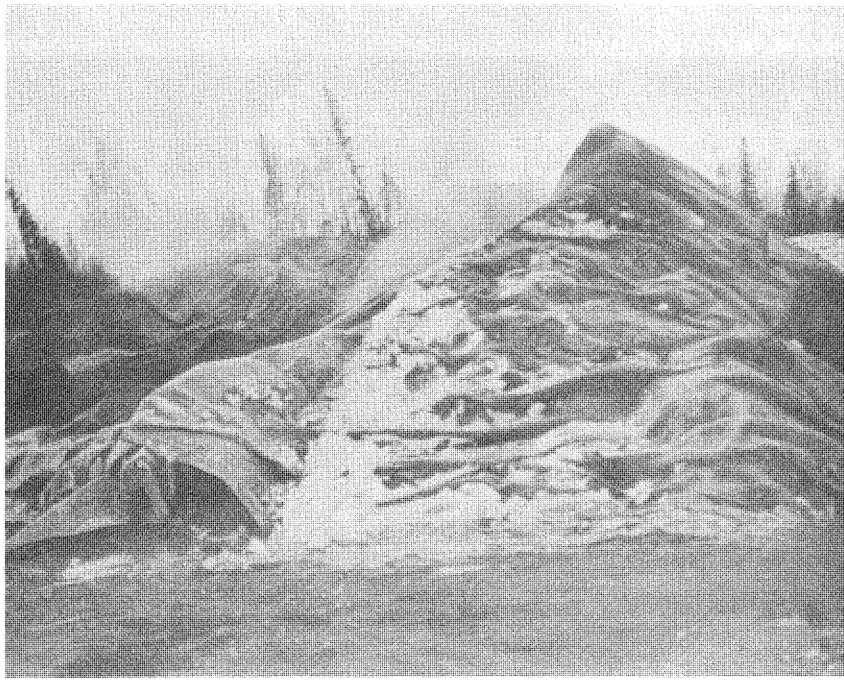


Figure 132. --Heating aggregate stockpiles. Note steam escaping from steam points embedded in aggregate beneath tarpaulins. P783-908-1133, October 30, 1952.

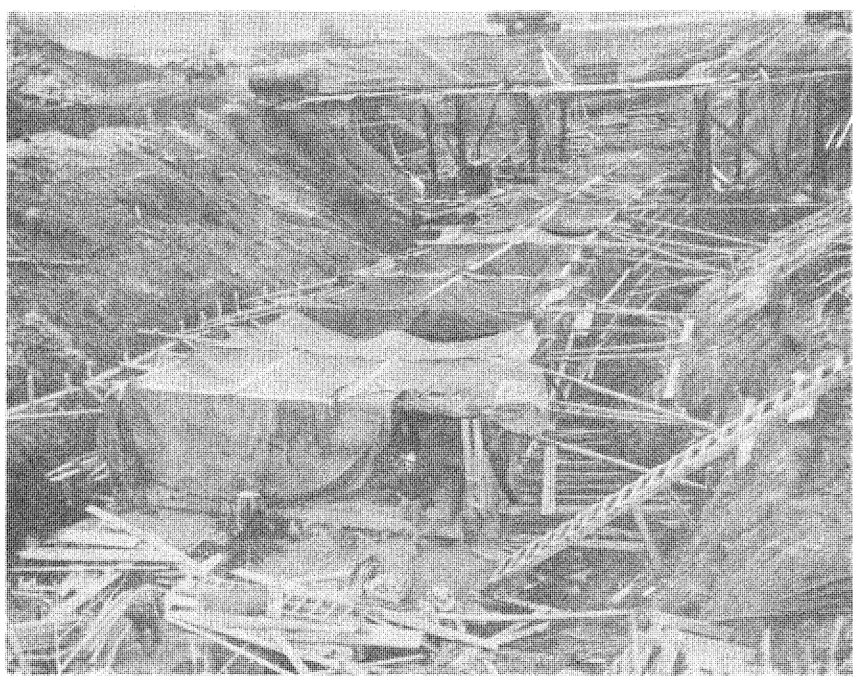


Figure 133. --Construction view of tailrace conduit, showing method of protecting newly placed concrete from freezing temperatures. P783-908-1118, October 18, 1952.

weather, the aggregates were covered with tarpaulins and heated with steam points charged by a 60-horsepower boiler.

127. Batching, Mixing and Placing for Tailrace Conduit. - Concrete aggregates for the tailrace conduit were batched in a batch plant equipped with four 3-cubic-yard storage hoppers and cumulative weighing 4-beam scale having a capacity of 1,500 pounds per beam. The batch plant was located adjacent to the concrete mixer, and the aggregate batches were discharged directly into a mixer skip.

Type II, low-alkali, sacked cement was used. Mixing water was obtained from the foundation unwatering operations and heated with a hot water heater during cold weather. One percent calcium chloride per weight of cement was added to provide higher early compressive strengths.

Air was entrained by introducing a commercial air-entraining agent simultaneously with the mixing water. An effort was made to maintain the amount of entrained air at 5 percent, plus or minus 1 percent, after final placement in the forms.

A crane, equipped with a 1/2-cubic-yard bucket, was used to transport the concrete from the mixer to the point of placement. After sandblast cleanup of the construction joint, concrete was placed in the invert and 6-inch stub walls, followed by placement of the wall and deck. Immersion-type vibrators were used to consolidate the concrete in the forms. Membrane curing compound was applied with a portable hand spray immediately after form stripping, and the concrete was protected from freezing by covering with tarpaulins and heating with heaters (fig. 133).

128. Batching, Mixing and Placing for Powerplant. - From the bins near the batch plant the aggregates were transported by a loader to the feed hopper. A 12-inch bucket elevator conveyed the materials from the hopper to a 2-deck 2- by 8-foot vibrating finish screen with 3/4-inch mesh top and 3/16-inch mesh bottom. The screen was mounted separately from the batch plant to eliminate vibration, and discharged directly into three storage bins having a combined capacity of about 45 cubic yards. The bins discharged into a batch plant with a 3-beam scale having capacities of 1,800, 1,800, and 1,250 pounds respectively on the beams. The batch plant was framed over and covered with 3/4-inch fiber wallboard.

Four-compartment batch trucks were used to haul aggregates from the batch plant to two portable mixers. Mixing water was obtained from the penstock drainage and was heated during freezing weather. Sacked type I, low-alkali cement was used. The contractor ordered cement for each individual placement and stored any surplus cement under tarpaulins.

Air was entrained by introducing a commercial air-entraining agent. An effort was made to maintain the amount of entrained air at 5 percent, plus or minus 1 percent, for mixes with 1-1/2-inch maximum aggregate, and at 6 percent, plus or minus 1 percent, for mixes with 3/4-inch maximum aggregates. Air-entraining agent was not used in bonded floor finishes.

A crane, equipped with a 1/2-cubic-yard bucket, was used to transport the concrete to the forms. For placement in areas beyond the reach of the crane, the concrete was transferred to a stationary bucket, and then transported by wheelbarrows to the point of placement. A wooden hopper with a canvas trunk was used to place the concrete in areas inaccessible to the crane or wheelbarrows. Construction joints were sandblasted and washed before the next placement. Immersion-type vibrators were used to consolidate the concrete in the forms. A commercial curing compound was applied immediately after stripping of forms.

129. Concrete Mixes. - Routine 6- by 12-inch concrete test cylinders were cast during concrete placing operations and tested in the project laboratory after 7, 28, or 90 days. A summary of concrete mixes used and the results of strengths tests are included in table 4.

Table 4. - Summary of concrete mix data for work under specifications No. DC-3704

Mix parts	Aggregates, percent clean separation			Concrete, cubic yards	Water-cement ratio, average	Slump, inches, average	Percent of entrained air, average	Cylinder strengths, pounds per square inch			
	Sand, average	Fine gravel, average	Intermediate gravel, average					7-day average	28-day average	90-day average	No. of cylinders
				Powerplant and Machine Shop							
1 : 2.34 : 4.08	34.5	32.1	33.4	11,439	0.46	2.25	4.6	2,730	3,890	4,630	253
1 : 2.00 : 3.74	36.1	30.3	33.6	225	0.45	2.5	1.0	3,180	5,180	6,670	5
1 : 1.90 : 3.92	33.7	33.9	32.4	914	0.43	2.25	4.4	2,690	3,940	4,860	65
1 : 1.72 : 3.90	30.6	34.7	34.7	36	0.43	1.25	4.1	2,060	3,440	4,440	6
1 : 2.10 : 4.20	33.4	31.5	35.1	299	0.42	1.75	3.4	2,400	4,000	4,200	16
1 : 1.00 : 2.13	32.1	67.9	0	70	0.29	0	-	4,420	5,560	6,580	26
				Tailrace Conduit							
1 : 2.29 : 3.89	37.0	31.5	31.5	663	0.49	2.7	3.8	2,150	3,320	4,660	23
1 : 1.98 : 2.52	44.0	56.0	0	35	0.47	3.0	3.0	1,560	4,880	5,430	3

G. Construction Equipment

130. Powerplant and Tailrace Area. - The following is a list of the principal items of construction equipment used:

No. of units	Equipment	Size or capacity
1	Crane and bucket	3/4 cu. yd.
1	Truck crane	10 ton
1	Crawler crane	
2	Flat bed truck	2 ton
3	Dump truck	8 cu. yd.
2	Pickup truck	1/2 ton
1	Loader dozer	40 hp., 1 cu. yd.
2	Motorized scraper	8 cu. yd.
2	Motorized scraper	15 cu. yd.
2	Bulldozers	75 hp.
1	Air hammer	
1	Drop hammer	3,000 lb.
1	Dragline	
1	Lowboy trailer	30 ton
1	Semitrailer	
1	Water pump	6 in. to 8 in.
2	Centrifugal electric pump	4 in.
1	Centrifugal electric pump	1-1/2 in.
1	Slush pump	4 in.
1	Slush pump	3 in.
1	Pressure pump	1-1/2 in. piston
1	Pressure pump	1 in. piston
2	Pumps	10 in.
2	Pumps	6 in.
1	Slush pump	3 in. diaphragm
1	High-pressure pump	75 g.p.m.
1	Centrifugal pump	3 in.
1	3-bin batch plant with scales	
1	2-deck vibrating finish screen	2 ft. by 8 ft.
1	Bucket conveyor	30 ft.
4	Concrete mixers	16 sack
1	4-bin batch plant with scales	

Miscellaneous small equipment such as jackhammers, air tampers, concrete pavement breakers, buckets, concrete vibrators, air compressors, welders, electric and gasoline heaters and shop equipment was also used.

H. Factors Affecting Construction Progress

131. Weather. - Construction progress was retarded very little because of the weather. To expedite construction of the powerplant substructure during severe winter conditions, the contractor tried enclosing each wall placement separately as shown in figure 134, but later abandoned this method in favor of completely housing the work from wall to wall as shown in figure 135. The latter method provided for more working space, better heat distribution, and more economical operation. In each case, space heaters and gasoline heaters were used for heating.

To provide protection from the spring and summer rains for the turbine installation work and second-stage concrete placement, the contractor was given permission to construct the elevation 91.83 structural roof slab prior to construction of the superstructure walls.

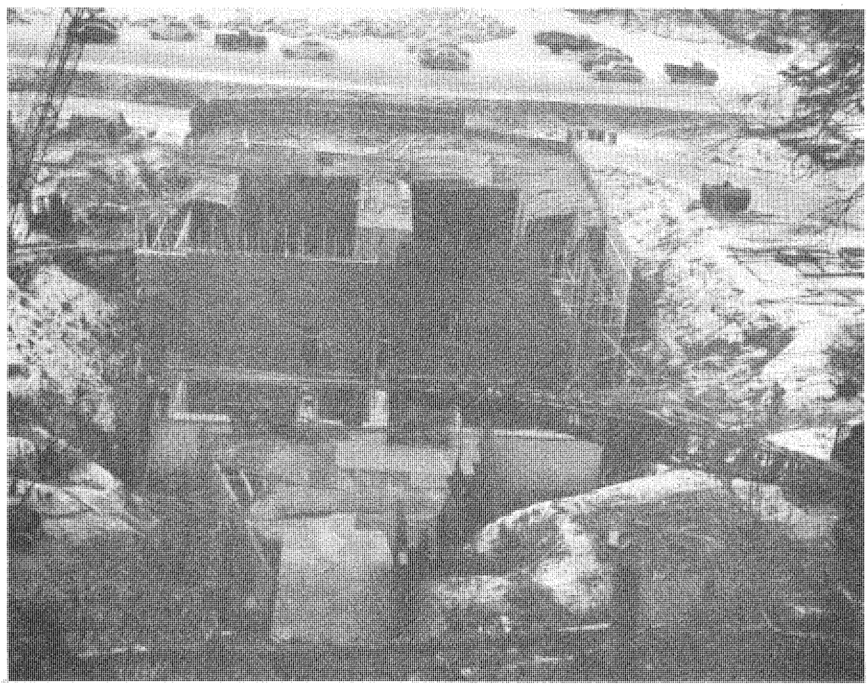


Figure 134. --View of powerhouse during erection of protective walls. P783-908-1512, November 23, 1953.

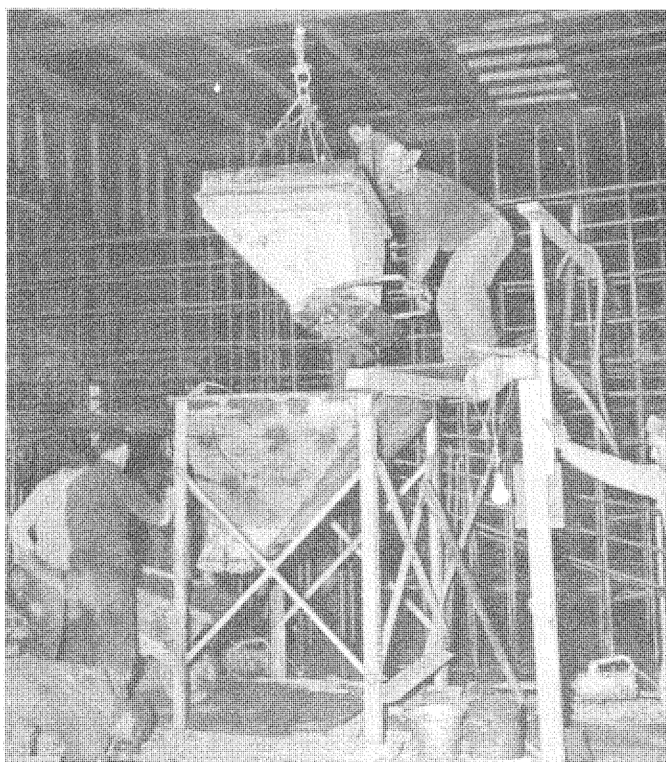


Figure 135. --Interior view of temporary protective shelter over area between lines 1 and 3 and lines B and C of the powerhouse. Floor slab and wall are being placed between elevations 24.00 and 27.96. Crane-operated bucket was lowered through opening in the roof. P783-908-1559, March 12, 1954.

132. Labor. - The labor supply for contract operations was generally adequate with respect to both quantity and quality. Union labor was used exclusively, and wage rates were set by master agreements for the Anchorage area. Work stoppages due to labor disputes were minor and had little effect on overall progress of the construction.

133. Delivery of Government-Furnished Materials. - In general, the materials and equipment furnished by the Government were received on the job on or ahead of schedule. The principal exceptions were the turbines and butterfly valves.

Findings of fact established the delay in delivery of the turbines as excusable on account of operation of the Government priority system, and the delay in delivery of the butterfly valves as due to late award of contract.

APPENDIX

APPENDIX A

Cost summary for Eklutna Tunnel and Powerplant, showing costs of construction and supply contracts and purchase orders. (Actual costs to July 1, 1957, plus estimated costs through June 1958):

Construction Contracts

Specification number	Item and contractor	Total cost to the Government
DC-3295	Erection of Warehouse Building, Sandvik, Roark and James, contract I2r-19472	$ 76,360
DC-3307	Permanent camp, construct six 2-bedroom and six 3-bedroom houses, Denali Construction Co., Inc., contract I2r-19412	413,374
DC-3348	Erection of 115-kv. transmission line, Wiggins, Morrison-Knudsen, contract I2r-19470	421,650
DC-3463	Temporary camp, 30 two-bedroom temporary houses, C. W. Hufeisen, contract I2r-19506	343,518
DC-3523	Tunnel (chiefly), Palmer Constructors, contract I2r-19609	18,248,399
DC-3672	Construction of Eklutna-Anchorage 115-kv. transmission line, Wiggins Construction Co., contract I2r-19794.	428,279
DC-3704	Powerplant building and switchyard, Rue Construction Co., contract 14-06-D-162.	2,629,554
DC-4047	Erection of Anchorage substation, City Electric of Anchorage, contract 14-06-D-595.	144,907
DC-4827	Erection of additional bay at Anchorage substation, City Electric of Anchorage, contract 14-06-D-2465	16,225
DC-4960	Relocating part of Palmer-Eklutna 115-kv. transmission line (contract not yet awarded)	265,000
Contract number		
I112r-2A	Transa house foundations, Ray F. James	2,407
I112r-13	Laboratory building, Sandvik and Roark	22,546
I112r-15	Exploratory drift, James Construction Co.	7,500
I112r-17	Exploratory drift, Sandvik and Roark	31,567
I112r-26	Driving piles, Sandvik and Roark.	9,619
I112r-27	Drive casings, E. J. Longgear	682
I112r-30	Install inter-com system, City of Anchorage.	999
I112r-34	Water line excavating, Valley Excavating	645
I112r-48	Pile testing, Sandvik and Roark	3,232
I112r-49	Pile testing, Palmer Constructors	5,100
I112r-55	Drill and test piling, Palmer Constructors	7,184
14-06-908-1	Construction of warehouse bins, Sandvik and Roark. .	4,290
14-06-908-19	Erection of 3-bedroom house at Anchorage substation, Ray F. James	24,973
I1105r-11	Erection of 16- by 24-foot building (utility) at Eklutna Lake, Sandvik and Roark	1,787
	Interest during construction 1951-1955	
	1951	6,435
	1952	60,411
	1953	206,437
	1954	386,034
	1955	413,973
	Subtotal, Construction Contracts	$24,183,087

Invitation or contract number	Item	Total cost to the Government
DS-3234	Structural steel warehouse.	$ 29, 869
DS-3270	Palmer substation equipment.	37, 729
DS-3506	Turbines	319, 867
DS-3536	Generators.	465, 536
DS-3590	Transformers	124, 354
DS-3596-Sch. 2	Hoist for bulkhead gate	9, 704
DS-3596-Sch. 1	Bulkhead gate leaf	1, 961
DS-3596-Sch. 3	Frame for bulkhead gate.	4, 260
DS-3596-Sch. 4	Anchorage for bulkhead gate	565
DS-3621	Penstocks	248, 280
DS-3628- Item 1	Surge tank gate leaf.	11, 857
DS-3628- Item 2	Fixed-wheel gate frame	5, 852
DS-3653-Sch. 1	Power transformers (Anchorage substation)	150, 108
DS-3653-Sch. 3 & 4	Disconnect switches.	6, 416
DS-3653-Sch. 2	Circuit breakers	60, 301
DS-3673	Gate hoist for surge tank	7, 190
DS-3676	Traveling crane	38, 050
DS-3688	Turbine governors	60, 255
DS-3694	Generator voltage switchgear	60, 211
DS-3709	Power transformers	38, 895
DS-3722	Transformer, 750 kv.-a.	6, 565
DS-3737	Circuit breakers	43, 847
DS-3739	Oil storage tanks	3, 521
DS-3756-Sch. 1 & 2	Air compressors	2, 845
DS-4044-Sch. 1	Pump equipment (sump)	2, 152
DS-4044-Sch. 3	Oil pumps	238
DS-4044-Sch. 2	Fire protection pump	553
DS-3716	Butterfly valves	73, 441
DS-4045	Fire extinguishment equipment.	3, 546
DS-4033-Sch. 1 & 2	Lightning arresters.	5, 292
DS-4034-Sch. 2	Resistor.	253
DS-4034-Sch. 1	Distribution transformers	1, 058
DS-4038	Air breakers, disconnect switches	15, 618
DS-4026-Sch. 4	Battery charger	8, 096
DS-4026-Sch. 2	Station-service transformers	9, 140
DS-4026-Sch. 3	Alternating-current distribution board	7, 162
DS-4026-Sch. 1	Control board and recording board	31, 319
DS-4022	Controls for gate hoist and butterfly valves	18, 513
DS-4028-Sch. 3	Battery chargers (Anchorage substation)	1, 569
DS-4028-Sch. 1 & 2	Control distribution board (Anchorage substation) . .	18, 849
DS-4048	Oil purifier and drying oven	7, 982
DS-4063-Sch. 1	Current and potential transformers.	12, 955
DS-4063-Sch. 2	Disconnect fuses and spares	601
DS-4121	Jet pumps	3, 258
(D)A-69, 428A	Current and potential transformers.	4, 214
(D)A-69, 430A	Structural steel.	2, 019
(D)A-69, 422A	Relay cabinet and relay	2, 878
(D)A-69, 426A	Turbine acceptance test	5, 350
(D)A-69, 429A	Control equipment	4, 615
(D)A-69, 400B	Transtat.	311
(D) 69, 401A	Parts for fixed-wheel gate hoist	269

Invitation or contract number	Item	Total cost to the Government
(D)A-69, 402A	Nameplates	$ 92
(D)A-69, 404A	Arresters	120
(D)A-69, 405A	Spacers and straps	15
(D)A-69, 406A	Nameplates	3
(D)A-69, 407A	Test plug	40
(D)A-69, 408A	Welder (arc)	467
(D)A-69, 412B	Twist drills	208
(D)A-69, 415A	Aluminum cable	1, 241
(D)A-69, 419A	Switch and takeoff structure	4, 072
(D)69,492A	Voltmeters, ammeters, and watt meters	481
(D)69,492A-3	Phase angle meter	592
(D)69,492A-4	Transformers	423
D-69, 491A	Lightning arresters	6, 606
D-69, 493A-1	Storage batteries	8, 692
D-69, 427B	Power circuit breakers	10, 150
D-69, 480A	Filter storage tank	1, 659
D-69, 492A-5	Insulation tester	547
D-69, 492-10	Phase shifter-phantom load	533
D-69, 498A	Radio units	7, 520
D-69, 497A	Lub oil	668
14. 06. 908-3	Gravel	614
14. 06. 908-16	Orifice plate and frame	667
14. 06. 908-18	Electric ranges and dryers	541
14. 06. 908-21	Metalwork	2, 630
14. 06. 908-37	Jib crane and 2-ton hoist	1, 475
14. 06. 908-43	Pole line hardware	7, 823
14. 06. 908-46	Bulkhead gates, etc.	3, 578
14. 06. 908-47	37. 5 kv. -a. transformers	546
14. 06. 908-50	Pole line hardware	9, 784
14. 06. 908-51	Transformers	915
14. 06. D. 34	Traveling crane	1, 028
14. 06. D. 244	Rubber water stop	1, 419
14. 06. D. 628	Copper cable	8, 797
14. 06. D. 637	Potheads.	1, 613
14. 06. D. 638	Hypochlorite Sal feeder	433
14. 06. D. 646	Fire extinguisher equipment	1, 429
14. 06. D. 647	Fire extinguisher equipment	447
14. 06. D. 682	Distribution transformer	862
14. 06. D. 645	Flexible metal hoses and couplings	1, 050
14. 06. D. 683	Pressure reducing valves	680
14. 06. D. 684	Plug valves	1, 876
I100r-2268	Core lifter and case.	606
I100r-2380	Warehouse hoist	8, 775
I100r-2411	Ranges, washers and dryers	4, 267
I100r-2416	Testing screen	619
I100r-2554	Electric water heaters	1, 971
I100r-2555	Ranges	4, 370
I100r-2664	Turbine pump	846
I100r-2779	Rubber water stop	1, 326
I100r-2812	Steel piling.	77, 649
I100r-2858	Lathe, engine	12, 400
I100r-2862	Lathe, pedestal.	1, 346
I100r-2871	Power saw	880
I100r-2873	Grinder and bolt and pipe threader	874
I100r-2874	Drill press.	4, 588
I100r-2889	Coupling capacitor	9, 900
I100r-2896	Shaper	8, 301

Invitation or contract number	Item	Total cost to the Government
I112r-5	Diamond bits	$ 1,237
I112r-7	Pipe	960
I112r-8	File units	2,157
I112r-9	Pipe	1,029
I112r-11	Auto parts	1,631
I112r-12	Intercommunciation system	2,512
I112r-14	Acetylene and oxygen	414
I112r-16	Radio equipment	6,632
I112r-18	Cleaning unit	715
I112r-21	Transit (mining)	889
I112r-22	Diamond bits	2,333
I112r-24	Electric lift	829
I112r-25	Deep well pump	528
I112r-28	Reinforcing steel	368
I112r-29	Ready mixed concrete	2,203
I112r-32	Concrete paint	320
I112r-33	Linoleum	588
I112r-35	Pipe fittings	459
I112r-36	Wheel balance	570
I112r-37	Radio equipment	2,593
I112r-38	Garage heating unit	1,050
I112r-39	Roofing and insulation	290
I112r-42	Asphalt tile	1,960
I112r-43	Coal	1,120
I112r-46	Pipe thawer	585
I112r-50	Oil storage tanks	810
I112r-52	Oil burners	2,307
I112r-53	Structural steel	803
I112r-54	Ready mix concrete	469
	Other materials and interest during construction	548,519
	Subtotal, Supply Contracts	$ 2,797,223

Noncontractual Costs

Land rights	12,110
Labor by Government forces	115,199
Construction facilities	667,130
Indirect costs:	
Preliminary surveys and investigations	503,214
Denver office charges	1,009,324
Engineering and inspection	717,840
Administrative and general expense	942,805
Subtotal, Noncontractual Cost	3,967,622
Total, Contractual and Noncontractual Costs	$30,947,932
Calculated purchase price Old Eklutna Powerplant from City of Anchorage	1,841,760
Subtotal	$32,789,692
Less transfers, credits and other expenditures	3,138,855
Total Estimated Cost of Eklutna Tunnel and Powerplant	$29,650,837

APPENDIX B

Construction costs by pay items--Specifications No. DC-3523, Eklutna Tunnel:

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
1	Excavation, open cut for inlet, first 205,000 cu. yd.	205,000	cu. yd.	$ 3.00	$ 615,000.00
2	Excavation, open cut for inlet, over 205,000 cu. yd.	188,720	cu. yd.	0.60	113,232.00
3	Constructing and installing intake trash-rack section	100%	Lump sum	150,000	150,000.00
4	Constructing and installing intake transition section	100%	Lump sum	37,000	37,000.00
5	Constructing and installing intake bulkhead section	100%	Lump sum	27,000	27,000.00
6	Furnishing and installing 9-ft. diameter precast conduit	225	lin. ft.	1,500.00	337,500.00
7	Constructing tunnel between station 20+00 and station 27+11.50	711.5	lin. ft.	1,500.00	1,067,250.00
8	Excavation, in open cut, for gate shaft	25,055.7	cu. yd.	5.00	125,278.50
9	Excavation for gate shaft	979.27	cu. yd.	400.00	391,708.00
10	Excavation for surge tank	5,837.215	cu. yd.	120.00	700,465.80
11	Excavation in tunnel	89,564.21	cu. yd.	80.00	7,165,136.80
12	Excavation in the inclined penstock tunnel	3,736.31	cu. yd.	250.00	934,077.50
13	Excavation for tunnel enlargement	876.61	cu. yd.	87.50	76,703.38
14	Backfill about intake structure	922.7	cu. yd.	12.00	11,072.40
15	Furnishing and installing permanent steel tunnel supports	1,682,450	lb.	0.25	420,612.50
16	Furnishing and erecting permanent timbering in tunnel	214.62	M b.m.	400.00	85,848.00

APPENDIX B (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
17	Furnishing and installing tunnel roof support bolts	3, 822	lin. ft.	$ 4.00	$ 15, 288.00
18	Drilling feeler or pilot holes ahead of tunnel excavation	41	lin. ft.	10.00	410.00
19	Drilling grout holes	334.25	lin. ft.	10.00	3, 342.50
20	Furnishing and placing grout pipes and connections	625.6	lb.	1.00	625.60
21	Pressure grouting	2, 312.5	cu. ft.	6.00	13, 875.00
22	Pumping first 100 million gallons of drainage water from tunnel at any rate	100	$\overline{M}$ gal.	5, 000.00	500, 000.00
23	Pumping drainage water from tunnel at the rate of 0 to 2 million gallons per 24 hours	140.988	$\overline{M}$ gal.	100.00	14, 098.80
24	Pumping drainage water from tunnel at the rate of 2 million and 1 gallon to 4 million gallons per 24 hours	0	$\overline{M}$ gal.	100.00	0.00
25	Pumping drainage water from tunnel at the rate of over 4 million gallons per 24 hours	381.58	$\overline{M}$ gal.	100.00	38, 158.00
26	Concrete in gate shaft	477.81	cu. yd.	100.00	47, 781.00
27	Concrete in surge tank	1, 553.58	cu. yd.	100.00	155, 358.00
28	Concrete in tunnel lining	30, 055.45	cu. yd.	75.00	2, 254, 158.75
29	Concrete around penstock	3, 857.21	cu. yd.	75.00	289, 290.75
30	Furnishing and handling cement	0	bbl.	12.00	0.00
31	Furnishing and placing reinforcement bars	2,353,402	lb.	0.25	588, 350.50
32	Installing penstock	1, 276, 695	lb.	0.25	319, 173.75

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
33	Installing frames and guides for bulkhead and fixed-wheel gates and hoist support beams	25, 417	lb.	$ 0. 25	$ 6, 354. 25
34	Installing fixed-wheel and bulkhead gates	27, 638	lb.	0. 25	6, 909. 50
35	Installing fixed-wheel and bulkhead gate hoists	17, 064	lb.	0. 25	4, 266. 00
36	Installing control apparatus and piping for bulkhead and fixed-wheel gates	3, 214	lb.	0. 50	1, 607. 00
37	Installing gate shaft and surge tank metalwork	26, 045	lb.	0. 50	13, 022. 50
38	Furnishing and erecting structural steel in surge tank roof	7, 513	lb.	0. 50	3, 756. 50
39	Furnishing and installing steel swinging door	0 19. 5	sq. ft. sq. ft.	5. 00 15. 00	0. 00 292. 50
40	Placing rubber water stop	654. 4	lin. ft.	5. 00	3, 272. 00
41	Excavation, stripping borrow areas and surfaces of dam embankment	512	cu. yd.	4. 00	2, 048. 00
42	Earthfill embankment for dam	692	cu. yd.	2. 00	1, 384. 00
43	Sand and gravel blanket under riprap	142	cu. yd.	5. 00	710. 00
44	Riprap	787. 3	cu. yd.	10. 00	7, 873. 00
45	Construction of anchor and extension to existing sheet-steel piling	100%	Lump sum	12, 000	12, 000. 00
46	Furnishing and driving timber piles	959. 3	lin. ft.	5. 00	4, 796. 50
47	Moving deck of existing trestle	100%	Lump sum	7, 480	7, 480. 00
	Total--Original Contract				$16, 573, 567. 28

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Order for Changes No. 1				
(a)	Reduction in contract prices for furnishing type I cement in lieu of type II for use in concrete in tunnel lining between station 20+00 and 27+11.5; cement used in concrete in the intake structure; cement used in precast concrete pipe	1,371.9	bbl.	$ 0.20	$ -274.38
(b)	Furnishing and handling type I low-alkali cement	61,273.33	bbl.	11.80	723,025.29
	Total--Order for Changes No. 1				722,750.91
	Order for Changes No. 2				
(b)	Adjustment in cost for installation of penstock				-33,300.00
	Order for Changes No. 3				
(a)	Unamortized costs of plant and facilities (exclusive of concrete plant)		Lump sum		403,109.33
(b)	Concrete plant complete including mixers, batch plant, cement silos, tramway conveyors, forms and form carriers, etc.		Lump sum		360,000.00
(d)	Charge for cancellation of contract for furnishing cement				10,000.00
(e)	Furnishing reinforcement bars		lb.	0.10	0.00
	Total--Order for Changes No. 3				773,109.33
	Order for Changes No. 5				
(a)	Adjustment for changed conditions in inlet channel excavation	100%	Lump sum	182,715	182,715.00

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Order for Changes No. 8				
	Reduction for reinstatement of work as provided for in Order for Changes No. 3			$	$ -673,109.33
	Order for Changes No. 9				
(a)	Changing delivery point of steel penstock				-257.00
(b)	Driving steel bearing piles	458.18	lin. ft.	4.00	1,832.72
(d)	Furnishing pipe and fittings	282.6	lb.	2.04	576.50
(f)	Capping steel H bearing pile	17	Each	50.00	850.00
	Total--Order for Changes No. 9				3,002.22
	Order for Changes No. 10				
(a)	Backcharge for freight on wire mesh bulkheads and coal-tar enamel furnished under specifications No. DS-3621 at contractor's expense	207.85	cwt.	7.429	-1,544.12
	Order for Changes No. 11				
(a)	Drilling backfill grout holes	783	hole	10.00	7,830.00
(b)	Backfill grouting	59,098	cu. ft.	3.00	177,294.00
(c)	Purchase by contractor of concrete plant		Lump sum		-100,000.00
	Total--Order for Changes No. 11				85,124.00
	Order for Changes No. 12				
(a)	Furnishing and delivering steel liner plates and supports		Lump sum		135,425.71
	Total--Orders for Changes				$ 1,194,173.72

APPENDIX B (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Extra Work Order No. 1				
(a)	Removing and replacing rotted stringers and sills in trestle	100%	Lump sum	$ 1,084.54	$ 1,084.54
	Extra Work Order No. 2				
(a)	Furnishing 6-inch-diameter pipe for lateral headers	7,537	lin. ft.	0.50	3,768.50
(b)	Furnishing couplings and gaskets for 6-inch-diameter pipe	249	Each	5.50	1,369.50
(c)	Furnishing other pipe-fittings and valves				2,535.58
(d)	Furnishing labor for installing drainage system				11,672.42
	Total--Extra Work Order No. 2				19,346.00
	Extra Work Order No. 3				
(a)	Modifying surge tank orifice plate	216.5	lb.	1.00	216.50
(b)	Furnishing and installing frame and door for adit plug	2,100	lb.	1.00	2,100.00
	Total--Extra Work Order No. 3				2,316.50
	Total--Extra Work Orders				$ 22,747.04
	Payment for electrical power in accordance with paragraph 33 of specifications	510,790 798,700	kw.-hr. kw.-hr.	0.057 0.0275	29,115.03 21,964.25
	Total Payment for Electrical Power				51,079.28
	Amortization of contractors' powerplant under paragraph 33 of the specifications from January 2, 1952 to December 22, 1954	1,086	Day	20,146.00	21,878.55
	Total Payment for Amortization of Plant				21,878.55

APPENDIX B (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Adjustment for changes in cost in accordance with paragraph 19 of specifications				
	Palmer Constructors			$	$ 359,445.89
	Ben C. Gerwick, Inc.				8,094.41
	Ben C. Gerwick and Hydraulic Dredging Co.				15,533.61
	Alaska Aggregate Corp.				2,658.93
	Total--Escalation Payments				385,732.84
	Recapitulation:				
	Total--Original Contract				16,573,567.28
	Total--Orders for Changes				1,194,173.72
	Total--Extra Work Orders				22,747.04
	Total Payment for Electric Power				51,079.28
	Total Payment for Amortization of Plant				21,878.55
	Total--Escalation Payments				385,732.84
	Total--Gross Earnings				$18,249,178.71
	Less:				
	Deduction for freight on bulk coal-tar enamel and primer				58.66
	Deduction for steel H-bearing pile not returned to Government warehouse	240.3	ft.	3.00	720.90
	Net Payments				$18,248,399.15

APPENDIX C

Construction costs by pay items--Specifications No. DC-3704, Eklutna Powerplant:

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
1	Unwatering	100%	Lump sum	$ 80,000	$ 80,000.00
2	Excavation for structures	20,443.7	cu. yd.	1.50	30,665.55
3	Excavation for tailrace channel	64,177	cu. yd.	2.00	128,354.00
4	Excavation for culverts and ditches	121	cu. yd.	7.00	847.00
5	Backfill	31,003	cu. yd.	1.50	46,504.50
6	Compacting backfill	19,793	cu. yd.	2.00	39,586.00
7	Screened gravel fill	35.61	cu. yd.	15.00	534.15
8	Gravel surfacing	8	cu. yd.	10.00	80.00
9	Riprap	1,519	cu. yd.	10.00	15,190.00
10	Roadway embankment	41,437.1	cu. yd.	1.50	62,155.65
11	Selected roadway subsurfacing	5,436	cu. yd.	3.00	16,308.00
12	Water for moistening embankment materials	53.32	$\overline{M}$ gal.	10.00	533.20
13	Rolling roadway embankments	0	Rol.-hr.	20.00	0.00
14	Crusher-run base	1,703.7	cu. yd.	12.00	20,444.40
15	Liquid-asphalt prime coat	8,865	Ton	200.00	1,773.00
16	Mineral aggregate for bituminous surfacing	292.5	cu. yd.	15.00	4,387.50
17	Liquid asphalt for bituminous surfacing and seal coat	32.28	Ton	125.00	4,035.00
18	Stone chips for seal coat	45.0	cu. yd.	45.00	2,025.00
19	Furnishing and laying 12-inch-diameter, 16-gage corrugated-metal pipe	0	lin. ft.	10.00	0.00

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
20	Furnishing and laying 24-inch-diameter, 14-gage, corrugated-metal pipe	0	lin. ft.	$ 14.00	$ 0.00
21	Furnishing and laying 36-inch-diameter, 12-gage, corrugated-metal pipe	188	lin. ft.	25.00	4,700.00
22	Driving vertical steel H bearing piles	13,354.38	lin. ft.	4.00	53,417.52
23	Driving batter steel H bearing piles	4,784.73	lin. ft.	4.50	21,531.29
24	Splicing steel H bearing piles	4	Splice	70.00	280.00
25	Capping steel H bearing piles	399	Cap	50.00	19,950.00
26	Furnishing and handling cement	983.25	bbl.	13.50	13,273.88
27	Furnishing and placing reinforcement bars 3/4-inch diameter and smaller	348,490	lb.	0.25	87,122.50
28	Furnishing and placing reinforcement bars 7/8-inch diameter and larger	475,369	lb.	0.25	118,842.25
29	First-stage concrete in powerplant substructure	3,011.12	cu. yd.	90.00	271,000.80
30	First-stage concrete in powerplant superstructure	950.55	cu. yd.	160.00	152,088.00
31	Second-stage concrete in powerplant structure	3,982.45	cu. yd.	75.00	73,683.75
32	Concrete in penstock anchor	425.91	cu. yd.	70.00	29,813.70
33	Concrete in transformer and miscellaneous structures	224.03	cu. yd.	150.00	33,604.50
34	Concrete in tailrace conduit	726.66	cu. yd.	170.00	123,532.20

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
35	Concrete in blockouts	7, 333	cu. yd.	$ 900.00	$ 6, 599.70
36	Constructing type A control joints	425.58	lin. ft.	7.00	2, 979.06
37	Constructing type B control joints	107.16	lin. ft.	9.00	964.44
38	Furnishing and placing 1-inch corkboard joint filler	2, 201.63	sq. ft.	4.00	8, 806.52
39	Placing rubber water stops	1, 958.57	lin. ft.	5.00	9, 792.85
40	Furnishing and placing roof insulation	6, 486.44	sq. ft.	2.00	12, 972.88
41	Furnishing and placing coal-tar-saturated-felt roofing	2, 101.82	sq. ft.	2.50	5, 254.55
42	Furnishing and placing membrane waterproofing	4, 627.95	sq. ft.	2.00	9, 255.90
43	Bonded concrete finish on floors, stairs, and stair landings	1, 286.73	sq. yd.	14.50	18, 657.59
44	Bonded concrete finish at base of walls	9.59	lin. ft.	7.00	67.13
45	Furnishing and installing rubber tile	668.44	sq. ft.	3.00	2, 005.32
46	Furnishing and installing rubber cove base	98.9	lin. ft.	2.00	197.80
48	Furnishing and installing 2-inch nominal thickness insulation on walls, ceiling, and cover plates	14, 022.8	sq. ft.	1.25	17, 528.50
49	Installing control room ceiling	644.85	sq. ft.	4.00	2, 579.40
50	Furnishing and installing flush-type metal partitions	155.83	sq. ft.	12.00	1, 869.96
51	Furnishing and installing industrial-type metal partitions	423.51	sq. ft.	5.00	2, 117.55

APPENDIX C (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
52	Furnishing and installing industrial-type ceiling	100.0	sq. ft.	$ 5.00	$ 500.00
53	Furnishing and installing metal toilet-stall partition and metal urinal partition	8.25	lin. ft.	20.00	165.00
54	Erecting drywall partitions and toilet-room ceiling	388.1	sq. ft.	3.00	1,164.30
55	Furnishing and erecting structural-steel building framing	286,811	lb.	0.40	114,724.40
56	Furnishing and installing embedded metal frames and embedded metal tubing	3,363.9	lb.	1.50	5,045.85
57	Furnishing and installing hatch covers, cover plates, and gratings	32,401	lb.	0.70	22,680.70
58	Furnishing and installing track rails on concrete	921	lb.	0.40	368.40
59	Furnishing and installing timber ties and guard timbers	11.385	Mb.m.	500.00	5,692.50
60	Furnishing and installing track rails on timber ties	18,087	lb.	0.40	7,234.80
61	Furnishing and placing rock ballast	224	cu. yd.	10.00	2,240.00
62	Furnishing and erecting switchyard steel structures	66,276	lb.	0.59	39,102.84
63	Furnishing and installing flush-type hollow-metal exterior swinging doors	80.5	sq. ft.	30.00	2,415.00
64	Furnishing and installing metal accordion doors	462	sq. ft.	12.00	5,544.00

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
65	Furnishing and installing tin-clad fire doors	129.63	sq. ft.	$ 10.00	$ 1,296.30
66	Furnishing and installing wood swinging doors	84	sq. ft.	12.00	1,008.00
67	Furnishing and installing steel windows	75.17	sq. ft.	10.00	751.70
68	Furnishing anchor bolts	3,541.58	lb.	0.60	2,124.95
69	Installing anchor bolts	6,130.38	lb.	1.00	6,130.38
70	Furnishing and installing pipe railings	4,825.4	lb.	1.20	5,790.48
71	Furnishing and installing pipe ladders	993	lb.	1.20	1,191.60
72	Furnishing and installing metal stairs	8,583	lb.	1.00	8,583.00
73	Furnishing and installing metal safety treads	175.33	lin. ft.	6.00	1,051.98
74	Furnishing and installing cable trays, cable tray supports, and cable ducts	4,232	lb.	1.07	4,528.24
75	Furnishing and installing asbestos-cement sheets for cable trays and cable ducts	861.98	sq. ft.	3.29	2,835.91
76	Furnishing and installing nonmagnetic conduit and cable supports	2,064.4	lb.	2.10	4,335.24
77	Furnishing and installing rotor erection base	1,641	lb.	0.75	1,230.75
78	Furnishing and installing metal enclosure	14.56	lin. ft.	20.00	291.20
79	Furnishing and installing toplog liners	3,397	lb.	0.75	2,547.75
80	Furnishing and installing miscellaneous metalwork	9,864.19	lb.	1.00	9,864.19
81	Installing penstock	116,838	lb.	0.30	35,051.40

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
82	Installing turbine guard valves	99, 259	lb.	$ 0.20	$ 19, 851.80
83	Installing guides and seats for bulkhead gate	4, 870	lb.	0.30	1, 461.00
84	Installing draft-tube bulkhead gate	3, 571	lb.	0.20	714.20
85	Installing cranes	72, 712.1	lb.	0.20	14, 542.42
86	Installing oil storage tanks	10, 130	lb.	0.20	2, 026.00
87	Installing machine tools	100%	Lump sum	5, 000	5, 000.00
88	Installing two 25, 000-horsepower hydraulic turbines	100%	Lump sum	150, 000	150, 000.00
89	Installing two governors for hydraulic turbines	100%	Lump sum	20, 000	20, 000.00
90	Installing motor-driven drainage and unwatering pumps	4, 624	lb.	0.75	3, 468.00
91	Installing motor-driven gear-type oil pump	225	lb.	1.00	225.00
92	Installing motor-driven centrifugal-type fire-protection pump	688	lb.	0.40	275.20
94	Installing jet pumps	1, 319	lb.	0.40	527.60
95	Installing 50-c.f.m. motor-driven, mounted air compressors	2, 794	lb.	0.40	1, 117.60
96	Installing 8-c.f.m. motor-driven portable air compressor	485	lb.	0.50	242.50
97	Installing carbon dioxide fire extinguishing systems for generators and for oil storage and oil purifier rooms	100%	Lump sum	5, 000	5, 000.00
98	Installing portable fire extinguishers and hose-reel cart	100%	Lump sum	2, 000	2, 000.00

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
99	Installing water level indicating instrument	100%	Lump sum	$ 1,500	$ 1,500.00
100	Installing miscellaneous indicating instruments	10	Each	50.00	500.00
101	Installing portable oil purifier and filter-paper drying oven	100%	Lump sum	2,500	2,500.00
102	Installing combination fire hose and service cabinets	7	Cabinet	72.00	504.00
103	Installing nameplates	201	Each	15.00	3,015.00
104	Installing special valves and special fittings	3,810.6	lb.	0.58	2,210.15
105	Installing flanged strainers in powerplant	2,181	lb.	0.40	872.40
106	Furnishing and installing cast-iron soil pipe and fittings	14,629.87	lb.	0.95	13,898.38
107	Furnishing and installing embedded cast-iron bell-and-spigot water pipe, fittings, and wall castings	9,938.22	lb.	1.14	11,329.57
108	Furnishing and installing buried cast-iron bell-and-spigot water pipe, valves, and fittings	5,360	lb.	0.85	4,556.00
109	Furnishing and installing embedded steel pipe and fittings 2 inches and smaller in nominal diameter	115	lb.	2.04	234.60
110	Furnishing and installing buried steel pipe, valves, and fittings 2 inches and smaller in nominal diameter	73.5	lb.	1.42	104.37
111	Furnishing and installing exposed steel pipe, valves, and fittings 2 inches and smaller in nominal diameter	10,185.89	lb.	1.36	13,852.81

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
112	Furnishing and installing exposed steel pipe, valves, and fittings 2-1/2 inches and larger in nominal diameter	28, 840. 64	lb.	$ 1. 31	$ 37, 781. 24
113	Furnishing and installing metal tubing, valves, and fittings	0	lb.	2. 00	0. 00
114	Furnishing and installing pipe hangers and supports	3, 214. 75	lb.	2. 00	6, 429. 50
115	Furnishing and installing water closets	2	Each	200. 00	400. 00
116	Furnishing and installing urinal	1	Each	216. 00	216. 00
117	Furnishing and installing lavatories	2	Each	162. 00	324. 00
118	Furnishing and installing service sink	1	Each	276. 00	276. 00
119	Furnishing and installing kitchen sink	1	Each	216. 00	216. 00
120	Furnishing and installing 30-gallon electric storage water heater	1	Each	384. 00	384. 00
121	Furnishing and installing 20-gallon electric storage water heater	1	Each	330. 00	330. 00
122	Installing electric drinking water cooler	1	Each	450. 00	450. 00
123	Furnishing and installing heating and ventilating system	100%	Lump sum	29, 360	29, 360. 00
124	Furnishing and installing grounding system in powerplant, transformer area, and switchyard	3, 142. 76	lb.	3. 36	10, 559. 67
125	Furnishing and installing grounding system in gate control house	0	lb.	6. 30	0

Pay item	Property and pay item description	Quantity		Labor and materials, by contractor	
		Amount	Unit	Unit cost	Total cost
126	Furnishing and installing embedded electrical rigid metal conduit 1/2 inch in diameter	53.5	lin. ft.	$ 1.79	$ 95.77
127	Furnishing and installing embedded electrical rigid metal conduit 3/4 inch in diameter	5,194.8	lin. ft.	1.95	10,129.86
128	Furnishing and installing embedded electrical rigid metal conduit 1 inch in diameter	1,878.90	lin. ft.	2.14	4,020.85
129	Furnishing and installing embedded electrical rigid metal conduit 1-1/4 inches in diameter	0	lin. ft.	2.65	0.00
130	Furnishing and installing embedded electrical rigid metal conduit 1-1/2 inches in diameter	2,400.62	lin. ft.	3.09	7,417.91
131	Furnishing and installing embedded electrical rigid metal conduit 2 inches in diameter	308.49	lin. ft.	3.82	1,178.43
132	Furnishing and installing embedded electrical rigid metal conduit 2-1/2 inches in diameter	289.03	lin. ft.	4.27	1,234.16
133	Furnishing and installing embedded electrical rigid metal conduit 3 inches in diameter	0	lin. ft.	7.35	0.00
134	Furnishing and installing embedded electrical rigid metal conduit 3-1/2 inches in diameter	0	lin. ft.	9.08	0.00
135	Furnishing and installing embedded electrical rigid metal conduit 4 inches in diameter	3.75	lin. ft.	11.17	41.89

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
136	Furnishing and installing exposed electrical rigid metal conduit 1/2 inch in diameter	216.2	lin. ft.	$ 1.79	$ 386.99
137	Furnishing and installing exposed electrical rigid metal conduit 3/4 inch in diameter	646.6	lin. ft.	1.95	1,260.87
138	Furnishing and installing exposed electrical rigid metal conduit 1 inch in diameter	236.3	lin. ft.	2.14	505.68
139	Furnishing and installing exposed electrical rigid metal conduit 1-1/2 inches in diameter	148.7	lin. ft.	3.36	499.63
140	Furnishing and installing exposed electrical rigid metal conduit 2 inches in diameter	265.5	lin. ft.	4.11	1,091.21
141	Furnishing and installing exposed electrical rigid metal conduit 3 inches in diameter	0	lin. ft.	7.72	0.00
142	Furnishing and installing exposed electrical rigid metal conduit 4 inches in diameter	103.7	lin. ft.	11.76	1,219.51
143	Furnishing and installing exposed electrical flexible metal conduit 1/2 inch in diameter	208.7	lin. ft.	1.58	329.74
144	Furnishing and installing exposed electrical flexible metal conduit 3/4 inch in diameter	21.7	lin. ft.	1.89	41.01
145	Furnishing and installing exposed electrical flexible metal conduit 1 inch in diameter	5.4	lin. ft.	2.67	14.42
146	Furnishing and installing exposed electrical flexible metal conduit 1-1/2 inches in diameter	1.8	lin. ft.	5.04	9.07

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
147	Furnishing and installing exposed electrical flexible metal conduit 2 inches in diameter	0	lin. ft.	$ 6.76	$ 0.00
148	Furnishing and installing exposed electrical flexible metal conduit 2-1/2 inches in diameter	2.0	lin. ft.	11.76	23.52
149	Furnishing and installing embedded electrical nonmetallic conduit 2 inches in diameter	55.75	lin. ft.	1.89	105.37
150	Furnishing and installing embedded electrical nonmetallic conduit 4 inches in diameter	455.17	lin. ft.	2.42	1,101.51
151	Furnishing and installing exposed electrical nonmetallic conduit 4 inches in diameter	699	lin. ft.	2.52	1,761.48
152	Furnishing and installing single-conductor, No. 12 AWG, 600-volt-insulated electrical wire	12,422.3	lin. ft.	0.15	1,863.35
153	Furnishing and installing single-conductor, No. 10 AWG, 600-volt-insulated electrical wire	12,717.7	lin. ft.	0.18	2,289.19
154	Furnishing and installing single-conductor, No. 8 AWG, 600-volt-insulated electrical wire	2,321.9	lin. ft.	0.23	534.04
155	Furnishing and installing single-conductor, No. 6 AWG, 600-volt-insulated electrical wire	2,490.5	lin. ft.	0.33	821.87
156	Furnishing and installing single-conductor, No. 4 AWG, 600-volt-insulated electrical wire	834.2	lin. ft.	0.44	367.05
157	Furnishing and installing single-conductor, No. 1 AWG, 600-volt-insulated electrical wire	219.5	lin. ft.	0.77	169.02

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
158	Furnishing and installing 2-conductor, No. 19/22 AWG, 600-volt-insulated electrical control cable	3, 617. 8	lin. ft.	$ 0. 65	$ 2, 351. 57
159	Furnishing and installing 3-conductor, No. 19/22 AWG, 600-volt-insulated electrical control cable	2, 164. 5	lin. ft.	1. 03	2, 229. 44
160	Furnishing and installing 5-conductor, No. 19/22 AWG, 600-volt-insulated electrical control cable	3, 480. 0	lin. ft.	1. 47	5, 115. 60
161	Furnishing and installing 7-conductor, No. 19/22 AWG, 600-volt-insulated electrical control cable	815. 0	lin. ft.	1. 68	1, 369. 20
162	Furnishing and installing 9-conductor, No. 19/22 AWG, 600-volt-insulated electrical control cable	925. 5	lin. ft.	2. 37	2, 193. 44
163	Furnishing and installing 12-conductor, No. 19/22 AWG, 600-volt-insulated electrical control cable	554. 0	lin. ft.	3. 53	1, 955. 62
164	Furnishing and installing 9-conductor, No. 16 AWG, 600-volt-insulated electrical control cable	0	lin. ft.	2. 94	0. 00
165	Furnishing and installing 19-conductor, No. 16 AWG, 600-volt-insulated electrical control cable	0	lin. ft.	5. 15	0. 00
166	Furnishing and installing single-conductor, 250, 000-circular-mil, 600-volt-insulated electrical power cable	639. 0	lin. ft.	1. 84	1, 175. 76

APPENDIX C (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
167	Furnishing and installing single-conductor, No. 4 AWG, 15,000-volt-insulated electrical power cable	0	lin. ft.	$ 5.04	$ 0.00
168	Furnishing and installing 2-conductor, No. 8 AWG, 600-volt-insulated electrical parkway cable	0	lin. ft.	1.80	0.00
169	Installing single-conductor 1,750,000-circular-mil, 15,000-volt-insulated electrical main power cable	1,648.6	lin. ft.	6.51	10,732.39
170	Installing generator voltage switchgear	100%	Lump sum	2,650	2,650.00
171	Installing two sets of generator-neutral grounding equipment	100%	Lump sum	945.00	945.00
172	Installing two generator surge-protective equipment cubicles	0	Lump sum	1,430	0.00
173	Installing carrier-current transmitter-receiver sets	0	lb.	1.58	0.00
174	Installing capacitor potential-device adjustment units	500	lb.	0.74	370.00
175	Installing large power transformers without oil in transformer area	147,366	lb.	0.05	7,368.30
176	Handling, filtering, and purifying insulating oil for power transformers and placing insulating oil in power transformers	36,200	lb.	0.04	1,448.00
177	Installing small power transformer without oil in transformer area	8,350	lb.	0.14	1,169.00
178	Installing 115-kilovolt power circuit breakers	2	bkr.	3,780	7,560.00

APPENDIX C (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
179	Handling, filtering, and purifying insulating oil for power circuit breakers and placing insulating oil in power circuit breakers	0	lb.	$ 0.035	$ 0.00
180	Installing 115-kilovolt bus-disconnecting air switches in switchyard and transformer area	7	Each	990.00	6,930.00
181	Installing 115-kilovolt lightning arresters	3	Each	515.00	1,545.00
182	Furnishing and installing suspension-type insulators	525	Each	10.50	5,512.50
183	Furnishing and installing 15-kilovolt pedestal insulators	6	Each	27.30	163.80
184	Furnishing and installing 115-kilovolt pedestal insulator stacks	12	Each	247.00	2,964.00
185	Furnishing and installing No. 4/0 AWG copper buses in switchyard and transformer area	1,086.5	lb.	2.84	3,085.66
186	Furnishing and installing 1-1/4-inch iron-pipe-size copper tubing in switchyard and transformer area	217.1	lb.	5.57	1,209.25
187	Furnishing and installing 2-1/2-inch iron-pipe-size copper tubing in transformer area	1,787.1	lb.	3.26	5,825.95
188	Furnishing and installing lighting fixtures in switchyard and transformer area	7	Each	95.00	665.00
189	Furnishing and installing weatherproof, outdoor-type plug receptacles in switchyard and transformer area	2	Each	28.40	56.80

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
190	Furnishing and installing strain insulator spring attachments	12	Each	$ 21.00	$ 252.00
191	Installing 115-kilovolt coupling capacitors and potential devices	3,615	lb.	0.26	939.90
192	Installing line traps	0	lb.	0.53	0.00
193	Installing carrier-current line tuning units and coaxial cables	0	lb.	0.65	0.00
194	Installing electrical apparatus in gate control house	139.5	lb.	2.63	366.89
195	Furnishing and installing wiring devices in gate control house	4	Each	30.00	120.00
196	Installing main control board	8,641	lb.	1.05	9,073.05
197	Installing low-voltage alternating-current power distribution board	3,618	lb.	0.63	2,279.34
198	Installing dry-type 50-kv.-a. distribution lighting transformers	1,300	lb.	0.63	819.00
199	Installing carbon dioxide gas control cabinets and associated equipment	328	lb.	1.05	344.40
200	Installing direct-current power distribution board	0	lb.	0.84	0.00
201	Installing two battery chargers	2,900	lb.	0.80	2,320.00
202	Installing 300-kv.-a. station-service transformers including associated bus and disconnect switches	15,058	lb.	0.10	1,505.80
203	Installing miscellaneous power distribution cabinets	3,144	lb.	1.26	3,961.44

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
204	Installing recording board	1, 121	lb.	$ 1.05	$ 1, 177.05
205	Furnishing and installing 460-volt power receptacles complete with metal enclosures and matching plugs	9	Per rec.	86.10	774.90
206	Furnishing and installing 115-volt power receptacles complete with matching plugs	1	Per rec.	55.00	55.00
207	Installing station-storage battery and battery rack	7, 315	lb.	0.15	1, 097.25
208	Furnishing and installing power contact conductors for 40-ton traveling crane	784.6	lb.	1.47	1, 153.36
209	Furnishing and installing recessed lighting panel boards	3	Each	325.00	975.00
210	Furnishing and installing lighting system wiring devices	151	Each	6.62	999.62
211	Furnishing and installing recessed emergency lighting contactor	1	Per assembly	231.00	231.00
212	Furnishing and installing type A lighting fixtures	2	Each	10.00	20.00
213	Furnishing and installing types B, C, D, and E lighting fixtures	93	Each	20.00	1, 860.00
214	Furnishing and installing type F lighting fixtures	15	Each	12.60	189.00
215	Furnishing and installing types G and H lighting fixtures	12	Each	25.20	302.40
216	Furnishing and installing type J lighting fixtures	6	Each	25.20	151.20
217	Furnishing and installing types K, L, and M lighting fixtures	19	Each	46.20	877.80

APPENDIX C (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
218	Furnishing and installing type N lighting fixtures	12	Each	$ 94.50	$ 1,134.00
219	Furnishing and installing type P lighting fixtures	2	Each	16.80	33.60
220	Furnishing and installing type Q lighting fixtures	12	Each	69.30	831.60
221	Furnishing and installing type R lighting fixtures	2	Each	27.30	54.60
222	Furnishing and installing type S lighting fixtures	10	Each	78.75	787.50
223	Furnishing and installing type T lighting fixtures	2	Each	79.50	159.00
224	Furnishing and installing types U and V lighting fixtures	2	Each	420.00	840.00
225	Furnishing and installing type AA fluorescent lighting fixtures	22	Each	50.40	1,108.80
226	Furnishing complete set of incandescent lamps for spare stock for lamp replacement	1	Set	147.00	147.00
227	Furnishing F48T 12/ww slimline fluorescent lamp for spare stock for lamp replacement	24	Lamp	3.15	75.60
228	Furnishing 2-lamp 430-ma. ballasts for 48T12 slimline fluorescent lamps for spare stock for ballast replacement	5	Ballast	12.61	63.05
229	Finishing recesses for lighting panel boards, distribution panel boards and other recessed electrical equipment	8	Recess	30.00	240.00
230	Finishing recesses for type A incandescent lighting fixtures	2	Recess	25.00	50.00

APPENDIX C (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
231	Furnishing and installing overhead power and control cable circuits from powerplant to gate control house	100%	Lump sum	$ 15,120	$ 15,120.00
232	Painting exterior surfaces of generators except handrailings, stairs and walkways	1,438	sq. ft.	0.80	1,150.40
233	Painting interior surfaces of generator housings and exposed surfaces of handrailings, stairs, and walkways	3,756	sq. ft.	1.00	3,756.00
234	Installing pressure water filter, pressure tank, and chlorinating equipment	3,681	lb.	0.75	2,760.75
	Total--Original Contract				$ 2,396,920.34
	Order for Changes No. 2				
(a)	Furnishing and handling type I low-alkali cement	8,197.13	bbl.	13.30	109,021.83
	Order for Changes No. 6				
	Backcharge for freight on wire mesh bulkheads and coal-tar enamel furnished with penstock under specifications no. DS-3621 at contractor's expense	16.0	cwt.	7.429	-118.86
	Order for Changes No. 7				
(a)	Furnishing 1-inch-diameter anchor bars	464.00	lb.	0.24	111.36
(b)	Furnishing 1.41-inch-diameter anchor bars	672	lb.	0.23	154.56
(c)	Furnishing plug valves	2,257	lb.	1.38	3,114.66

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
(d)	Installing laminated bakelite identification signs on powerplant switchgear	17	Sign	$ 5.25	$ 89.25
(e)	Furnishing and installing single-conductor, No. 2 AWG 15,000-volt-insulated electrical power cable	405.3	lin. ft.	6.38	2,585.81
(f)	Furnishing and installing four galvanized ladder rungs for septic tank	100%	Lump sum	14.00	14.00
	Total--Order for Changes No. 7				6,069.64
	Order for Changes No. 8				
(a)	Adjustment for furnishings and installing 12-conductor control cable	1,640	lin. ft.	1.87	3,066.80
(b)	Furnishing and installing additional 12-conductor control cable	103	lin. ft.	5.76	593.28
(c)	Furnishing and installing additional power cable	103	lin. ft.	5.37	553.11
(d)	Furnishing and installing additional line poles and hardware	3	Pole	414.40	1,243.20
(e)	Furnishing and installing additional double-line guys	6	Each	179.24	1,075.44
	Total--Order for Changes No. 8				6,531.83
	Order for Changes No. 9				
(a)	Furnishing and installing structural steel cable termination support	100%	Lump sum	126.27	126.27
(b)	Furnishing and installing steel terminal box	100%	Lump sum	112.13	112.13
(c)	Furnishing and installing revised Type K lighting fixtures	2	Each	42.09	84.18

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
(d)	Furnishing and installing type W lighting fixture	1	Each	$ 34.37	$ 34.37
(e)	For eliminating the requirements for furnishing and installing motor starters for 3,000, 7,000, 8,000/4,000 and 20,000-c.f.m. fans	100%	Lump sum	-109.20	-109.20
(f)	Furnishing and installing vapor barrier on powerplant and machine shop roof	5,015.63	sq. ft.	0.26	1,304.06
	Total--Order for Changes No. 9				1,551.81
	Order for Changes No. 10				
(a)	Furnishing and installing sheet-metal seal	53	lin. ft.	1.00	53.00
(b)	Furnishing and installing cotton fabric	40	lin. ft.	0.94	37.60
(c)	Repairing turbine wicket gates	100%	Lump sum	209.46	209.46
(d)	Furnishing operator for 40-ton overhead powerplant crane	126.5 33 0	hr. hr. hr.	4.51 6.765 9.02	570.52 223.25 0.00
(e)	For eliminating the requirement for installing and connecting the 63 protective and auxiliary relays	100%	Lump sum	-414.00	-414.00
(f)	Furnishing and delivering a lighting fixture, pole, bracket, and hanger	100%	Lump sum	270.17	270.17
(g)	Furnishing and delivering catch basin frame and grating	100%	Lump sum	187.30	187.30
(h)	Furnishing and delivering 110 feet of 12-inch-diameter corrugated metal pipe and six connecting bands	100%	Lump sum	273.76	273.76
	Total--Order for Changes No. 10				1,411.06

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Order for Changes No. 11				
(a)	Excavation, backfill, compacting backfill, and salvaging and delivering salvaged materials	100%	Lump sum	$ 7,759.28	$ 7,759.28
(b)	Unwatering	100%	Lump sum	756.80	756.80
(c)	Cutting hole in wall and installing wall casting	100%	Lump sum	334.55	334.55
(d)	Installing 10-inch line	1,727.5	lb.	1.25	2,159.38
(e)	Cover lines with asphalt-saturated felt	100%	Lump sum	45.00	45.00
(f)	Delivering 10-inch pipe and fittings	100%	Lump sum	178.49	178.49
	Total--Order for Changes No. 11				11,233.50
	Order for Changes No. 12				
(a)	Furnishing and installing copper tubing	100%	Lump sum	982.37	982.37
(b)	Installing current transformer	100%	Lump sum	36.00	36.00
(c)	Furnishing and installing exposed electrical rigid metal conduit 2-1/2 inches in diameter	103.5	lin. ft.	5.93	613.76
(d)	Constructing permanent 115-kv. transmission line ties	100%	Lump sum	4,074.74	4,074.74
(e)	Applying surface coat to wall insulation	13,707	sq. ft.	0.215	2,947.00
(f)	Mounting and connecting two station-service watt-hour meters	100%	Lump sum	33.20	33.20
(g)	Mounting and connecting two start-stop indicating lights	100%	Lump sum	17.60	17.60
	Total--Order for Changes No. 12				8,704.67

APPENDIX C (continued)

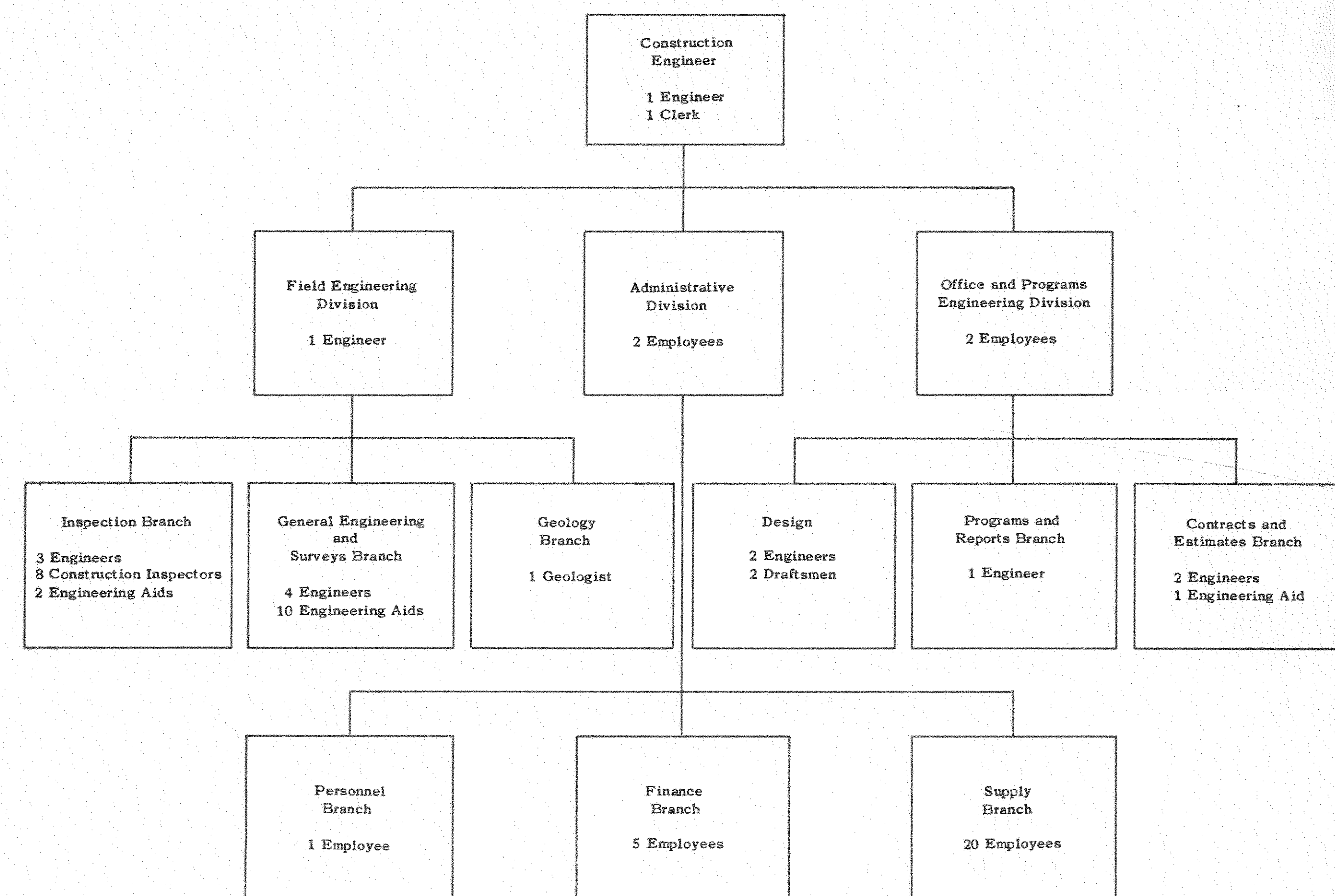
Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Order for Changes No. 13				
(a)	Repairing 115-kv. disconnecting switches	100%	Lump sum	$ 105.81	$ 105.81
(b)	Furnishing and delivering unused electrical cable	100%	Lump sum	3,330.51	3,330.51
(c)	Revising electrical control panels	100%	Lump sum	303.02	303.02
(d)	Painting exposed surface of cement-asbestos board	100%	Lump sum	75.00	75.00
	Total--Order for Changes No. 13				3,814.34
	Order for Changes No. 14				
(a)	Furnishing and delivering unused reducers	100%	Lump sum	81.71	81.71
(b)	Furnishing and delivering unused valves	100%	Lump sum	183.95	183.95
(c)	Furnish one 1-inch and one 1-1/4-inch water pressure regulator valves	100%	Lump sum	125.21	125.21
	Total--Order for Changes No. 14				390.87
	Total--Orders for Changes				148,610.69
	Extra Work Order No. 1				
(a)	Additional driving of piles	6	hr.	174.32	1,045.92
	Extra Work Order No. 2				
(a)	Correcting the oversize butt straps on penstock joints Y-BIA and Y-BIB	100%	Lump sum	3,719.43	3,719.43
	Total--Extra Work Orders				4,765.35
	Miscellaneous				
	Payment to Corps of Engineers				-117.84

APPENDIX C (continued)

Pay item	Property and pay item description	Quantity		Labor and materials by contractor	
		Amount	Unit	Unit cost	Total cost
	Replacement of two damaged No. St-179-G potheads				$ -163.63
	Total Miscellaneous Payments				-281.47
	Adjustment for changes in cost in accordance with paragraph 19 of the specifications				
	Rue Contracting Co.				52,021.37
	Western Industrial Corp.				882.43
	City Electric of Anchorage				8,385.97
	Munter Construction Co.				9,002.39
	C. R. Lewis Co.				6,790.24
	Northern Roofing and Sheet Metal Co.				309.20
	Oscar Sundberg and Sons				2,147.92
	Total Escalation Payments				79,539.52
	Recapitulation:				
	Total--Original contract				2,396,920.34
	Total--Order for changes				148,610.69
	Total--Extra Work Orders				4,765.35
	Total--Miscellaneous Payments				-281.47
	Total--Escalation Payments				79,539.52
	Total--Gross Earnings				2,629,554.43
	Net Payments				$ 2,629,554.43

APPENDIX D

Government organization chart for Eklutna project, 1952:



APPENDIX E

List of Eklutna project specifications and invitations:

Number	Title
DS-4121	6- by 4-Inch Jet Pumps
DS-4045	Carbon Dioxide Fire Extinguishing Equipment
DS-4044	Motor-Driven Sump Pumps, Fire Protection Pump and Oil pumps
DS-4038	Air Switches
DS-4034	Grounding Transformers and Resistors for Units 1 and 2
DS-4033	Lightning Arresters
DS-4026	Control, Recording, and A. C. Distribution boards, Station-Service Transformer, and Battery Chargers
DS-4022	Controls for 7.08-Foot by 9-Foot Bulkhead Gate Hoist at Pressure Tunnel Station 27+25 and for 7.08-Foot by 9-Foot Fixed-Wheel Gate Hoist at Pressure Tunnel Station 255+30 and for 66-Inch Butterfly Valves
DS-4048	Portable Oil Purifier and Drying Oven
DS-3756	Air Compressors
DS-3739	Oil Storage Tanks
DS-3737	Power Circuit Breakers, Lightning Arresters, and Air Switches
DS-3722	750-kv.-a. Power Transformer
DS-3716	66-Inch Butterfly Valves Operating Units and Handling Equipment
DC-3704	Powerplant
DS-3694	Generator-Voltage Switchgear
DS-3688	Governors for Hydraulic Turbines
DS-3676	40-Ton Traveling Crane
DC-3672	Eklutna-Anchorage 115-Kilovolt Transmission Line
DS-3673	Fixed-Wheel Gate Hoist for Surge Tank in Pressure Tunnel Station 255+30
DS-3628	Fixed-Wheel Gate Frame and Anchorage for Surge Tank of Pressure Tunnel, Station 255+30
DS-3621	Penstocks
DS-3596	Bulkhead Gate, Frame, Anchorage, Bulkhead Gate for Gate Shaft at Pressure Tunnel
DS-3590	Power Transformers for Switchyard
DC-3536	Generators
DC-3523	Eklutna Tunnel
DS-3506	Hydraulic Turbines
DC-3463	Thirty 2-Bedroom Temporary Residences
DC-3348	115-kv. Eklutna-Palmer Transmission Line and 12.47-kv. Distribution Line and Distribution System for Eklutna Government Camp
DC-3307	Six 3-Bedroom Residences, Six 2-Bedroom Residences, Two 10-Car Garages, Streets and Utilities at Eklutna Government Camp
DC-3295	Erecting Steel Warehouse at Eklutna Government Camp
DC-3294	Drilling Water Supply Well for Government Camp
DS-3234	Materials for Steel Warehouse

APPENDIX F

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