PLAINTIFF'S EXHIBIT
BAB-351

PUBLIC SERVICE COMPANY OF COLORADO
ARAPAHOE STEAM ELECTRIC STATION
1950-51-88,000 K W INSTALLATION
1951-44,000 K W EXTENSION

FINAL CONSTRUCTION REPORTS
1950-51

EBASCO SERVICES INCORPORATED
NEW YORK

WAD01931

AF-754

FINAL CONSTRUCTION REPORT

WAD01932

ARAPAHOE 1,2,3

129

AR754

ARAPAHOE STEAM ELECTRIC STATION

1950-51-88,000 KW INSTALLATION

1951-44,000 KW EXTENSION

FINAL CONSTRUCTION REPORTS

BUILT FOR

PUBLIC SERVICE COMPANY OF COLORADO

1949 - 1951

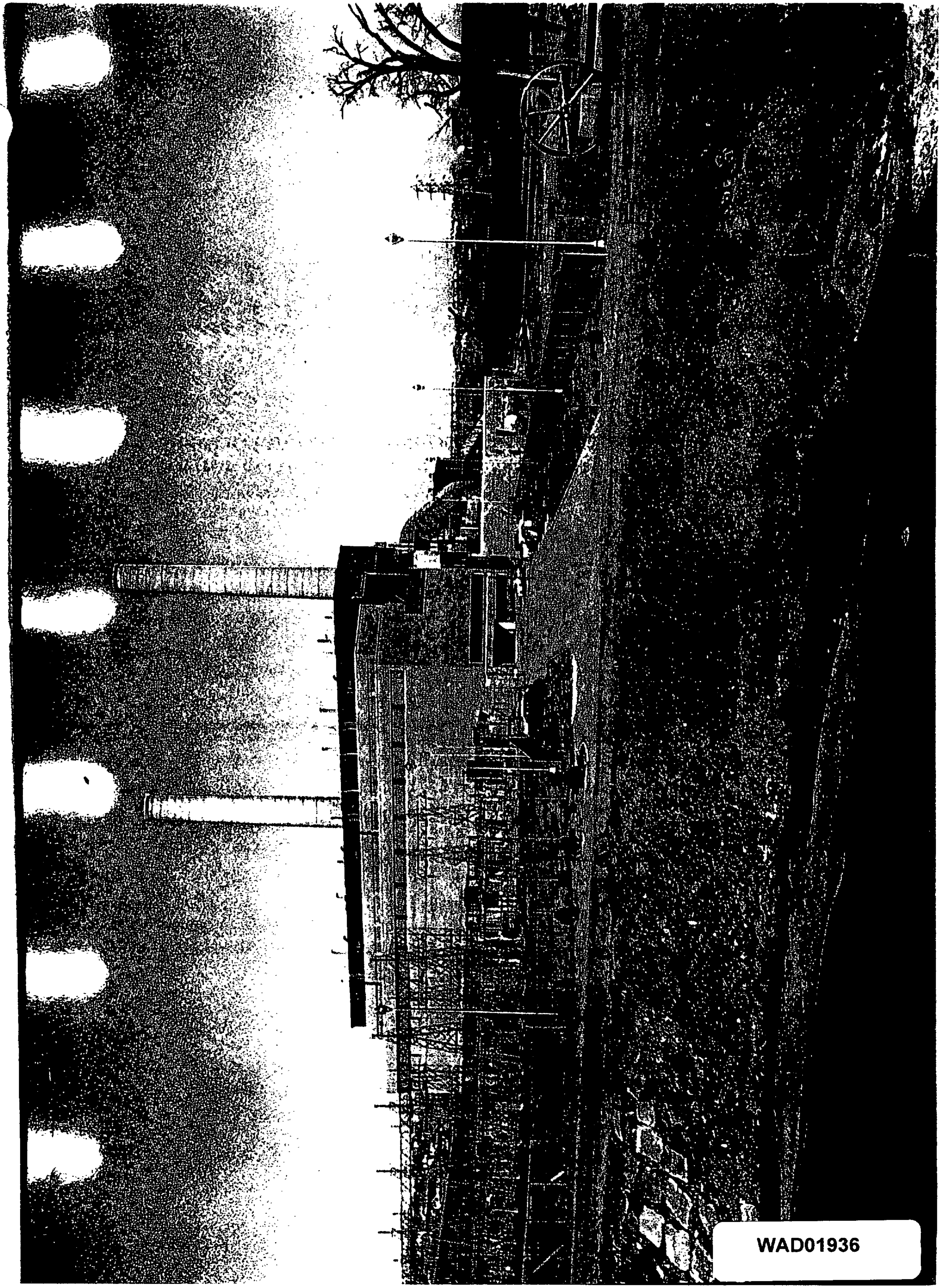
PREPARED BY WM. I. MILBURN
RESIDENT ENGINEER

APPROVED BY B. A. SNOW
SUPERINTENDENT

EBASCO SERVICES INCORPORATED

MARCH 1953

WAD01935



WAD01936

WAD01937

WAD01938

WAD01939

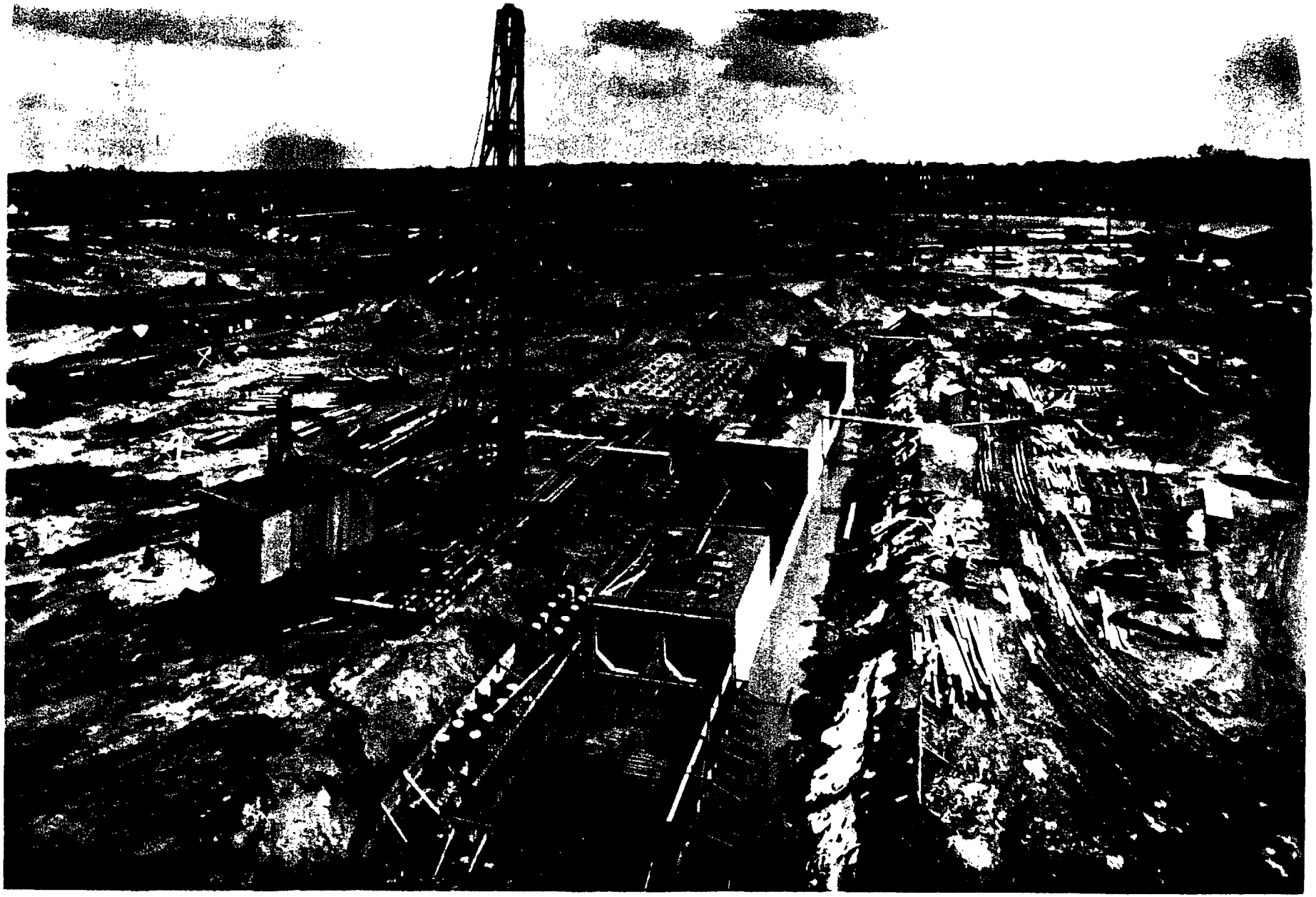
LOOKING WEST AT EXCAVATION FOR TURBINE
ROOM FOUNDATION MAT.
UNITS 1-2 PROGRESS PICTURE 9 AUG. 17, 1948

LOOKING SOUTHEAST AT CLEARING FOR RAILROAD SPUR FILL
UNITS 1-2 PROGRESS PICTURE 12 AUG. 17, 1948

WAD01940

DRIVING PILES FOR CIRCULATING WATER TUNNELS ALONG
SOUTH SIDE OF BUILDING SITE
UNITS 1-2 PROGRESS PICTURE 30 FEB. 4, 1949

WAD01941

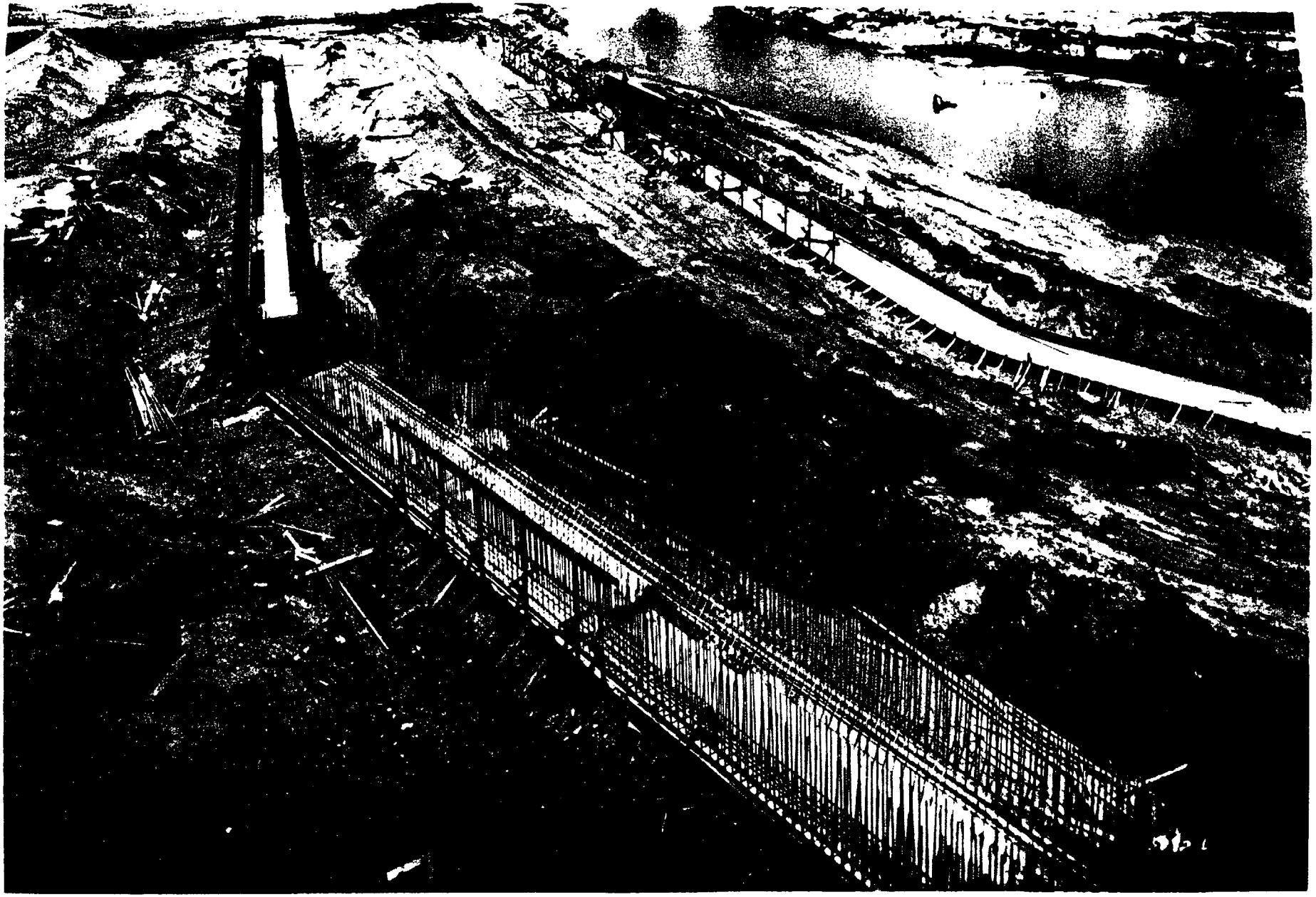


CIRCULATING WATER TUNNELS ALONG SOUTH SIDE OF BUILDING SITE
UNITS 1-2 PROGRESS PICTURE 38A APRIL 4, 1949

WAD01942

CIRCULATING WATER TUNNELS ALONG SOUTH SIDE OF BUILDING SITE
ALSO PILING FOR BUILDING AND BOILERS
UNITS 1-2 PROGRESS PICTURE 44 MAY 9, 1949

WAD01943



CIRCULATING WATER TUNNELS

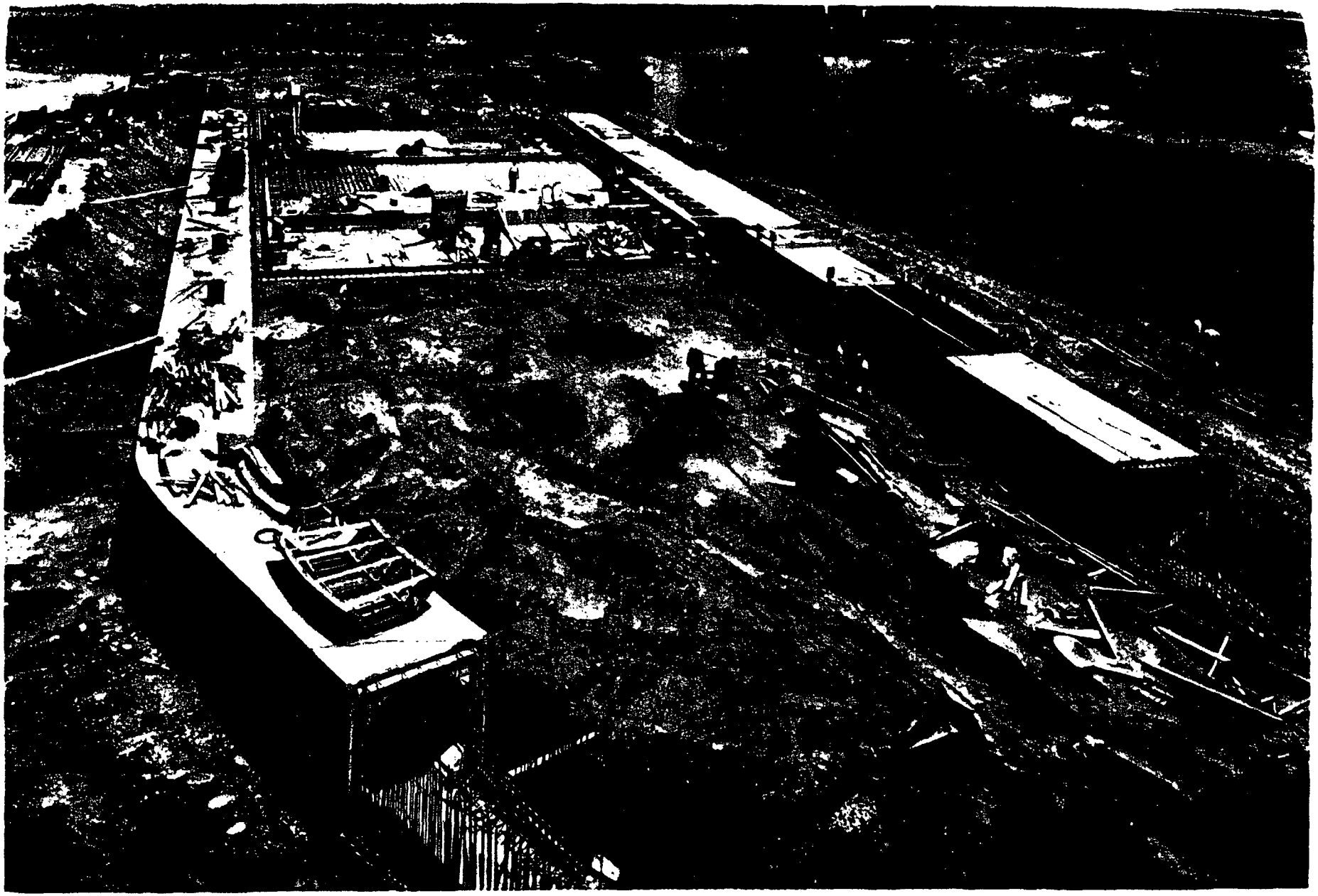
UNITS 1-2 PROGRESS PICTURE 48 MAY 9, 1949

WAD01944

TEMPORARY CONSTRUCTION BUILDINGS

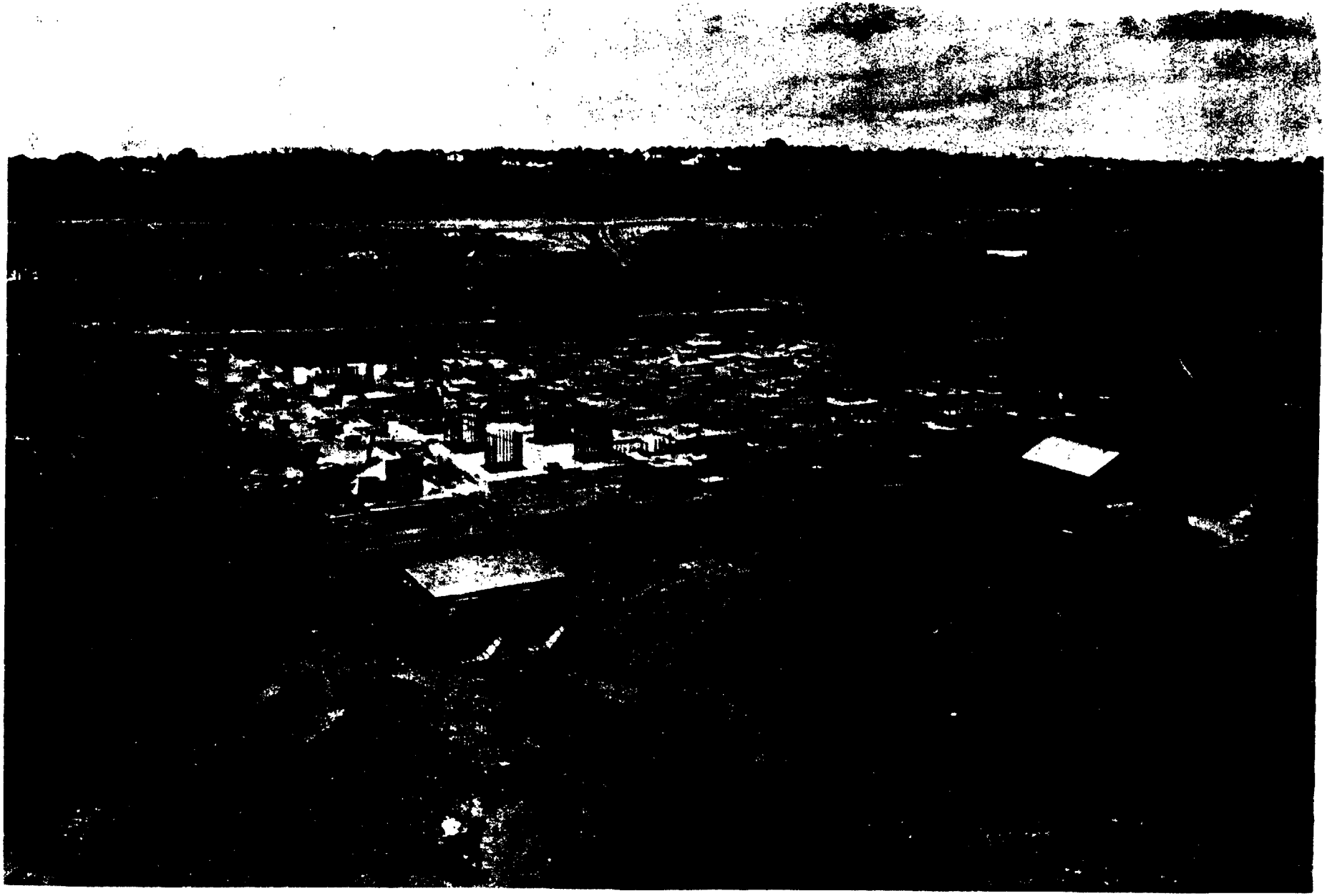
UNITS 1-2 PROGRESS PICTURE 56 JULY 5, 1949

WAD01945



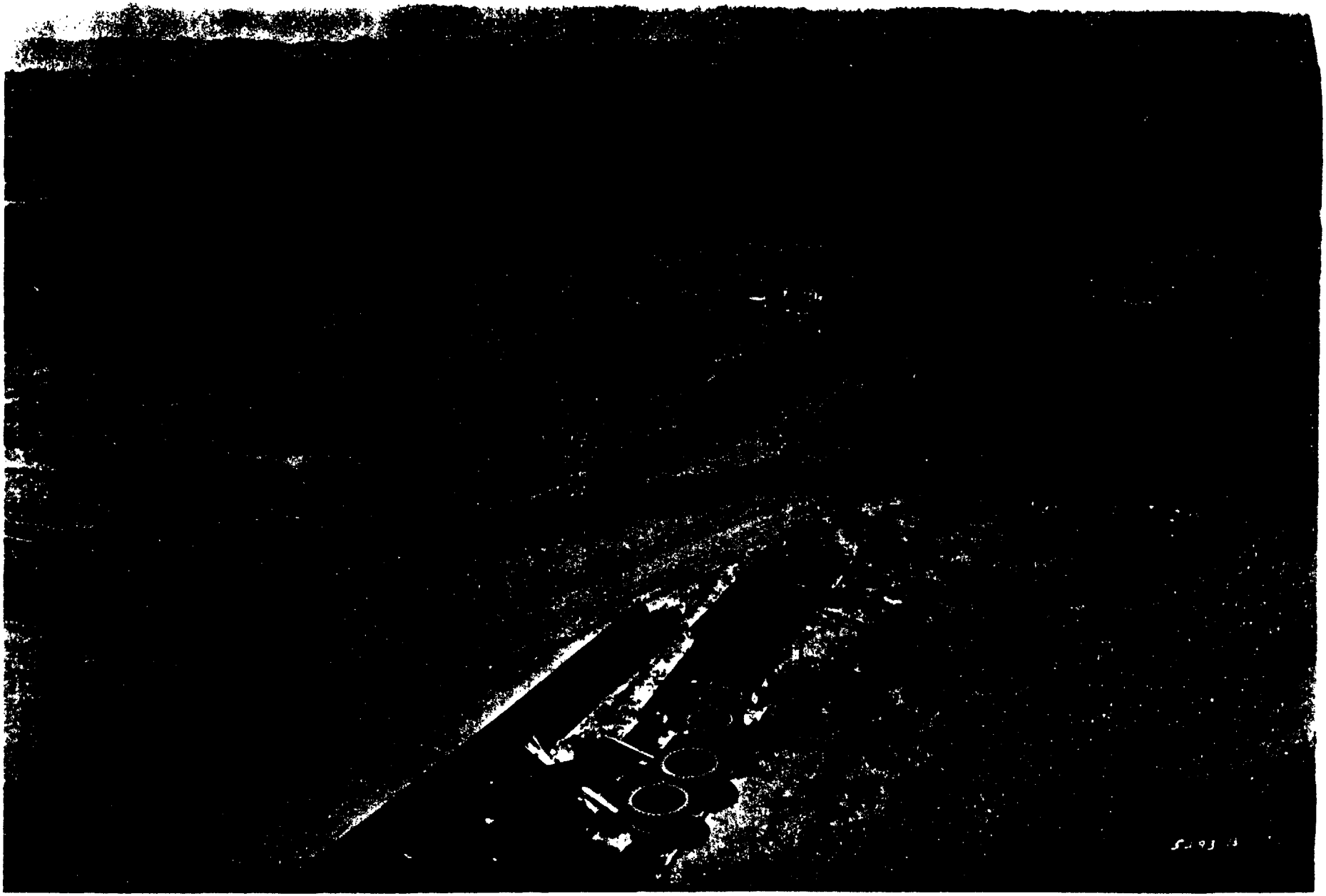
CIRCULATING WATER TUNNELS AND COOLING TOWER BASIN
UNITS 1-2 PROGRESS PICTURE 59 JULY 5, 1949

WAD01946



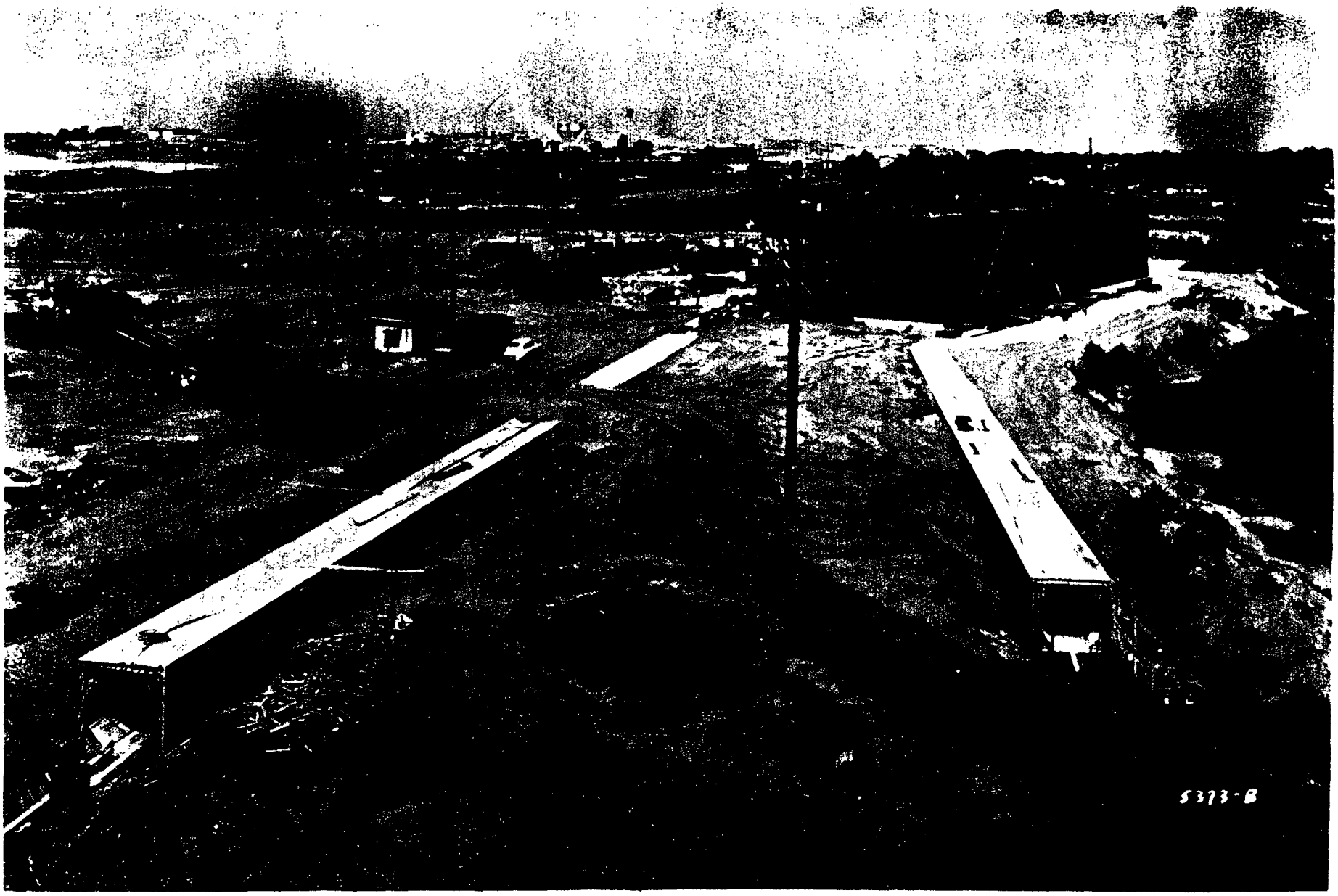
BUILDING FOUNDATIONS AND RAILROAD FILL
UNITS 1-2 PROGRESS PICTURE 61 JULY 5, 1949

WAD01947



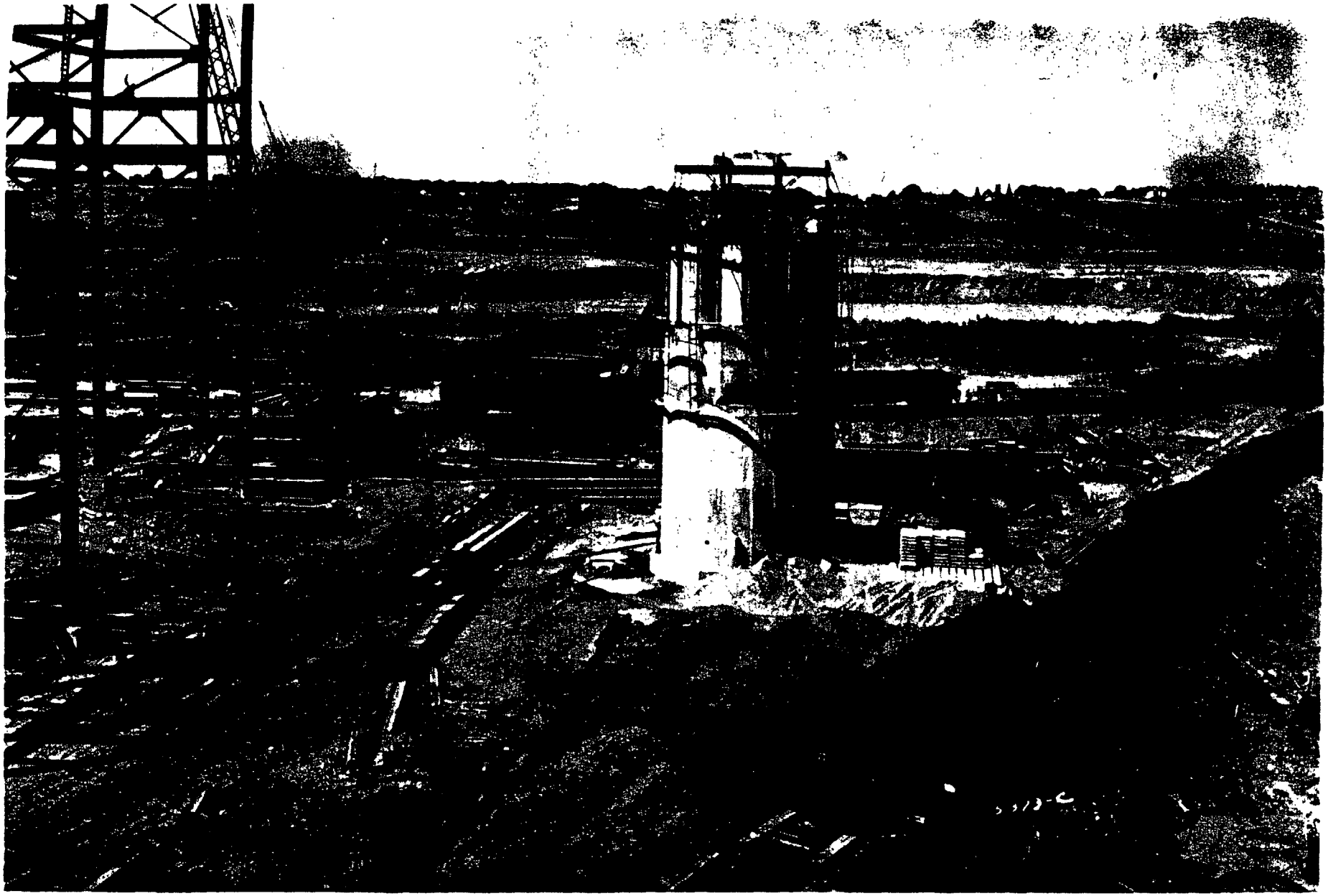
SWITCHYARD EXCAVATIONS FOR FOUNDATIONS
UNITS 1-2 PROGRESS PICTURE 65 AUG. 1, 1949

WAD01948



CIRCULATING WATER TUNNELS AND COOLING TOWER
UNITS 1-2 PROGRESS PICTURE 70 SEPT. 1, 1949

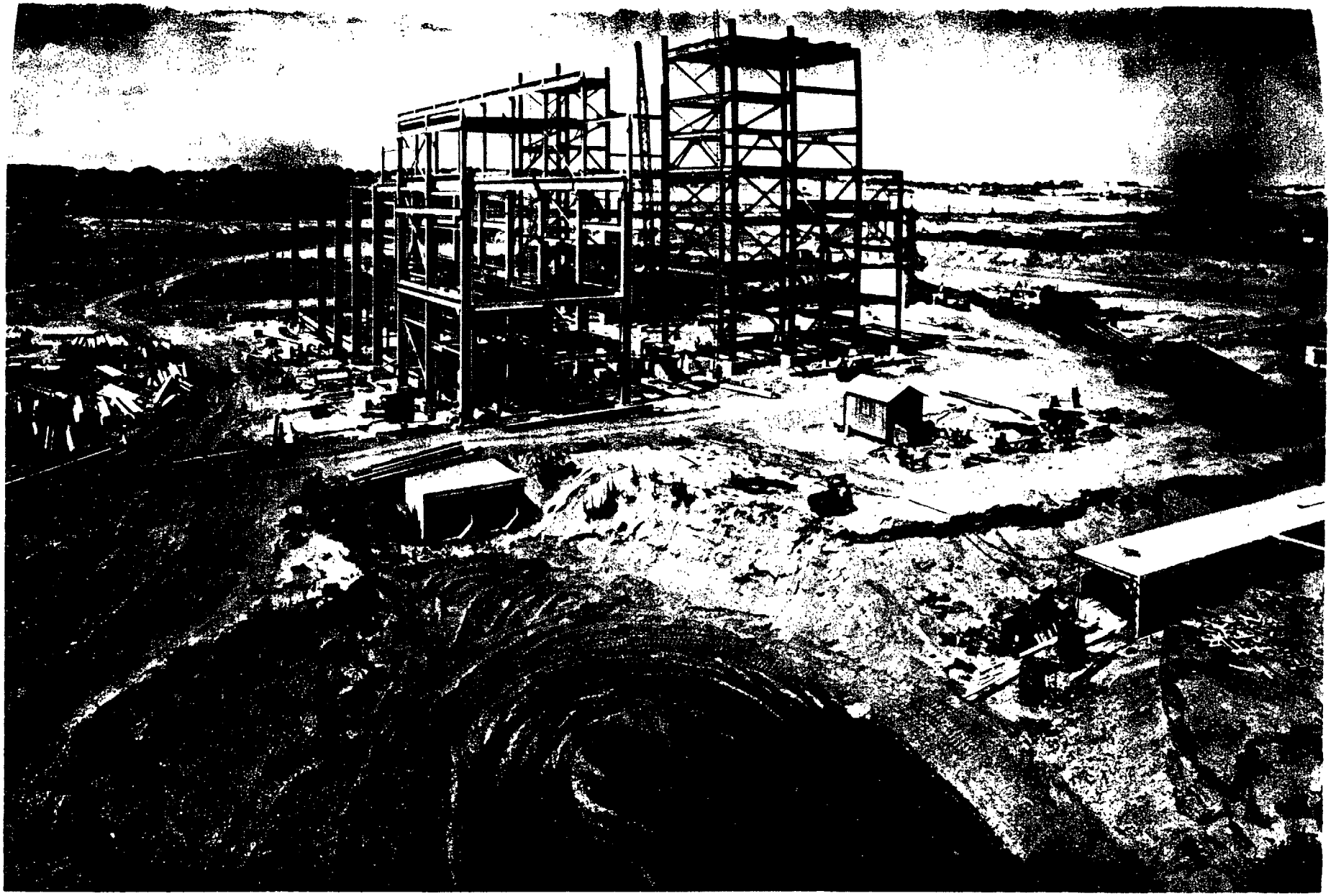
WAD01949



STACK NO. 1

UNITS 1-2 PROGRESS PICTURE 72 SEPT. 1, 1949

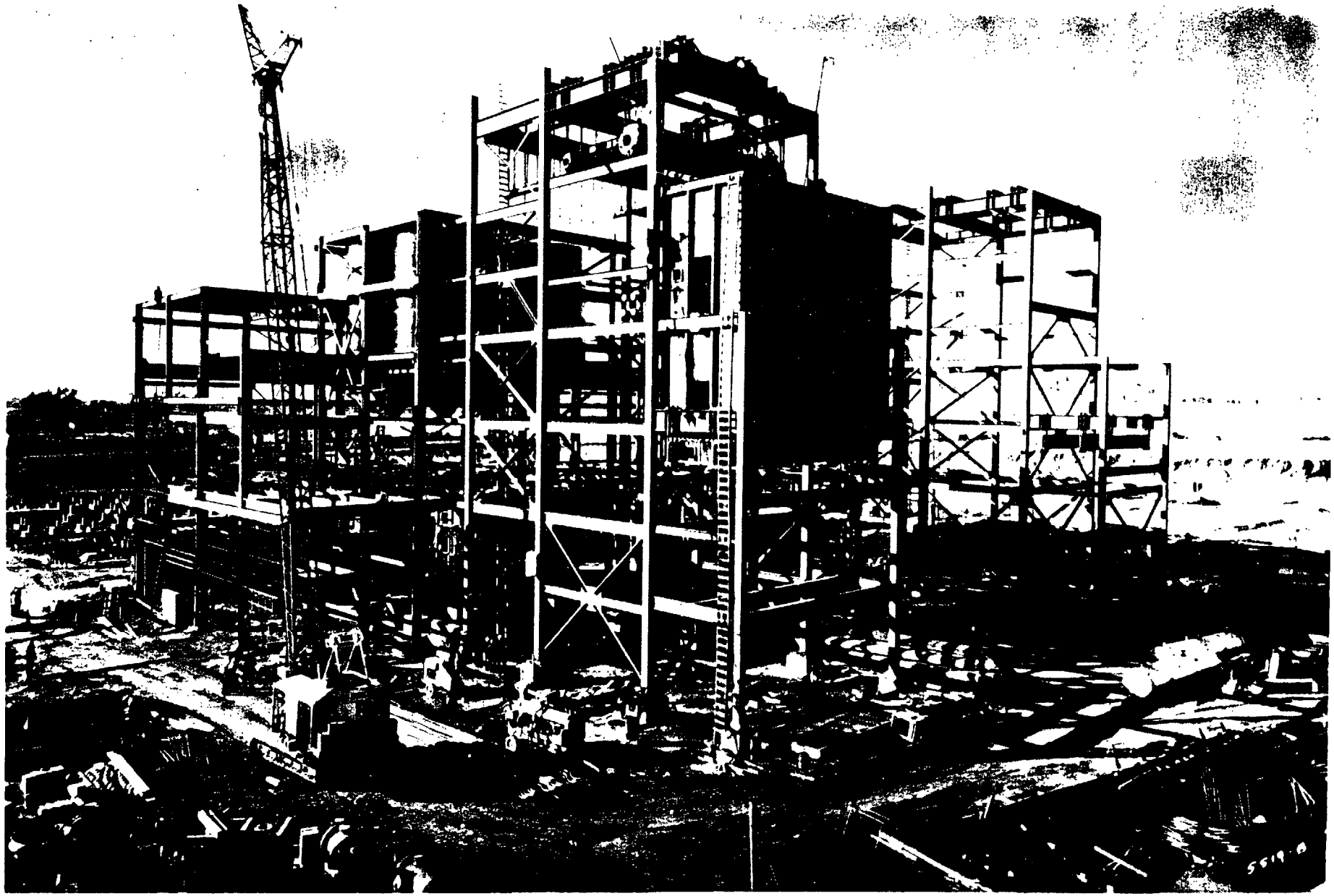
WAD01950



BUILDING STRUCTURAL STEEL

UNITS 1-2 PROGRESS PICTURE 74 SEPT. 1, 1949

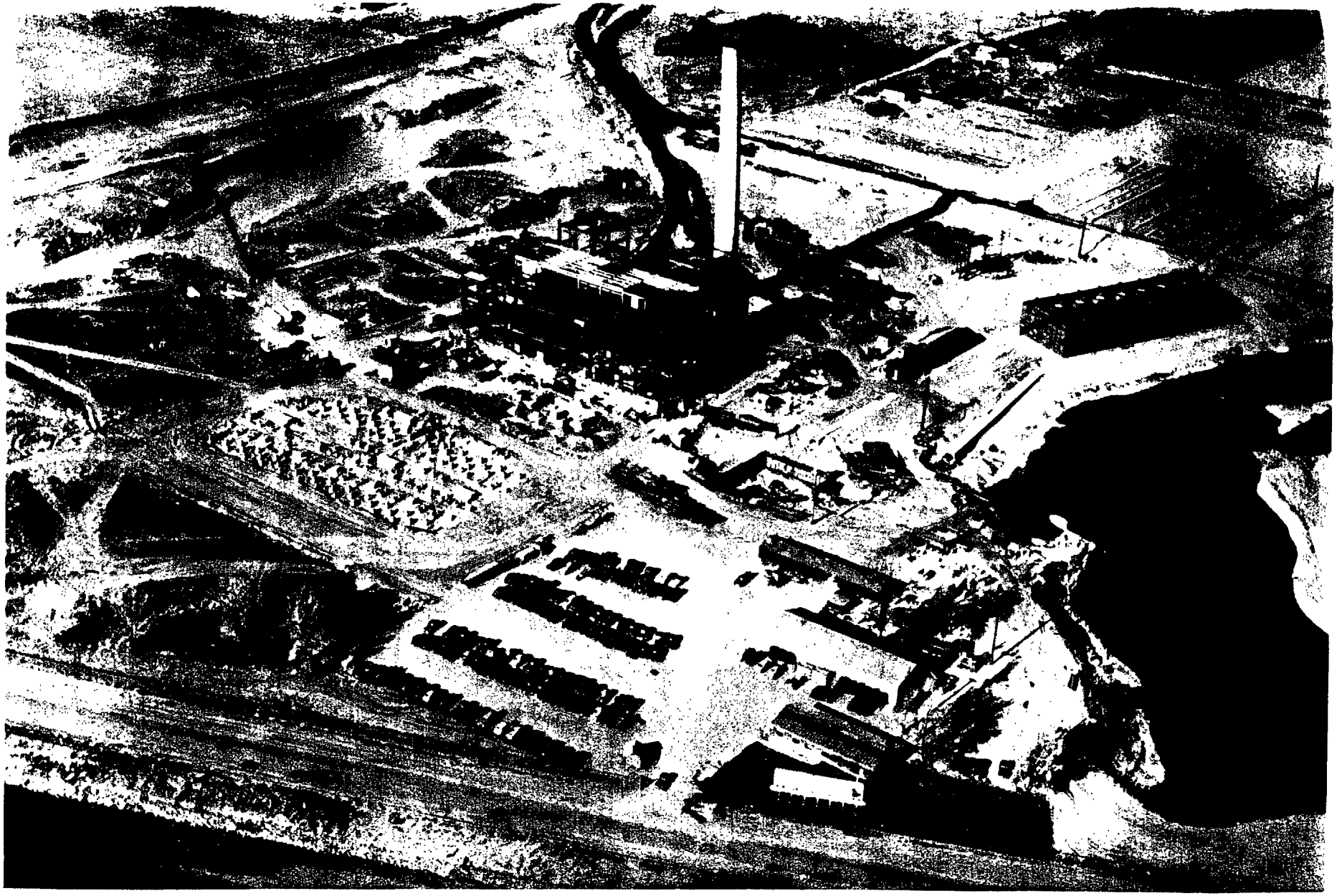
WAD01951



BOILER NO. 1

UNITS 1-2 PROGRESS PICTURE 91 NOV. 1, 1949

WAD01952



AERIAL VIEW LOOKING NORTHWEST

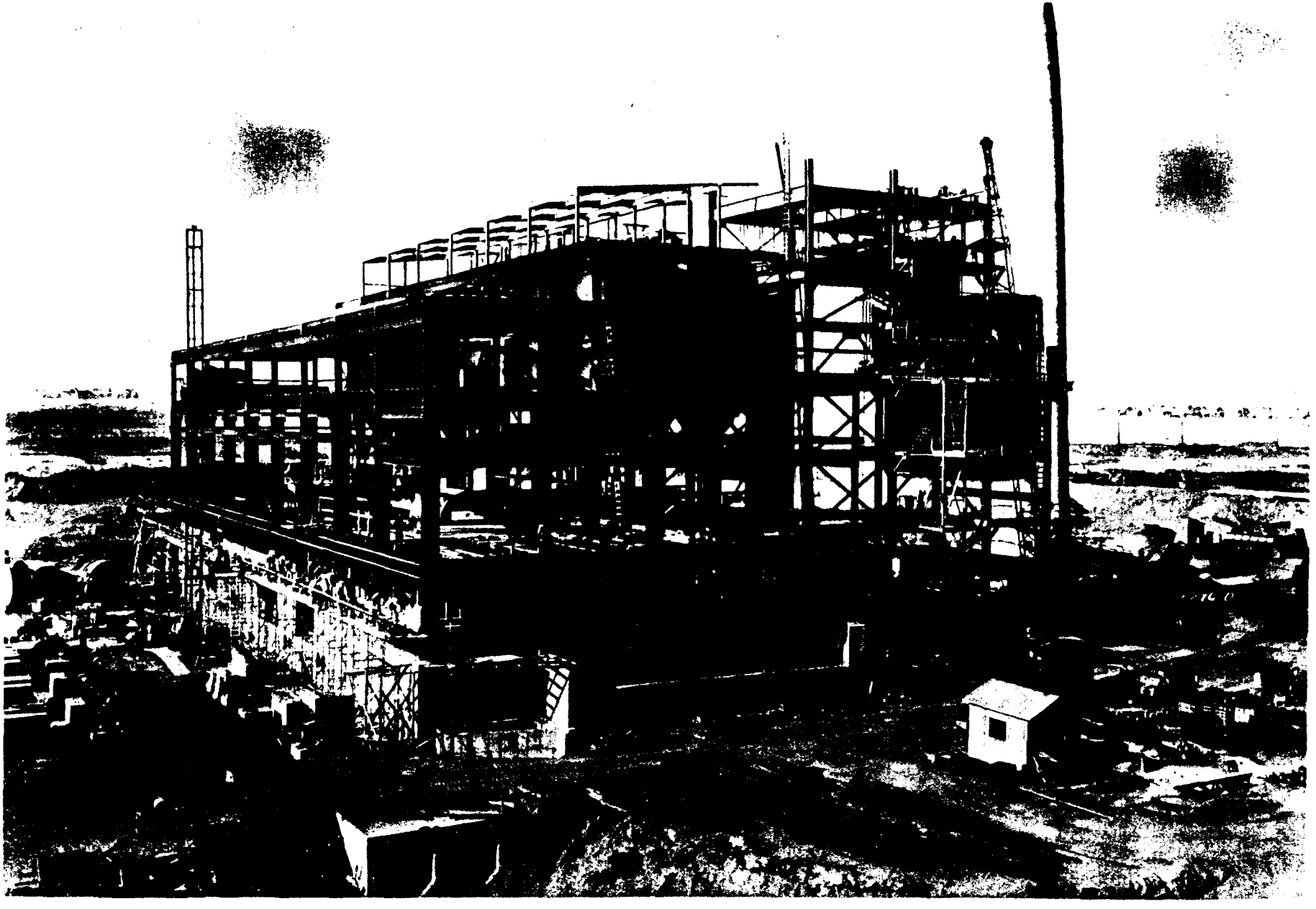
UNITS 1-2 PROGRESS PICTURE 94 NOV. 16, 1949

WAD01953

SWITCHYARD FOUNDATIONS

UNITS 1-2 PROGRESS PICTURE 95 DEC. 2, 1949

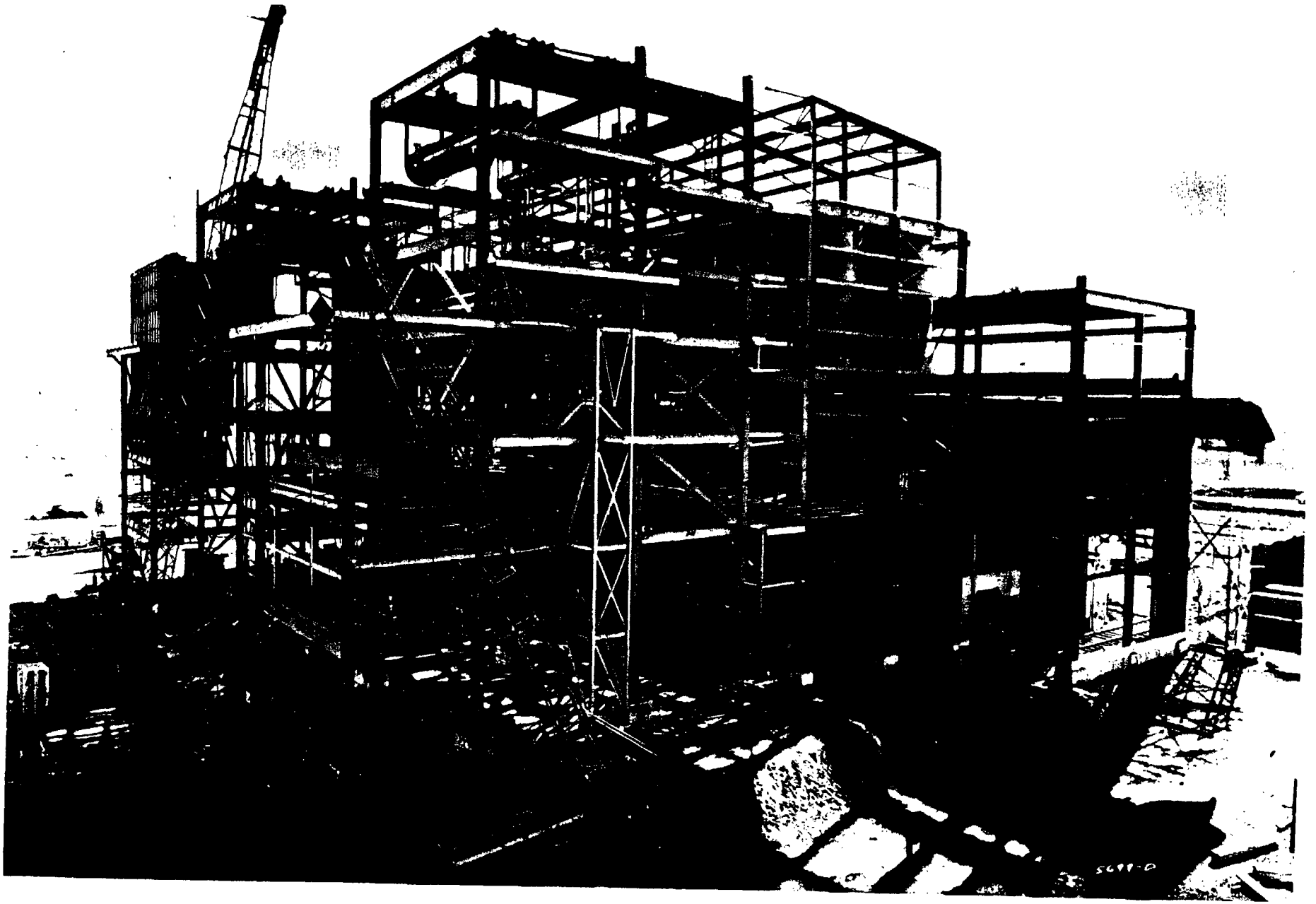
WAD01954



STATION BUILDING LOOKING NORTHWEST

UNITS 1-2 PROGRESS PICTURE 97 DEC. 2, 1949

WAD01955



BOILER NO. 2

UNITS 1-2 PROGRESS PICTURE 106 JAN. 10, 1950

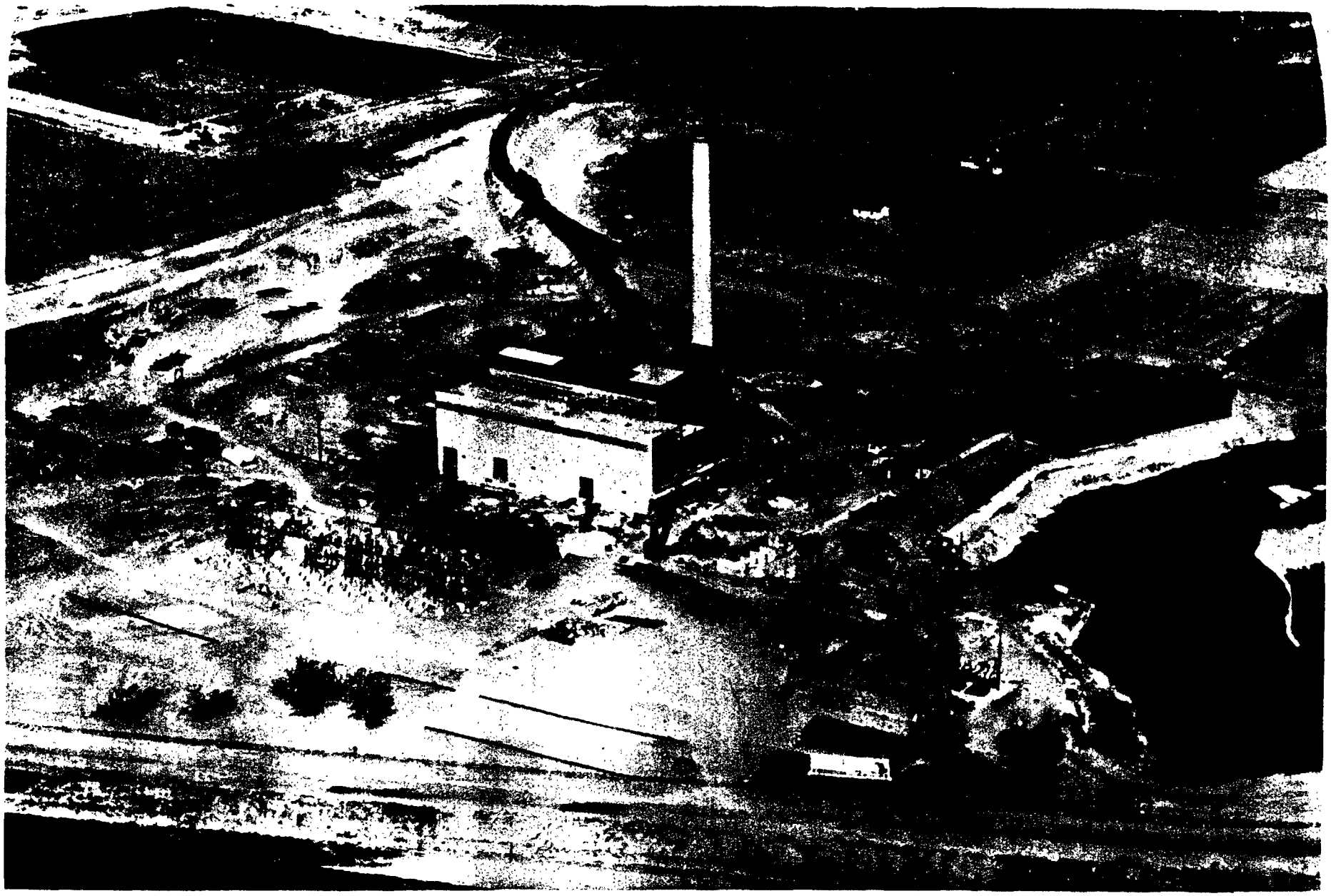
WAD01956

CIRCULATING WATER PUMP CHAMBER
UNITS 1-2 PROGRESS PICTURE 108 JAN. 10, 1050

WAD01957

CIRCULATING WATER PUMP CHAMBER AND TUNNEL
CONNECTIONS
UNITS 1-2 PROGRESS PICTURE 120 MARCH 3, 1950

WAD01958



AERIAL VIEW LOOKING NORTHWEST

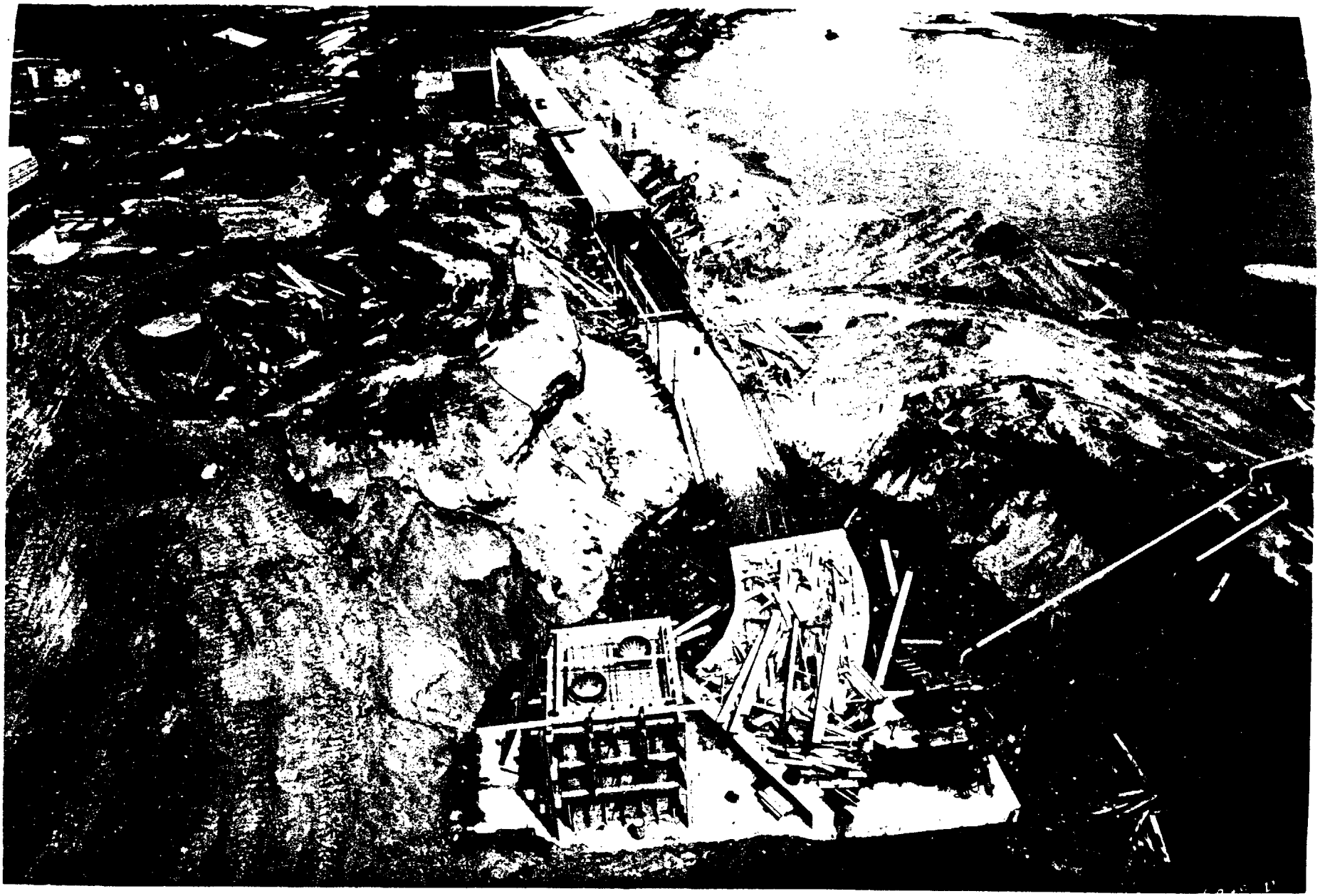
UNITS 1-2 PROGRESS PICTURE 127 MARCH 4, 1950

WAD01959

SWITCHYARD TOWERS

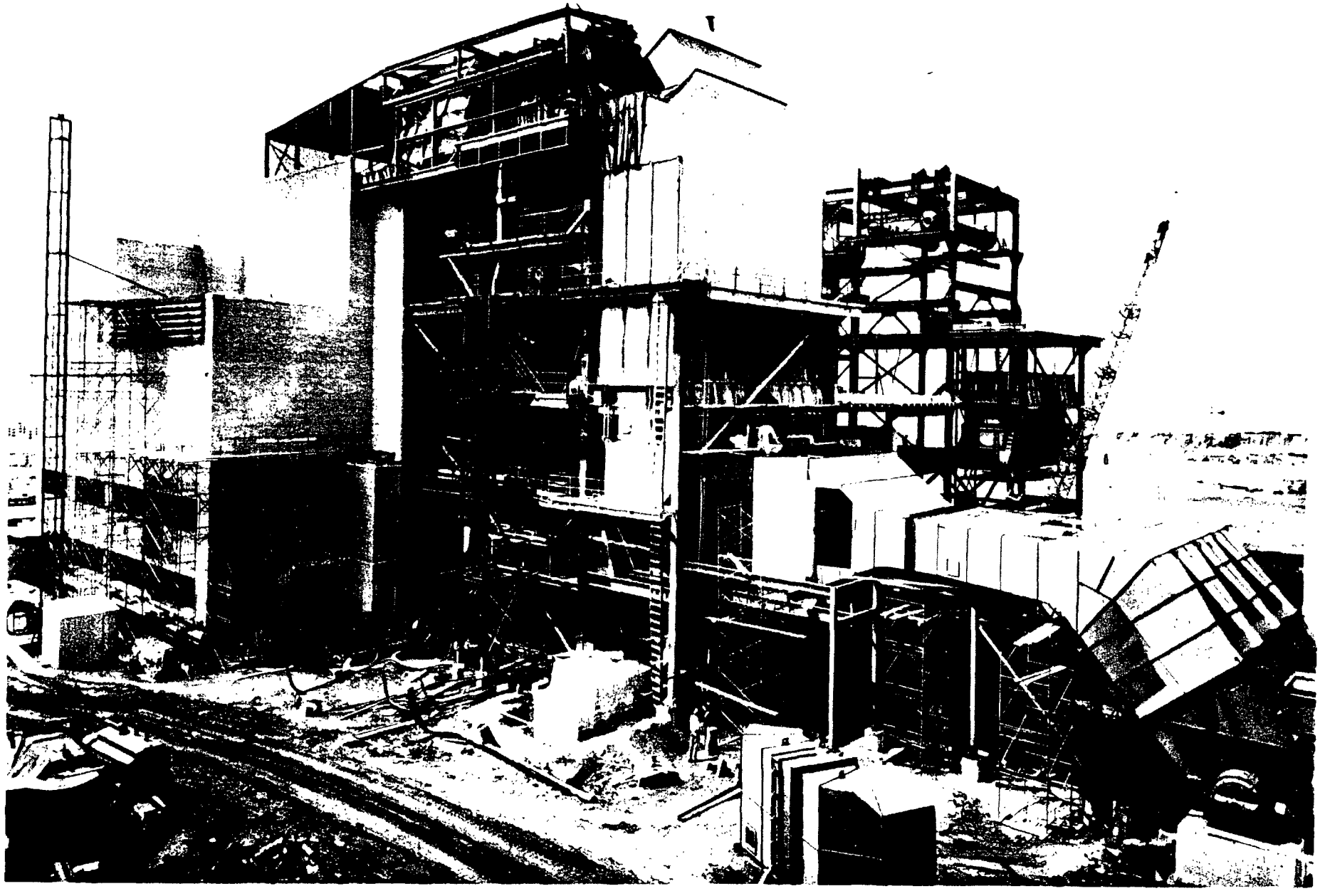
UNITS 1-2 PROGRESS PICTURE 133 MARCH 31, 1950

WAD01960



CIRCULATING WATER INTAKE TUNNEL
UNITS 1-2 PROGRESS PICTURE 136 MAY 1, 1950

WAD01961



BOILER NO. 1

UNITS 1-2 PROGRESS PICTURE 137 MAY 1, 1950

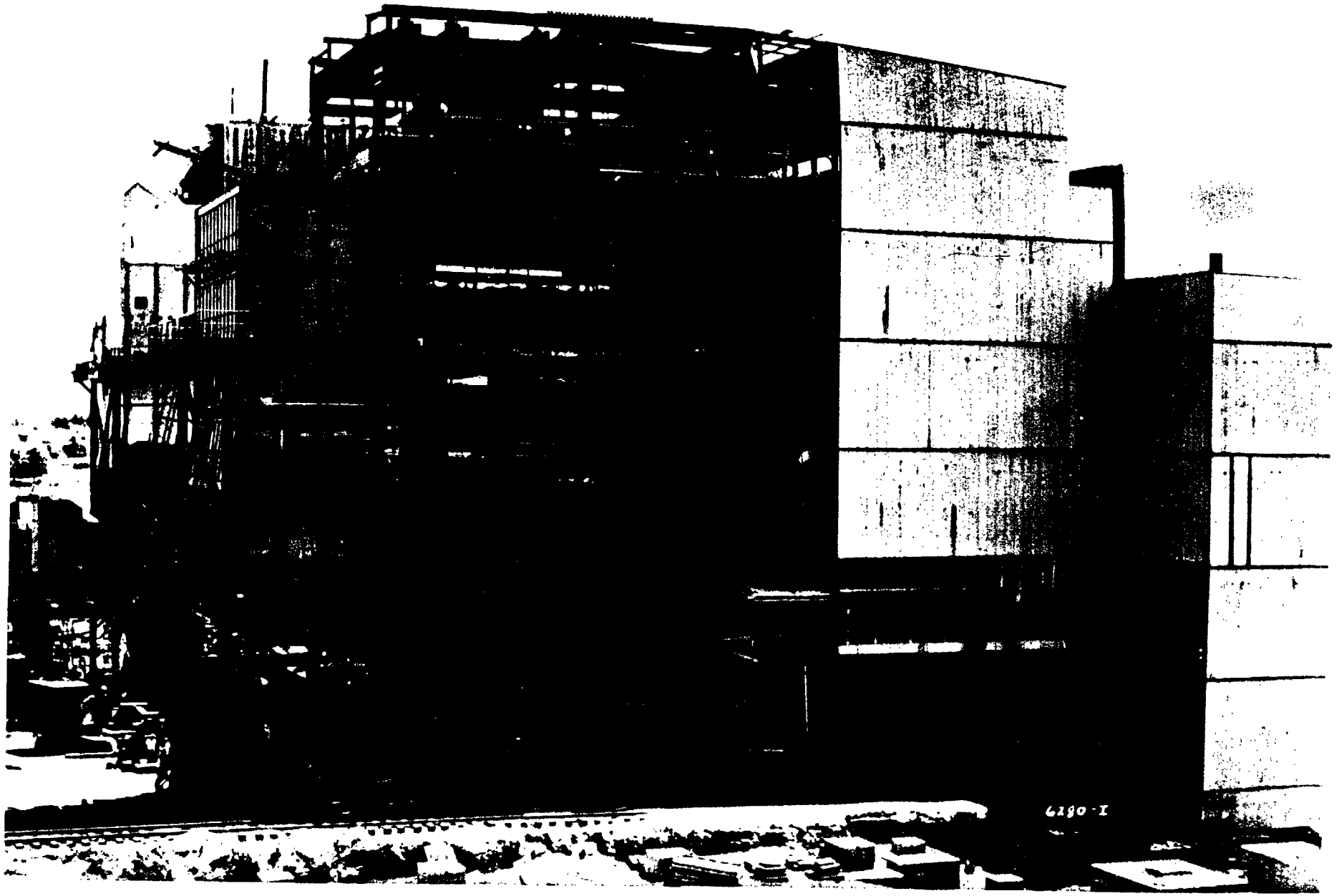
WAD01962

COAL CRUSHER HOUSE AND TRACK HOPPER
UNITS 1-2 PROGRESS PICTURE 143 AUG. 1, 1950

WAD01963

CIRCULATING WATER PUMP CHAMBER AND DISCHARGE TUNNEL
UNITS 1-2 PROGRESS PICTURE 144 AUG. 1, 1950

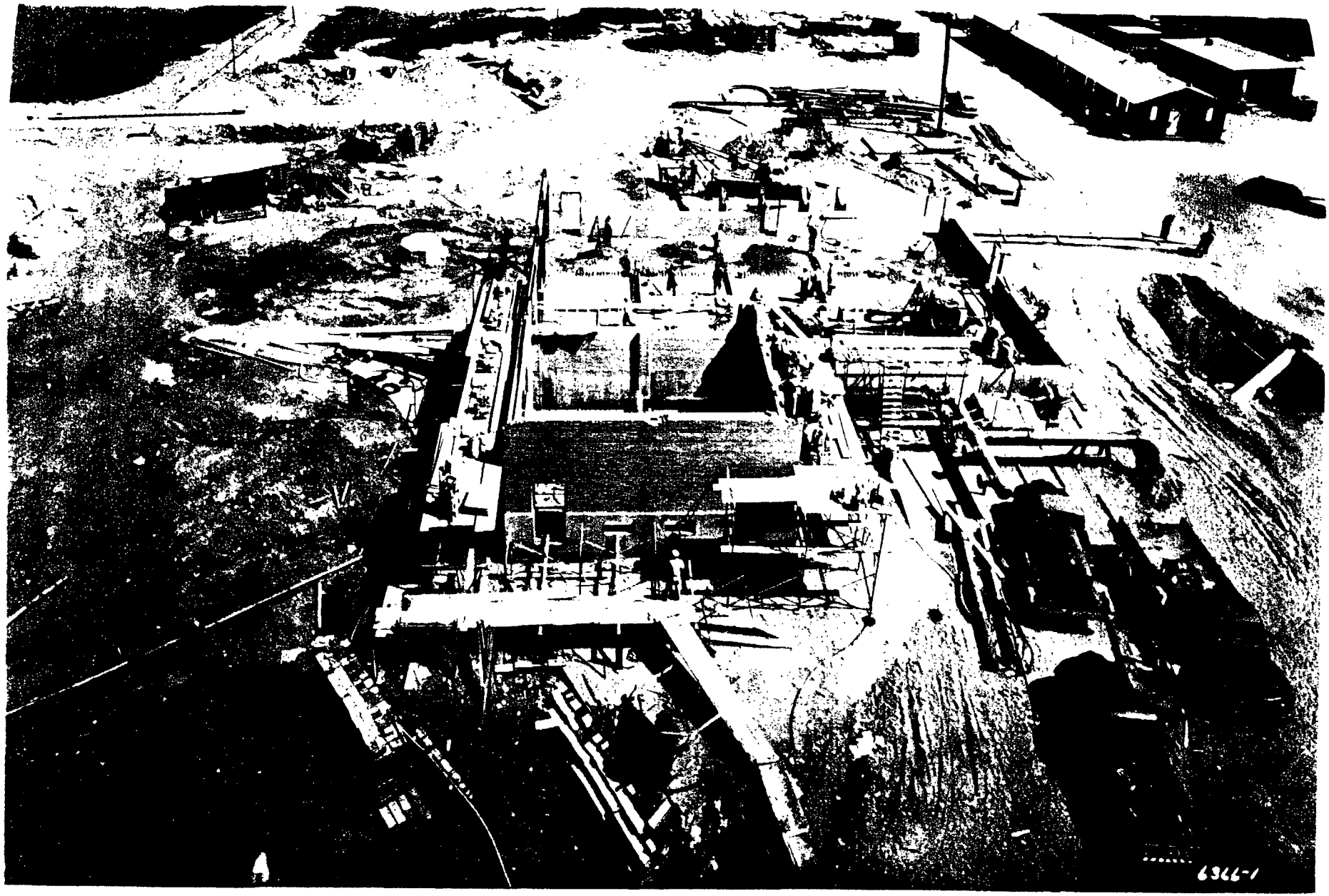
WAD01964



BOILER NO. 2

UNITS 1-2 PROGRESS PICTURE 147 AUG. 1, 1950

WAD01965



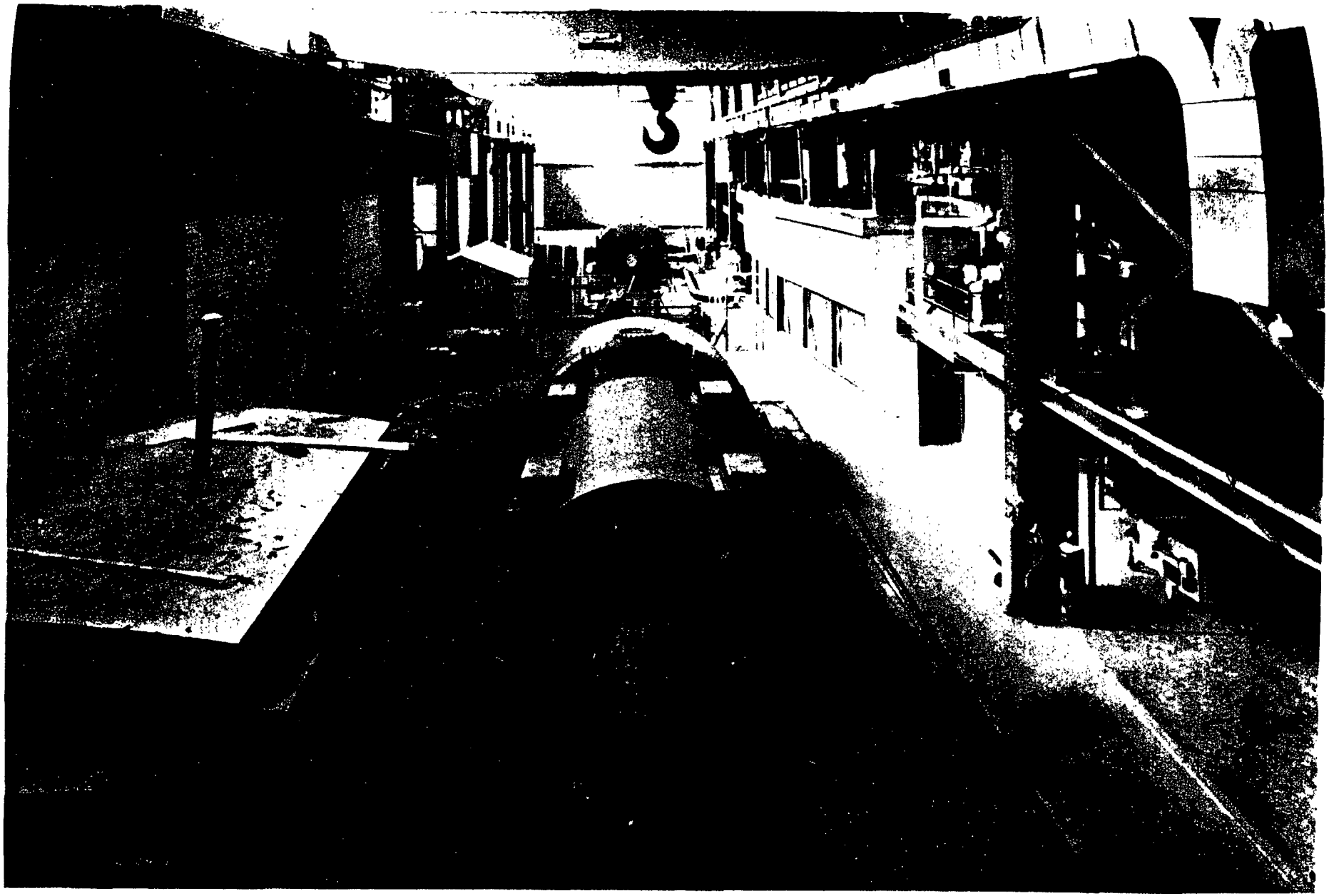
BUILDING FOR CIRCULATING AND SERVICE WATER PUMPS.
WATER TREATING EQUIPMENT AND GAS METERING
UNITS 1-2 PROGRESS PICTURE 154 SEPT. 1, 1950

WAD01966

COAL HANDLING SYSTEM

UNITS 1-2 PROGRESS PICTURE 159 OCT 2, 1950

WAD01967



TURBINE ROOM

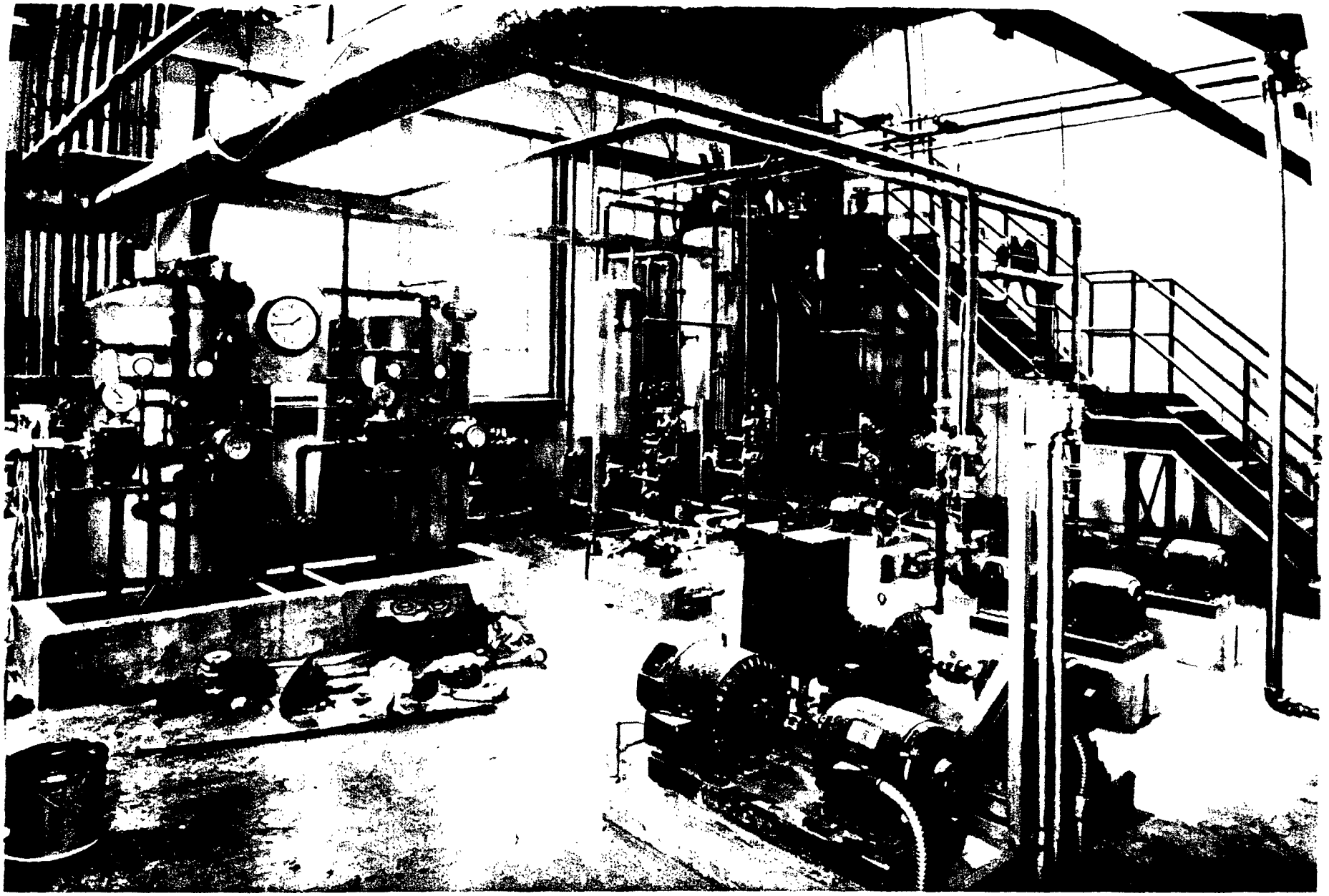
UNITS 1-2 PROGRESS PICTURE 163 NOV. 3, 1950

WAD01968

AERIAL VIEW LOOKING SOUTHEAST

UNITS 1-2 PROGRESS PICTURE 172 DEC. 11, 1950

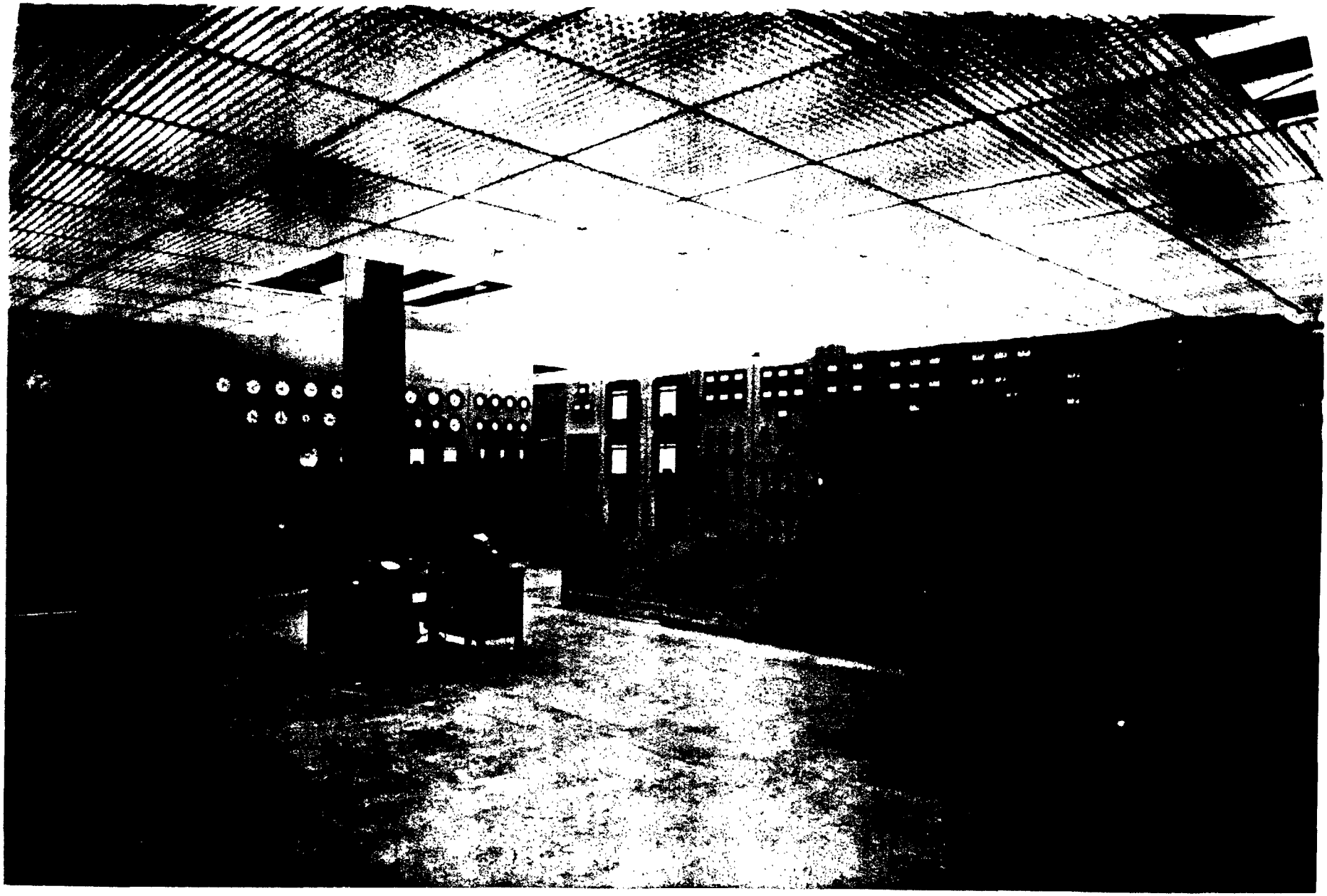
WAD01969



CHEMICAL PUMP ROOM

UNITS 1-2 PROGRESS PICTURE 181 MARCH 3, 1951

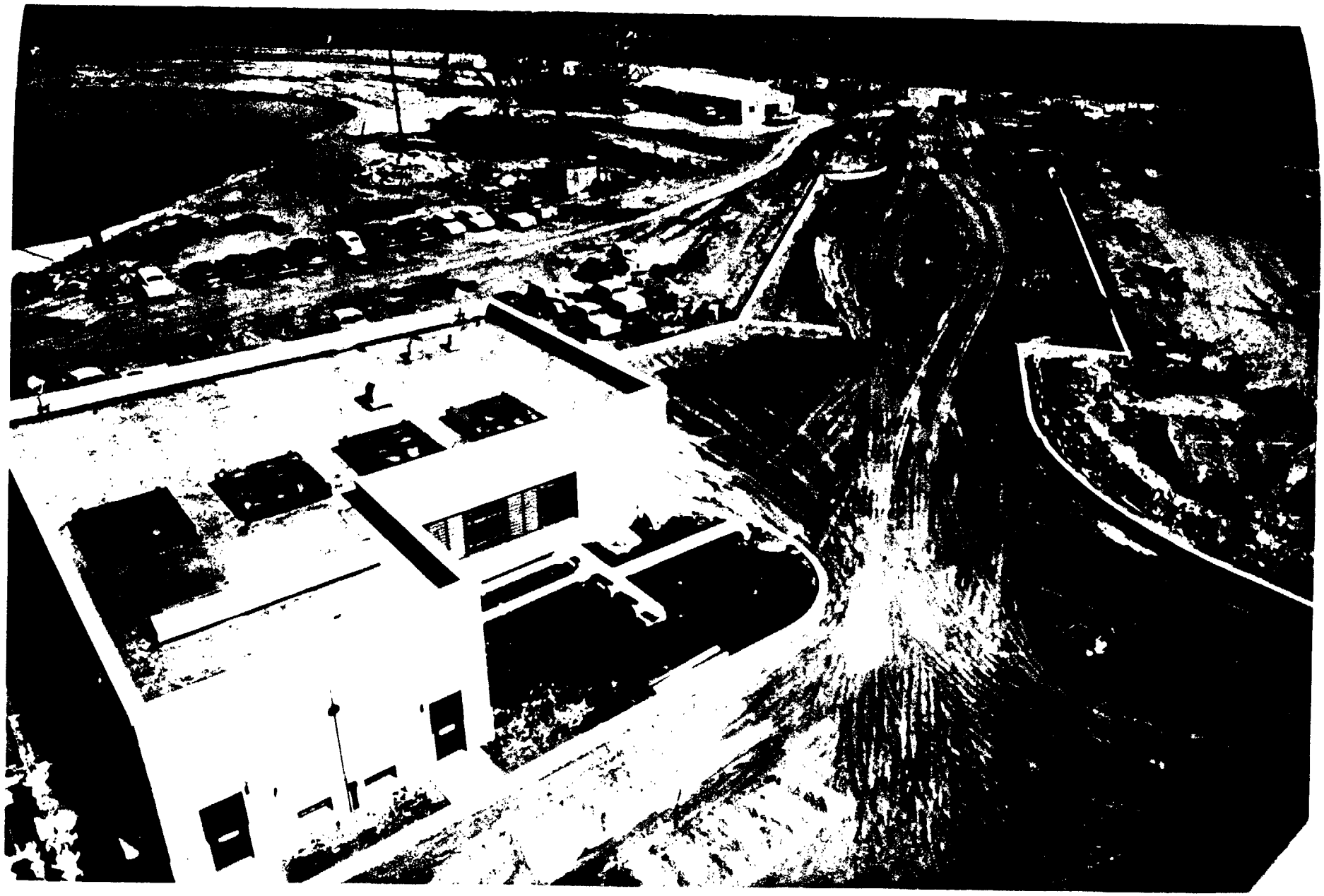
WAD01970



PORTION OF CONTROL ROOM

UNITS 1-2 PROGRESS PICTURE 185 APRIL 2, 1951

WAD01971



MAIN ENTRANCE ROAD

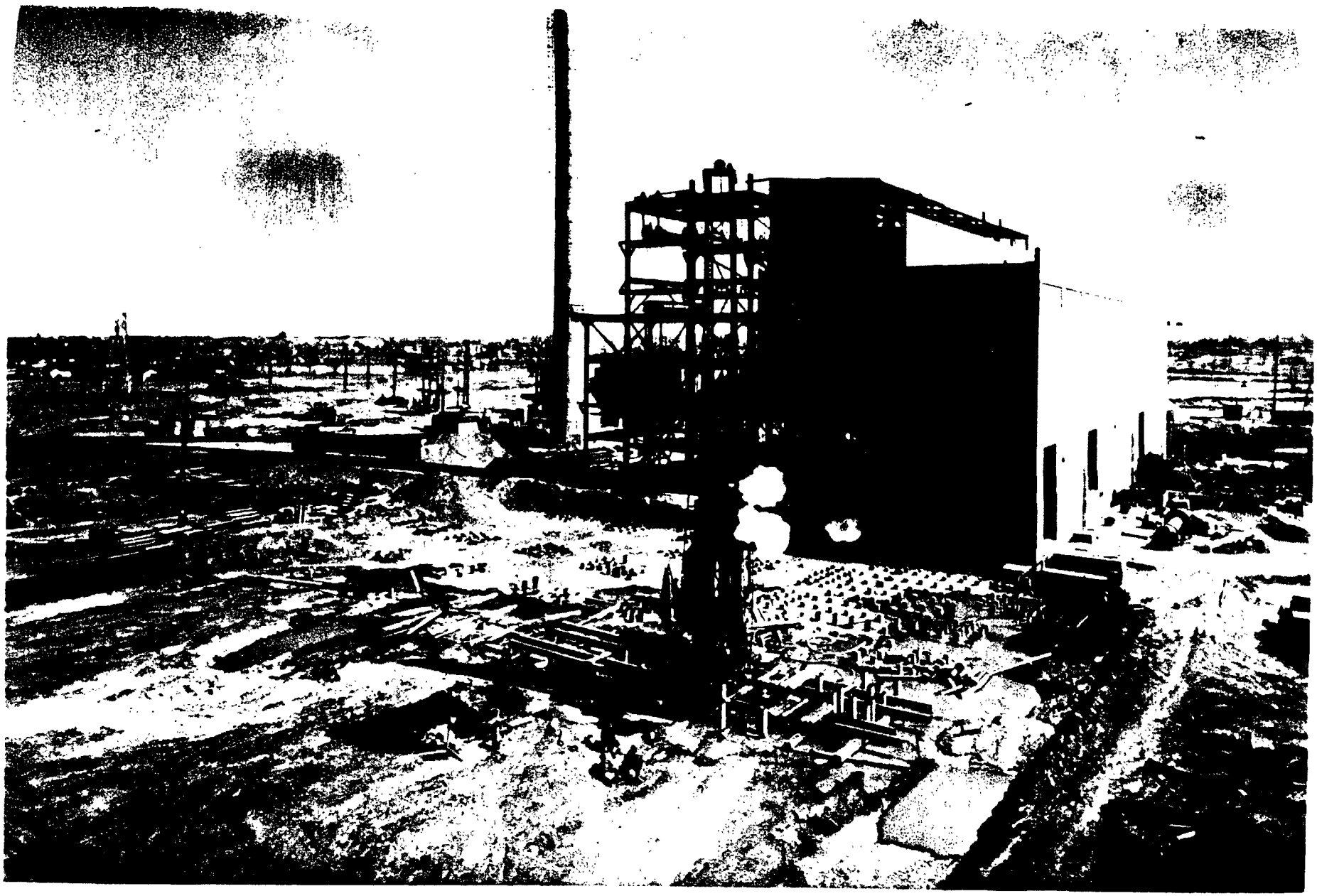
UNITS 1-2 PROGRESS PICTURE 188 MAY 2, 1952

WAD01972

COOLING TOWER CONNECTING FOOT BRIDGE

UNITS 1-2 PROGRESS PICTURE 189 MAY 3, 1952

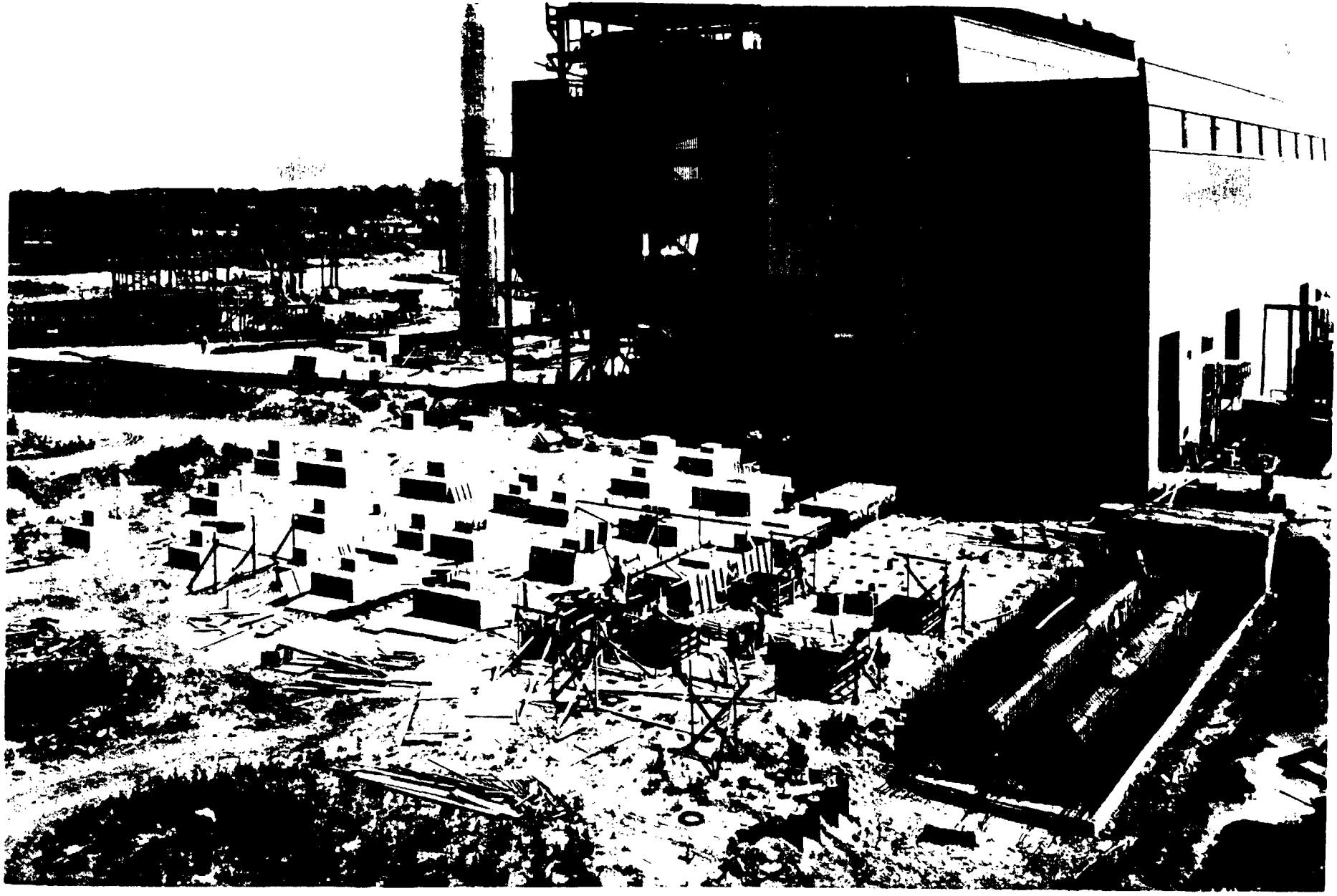
WAD01973



BUILDING AND BOILER FOUNDATION PILES

UNIT 3 PROGRESS PICTURE 2 MARCH 31, 1950

WAD01974



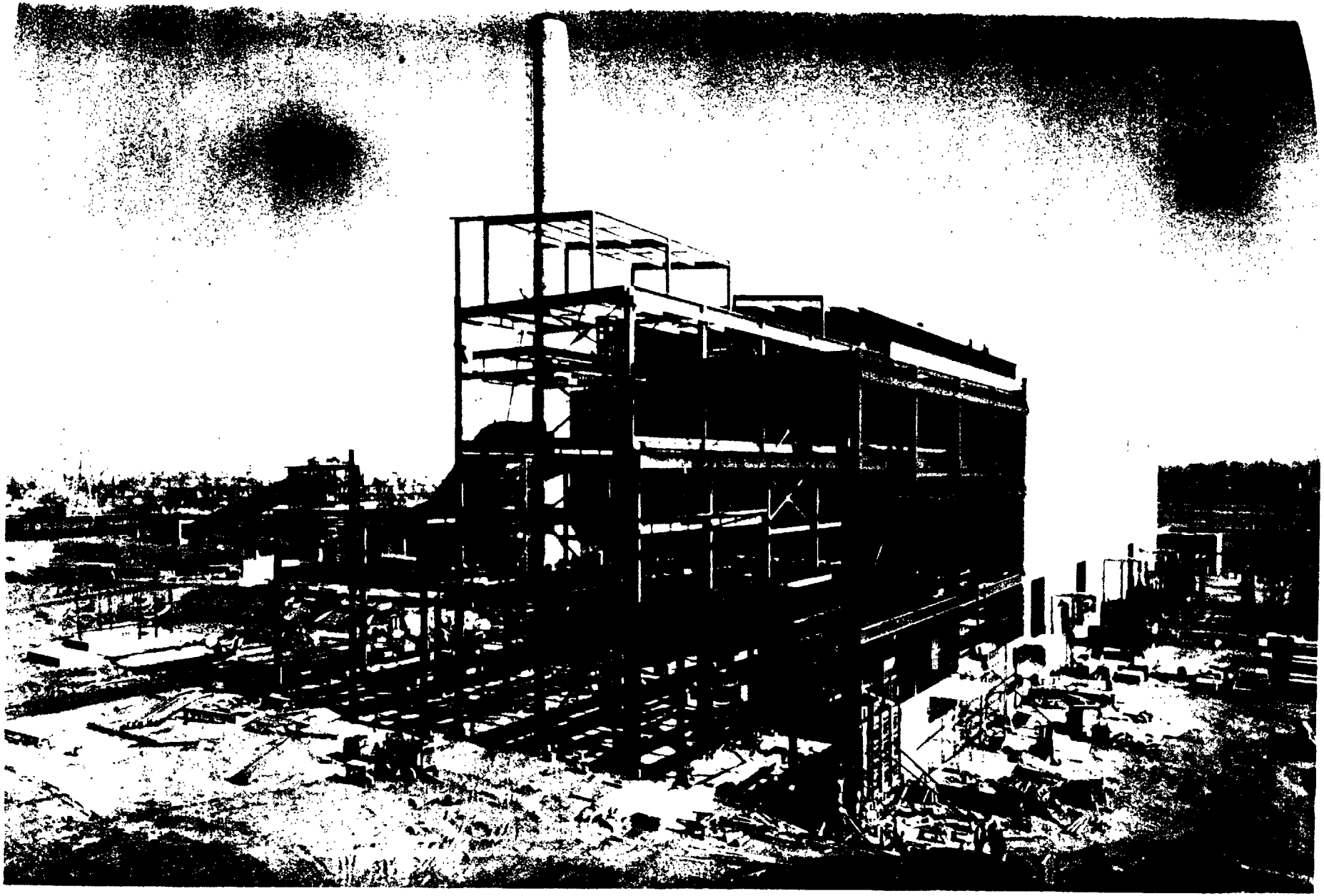
BUILDING AND BOILER FOUNDATIONS ALSO CIRCULATING
WATER TUNNELS
UNIT 3 PROGRESS PICTURE 6 AUG. 1, 1950

WAD01975

CIRCULATING WATER TUNNELS

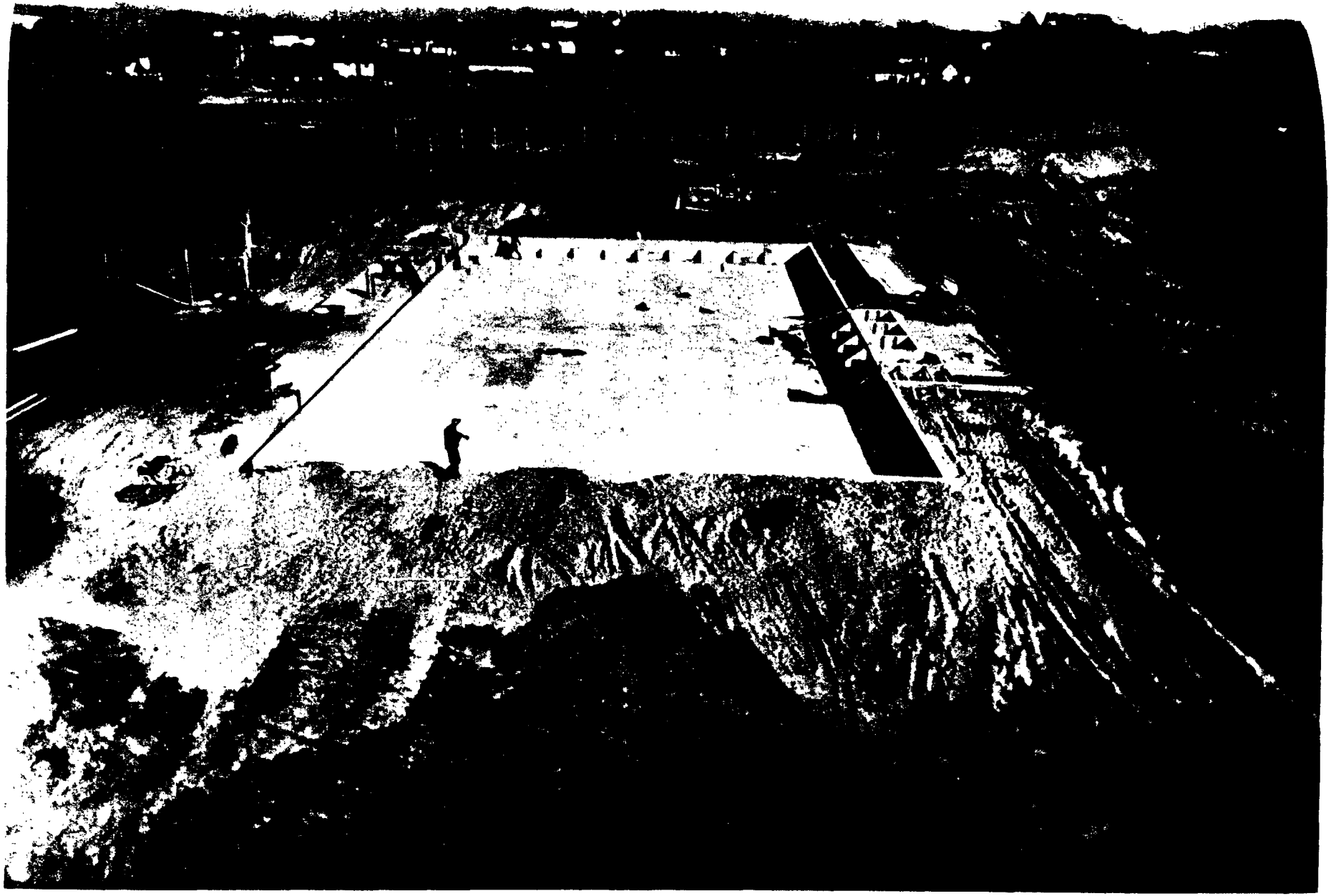
UNIT 3 PROGRESS PICTURE 15 OCT. 2, 1950

WAD01976



BUILDING STRUCTURAL STEEL
UNIT 3 PROGRESS PICTURE 19 NOV. 3, 1952

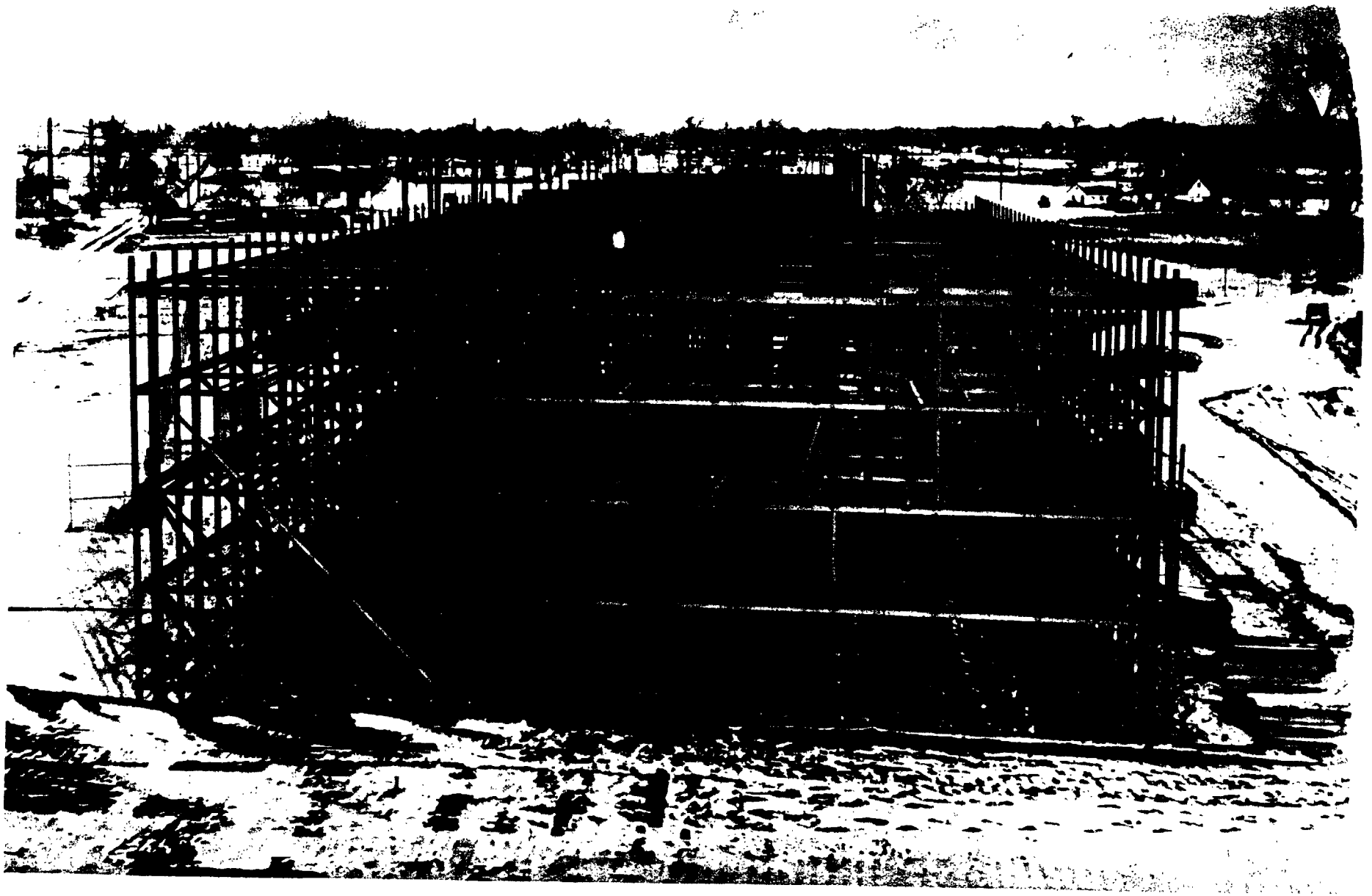
WAD01977



COOLING TOWER BASIN

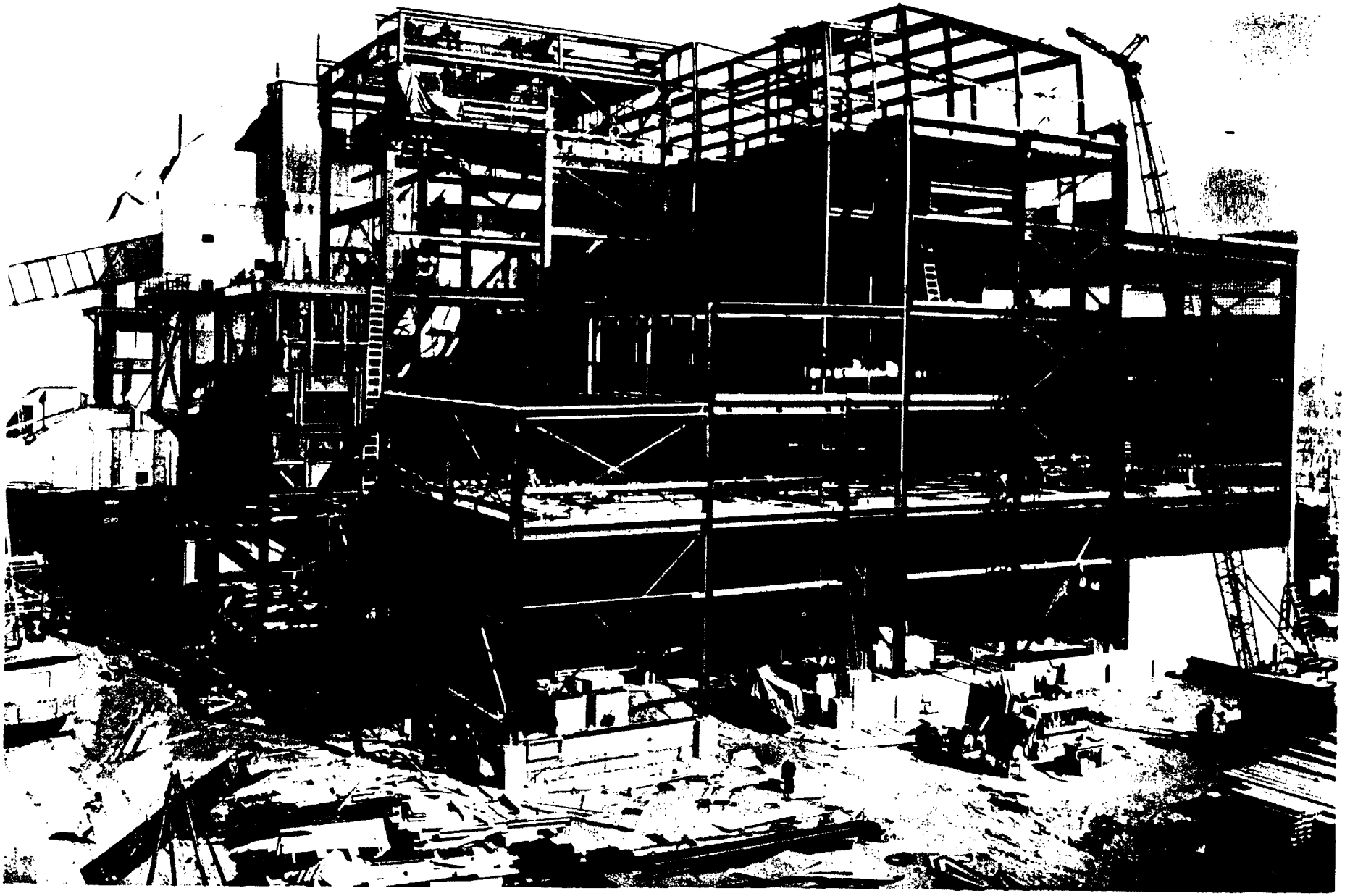
UNIT 3 PROGRESS PICTURE 21 NOV. 3, 1950

WAD01978



COOLING TOWER NO. 3
UNIT 3 PROGRESS PICTURE 29 FEB. 5, 1951

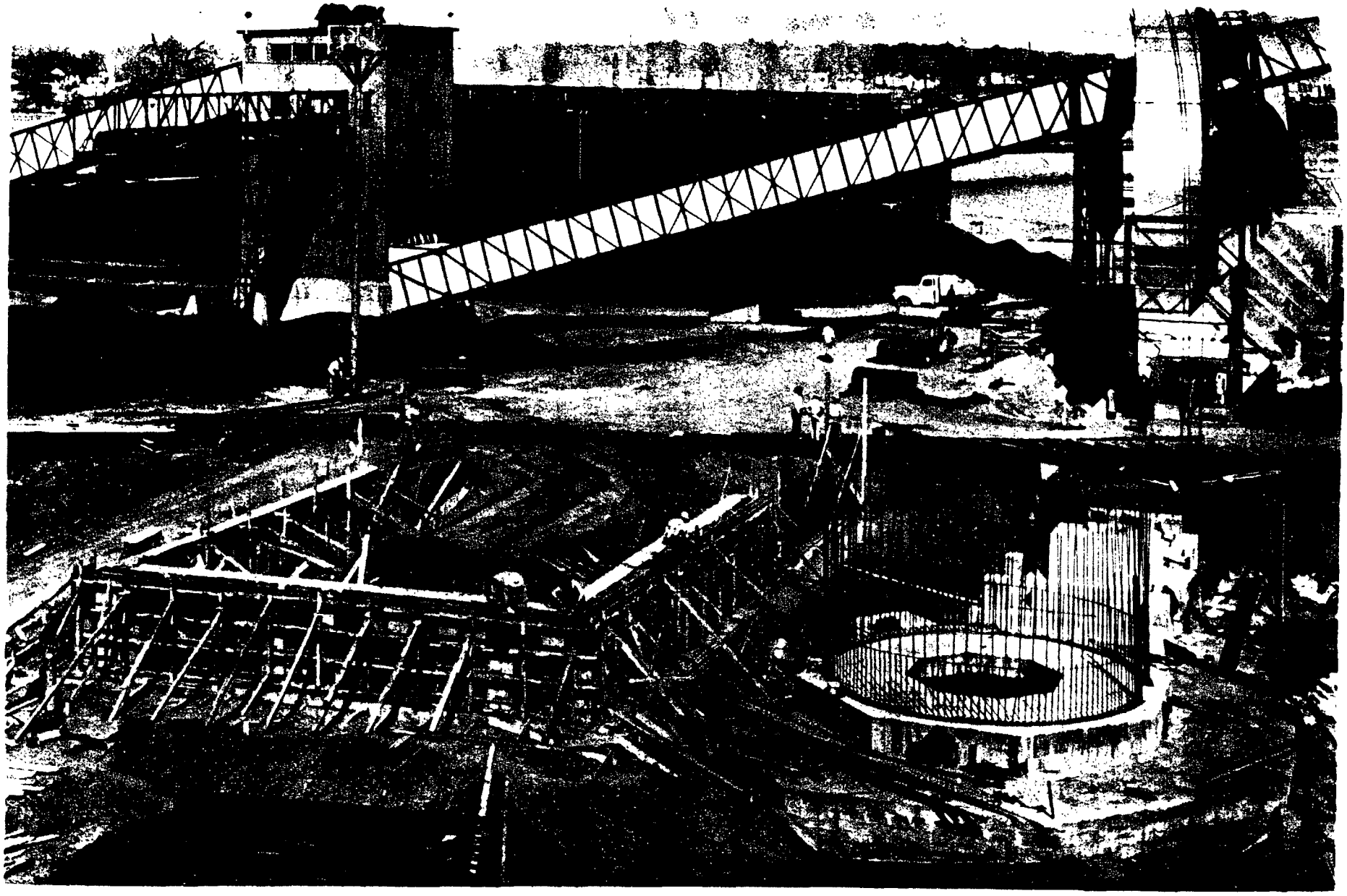
WAD01979



BOILER NO. 3

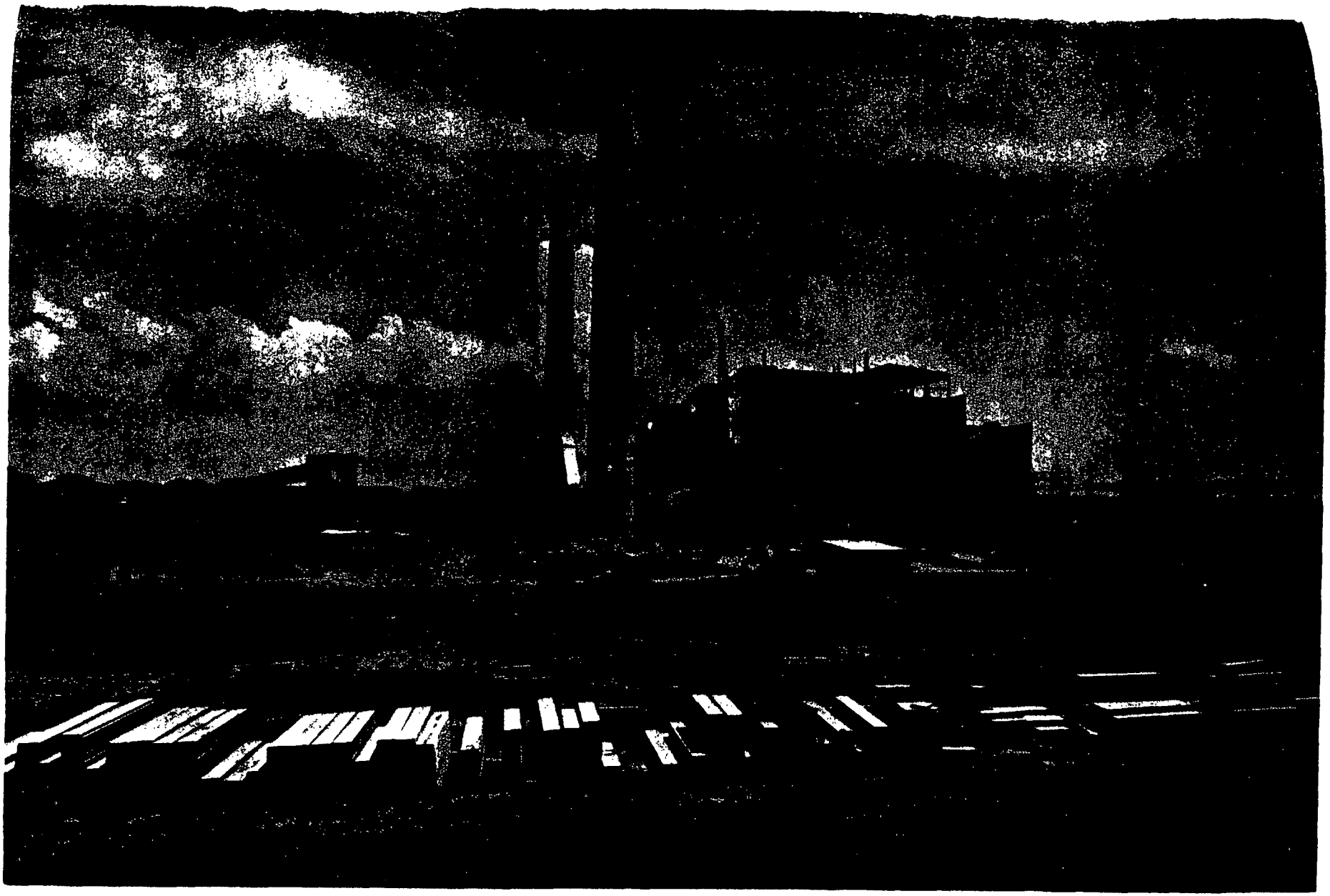
UNIT 3 PROGRESS PICTURE 35 APRIL 2, 1951

WAD01980



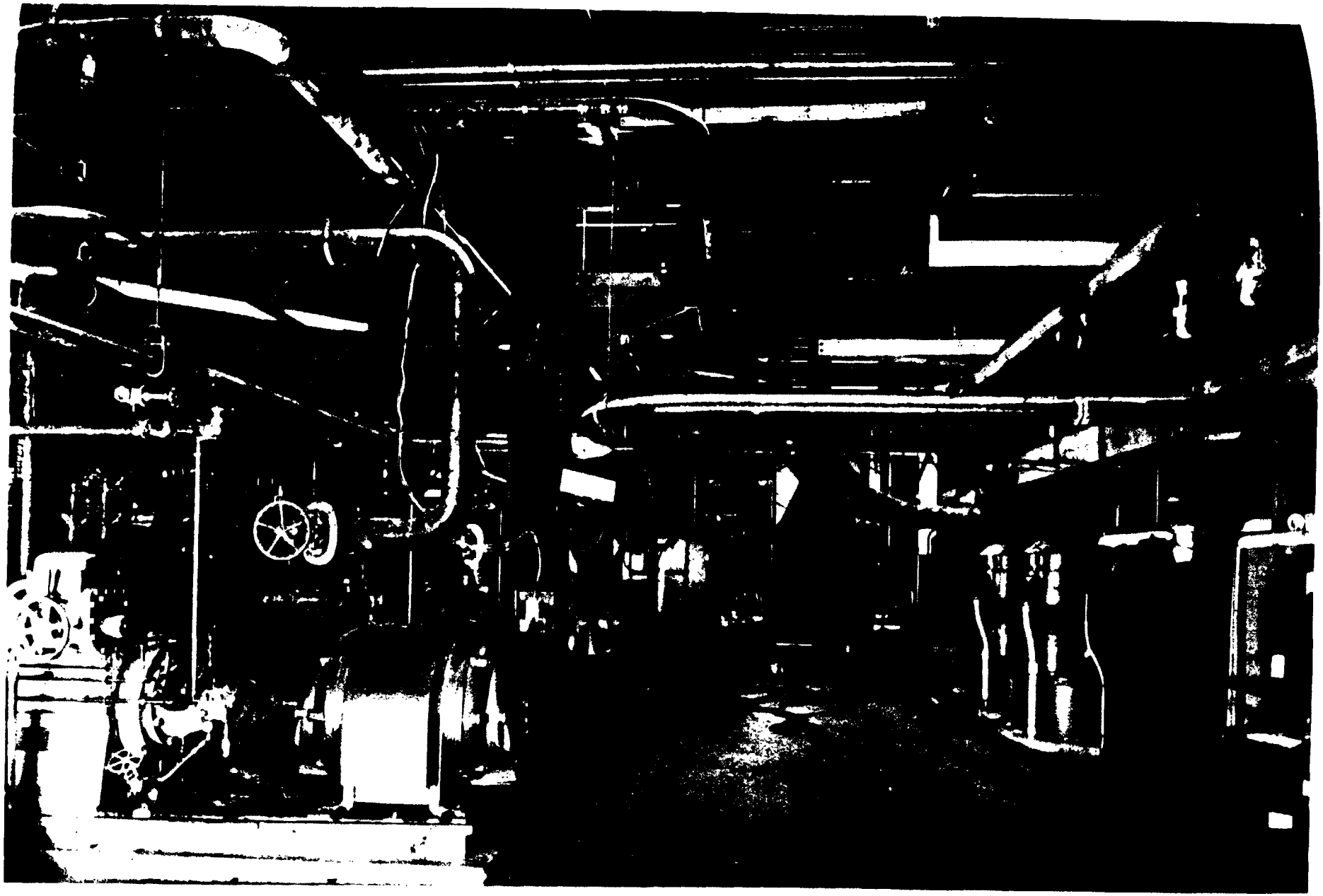
STACK NO. 2 AND WAREHOUSE FOUNDATION
UNIT 3 PROGRESS PICTURE 42 APRIL 27, 1951

WAD01981



GENERAL VIEW LOOKING EAST
UNIT 3 PROGRESS PICTURE 66 JULY 31, 1951

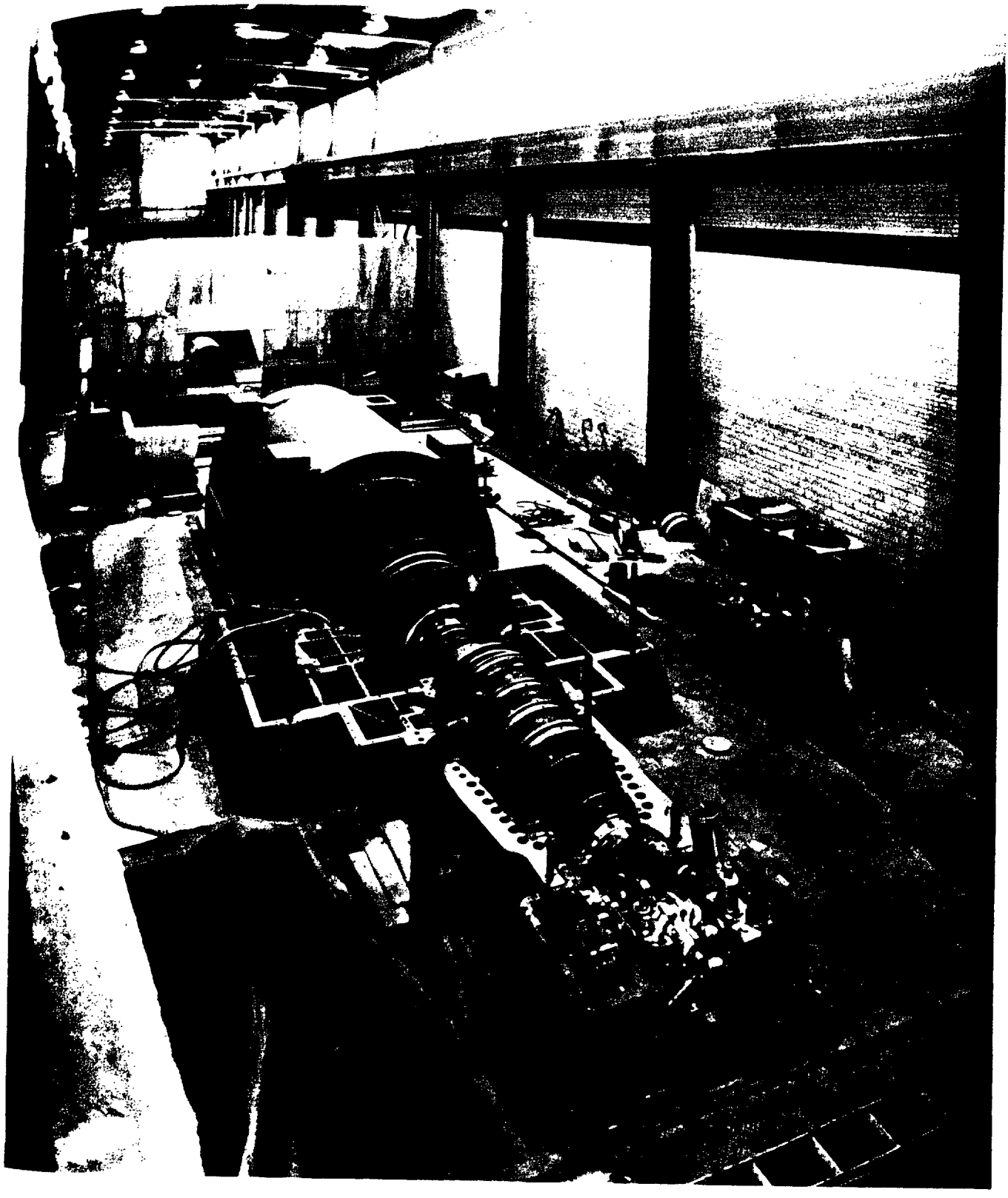
WAD01982



PUMP AREA

UNIT 3 PROGRESS PICTURE 75 SEPTEMBER 1, 1951

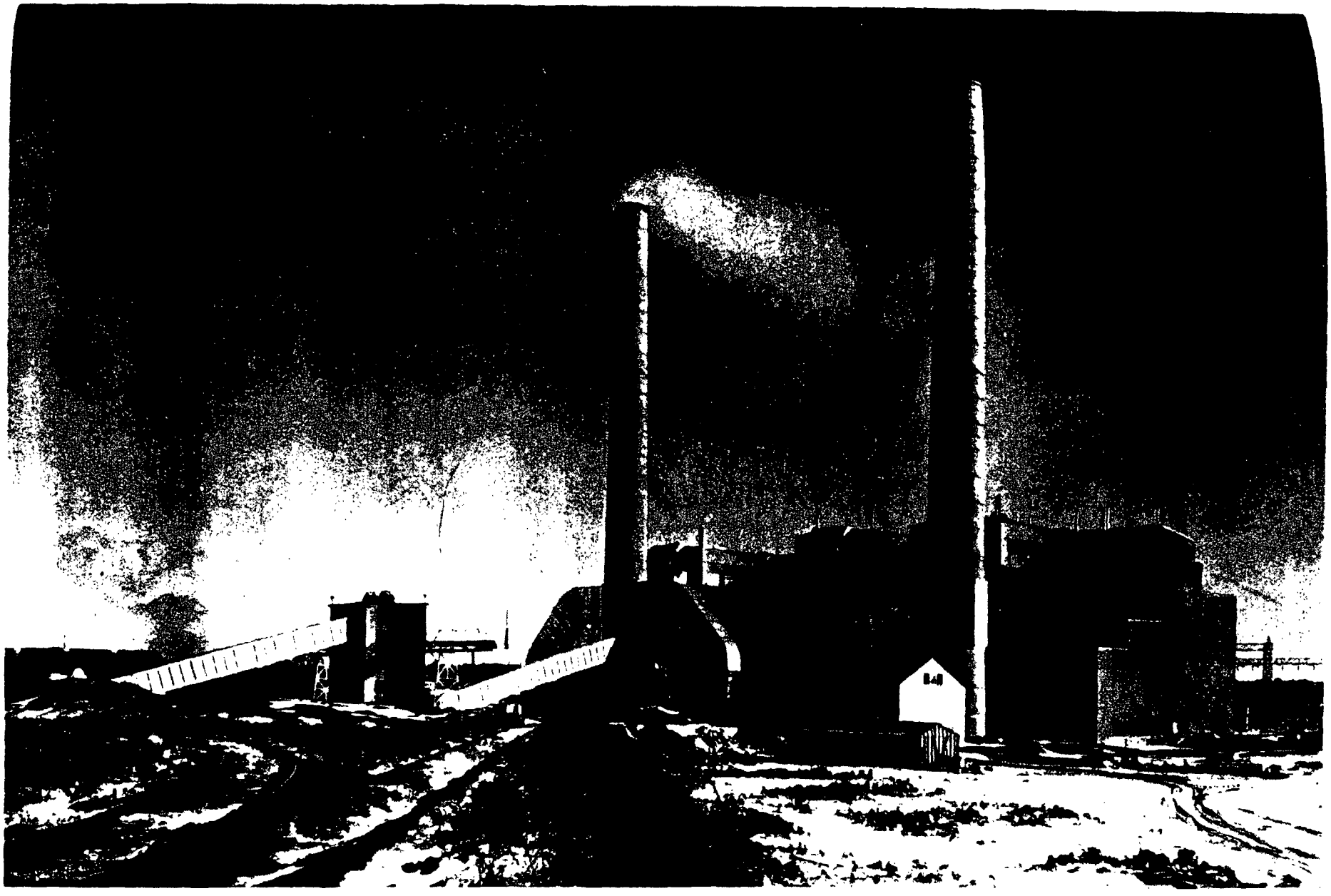
WAD01983



TURBINE GENERATOR

UNIT 3 PROGRESS PICTURE 80 OCTOBER 1, 1951

WAD01984



GENERAL VIEW LOOKING SOUTH-EAST

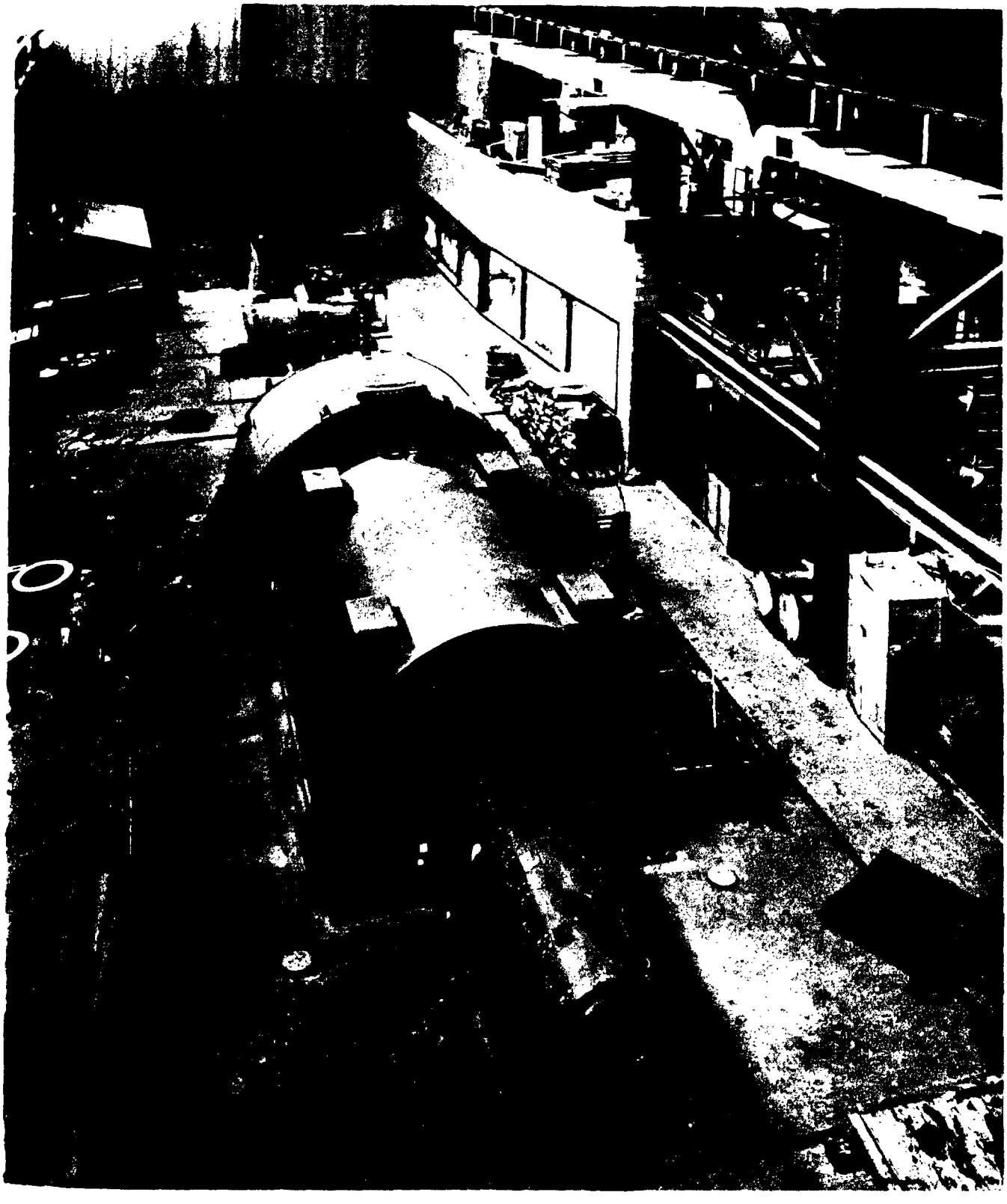
UNIT 3 PROGRESS PICTURE 82 NOVEMBER 2, 1951

WAD01985

DEAERATOR AND HEATER FLOOR

UNIT 3 PROGRESS PICTURE 85 NOVEMBER 2, 1951

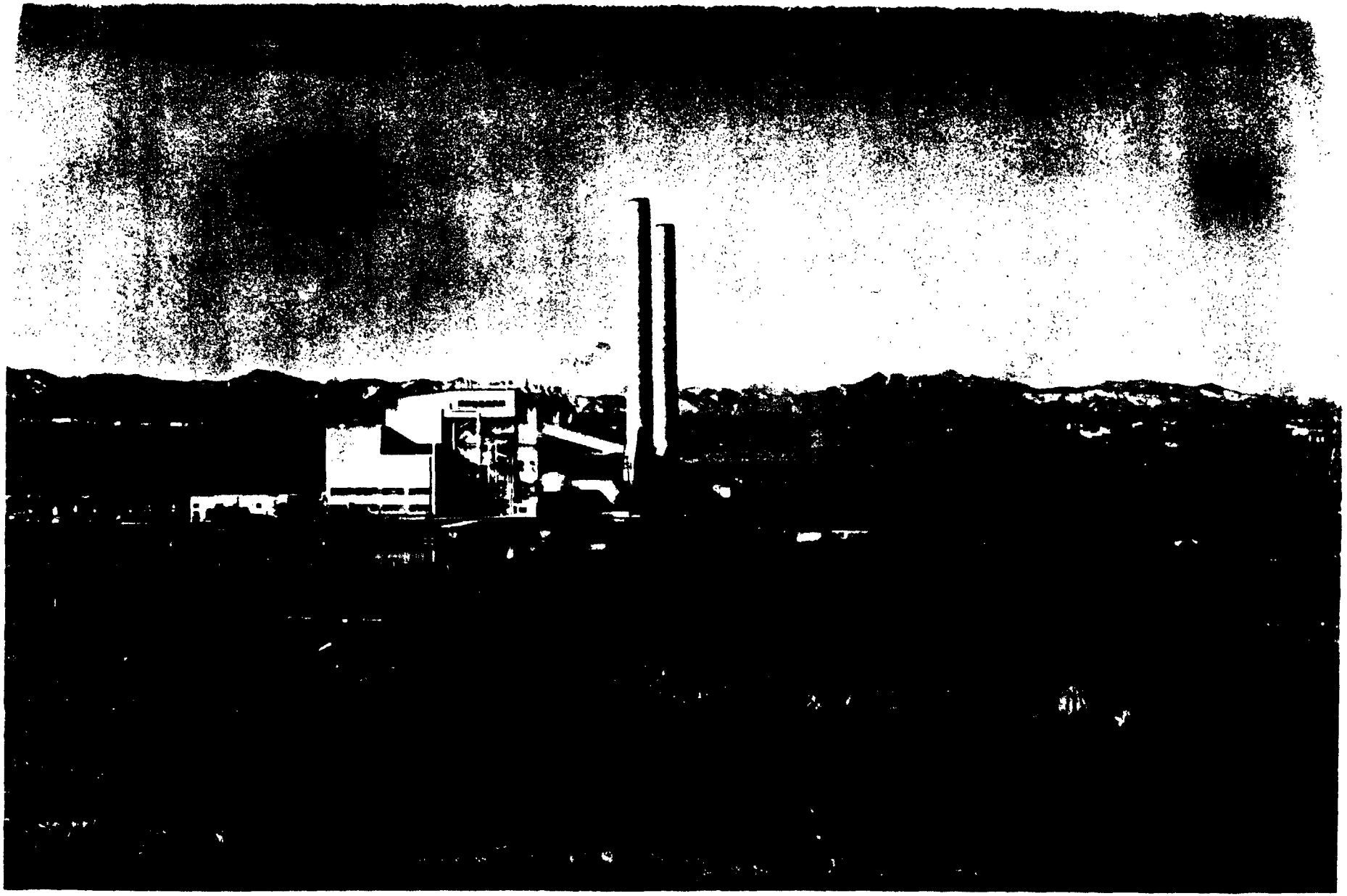
WAD01986



TURBINE GENERATOR

UNIT 3 PROGRESS PICTURE 86 NOVEMBER 2, 1951

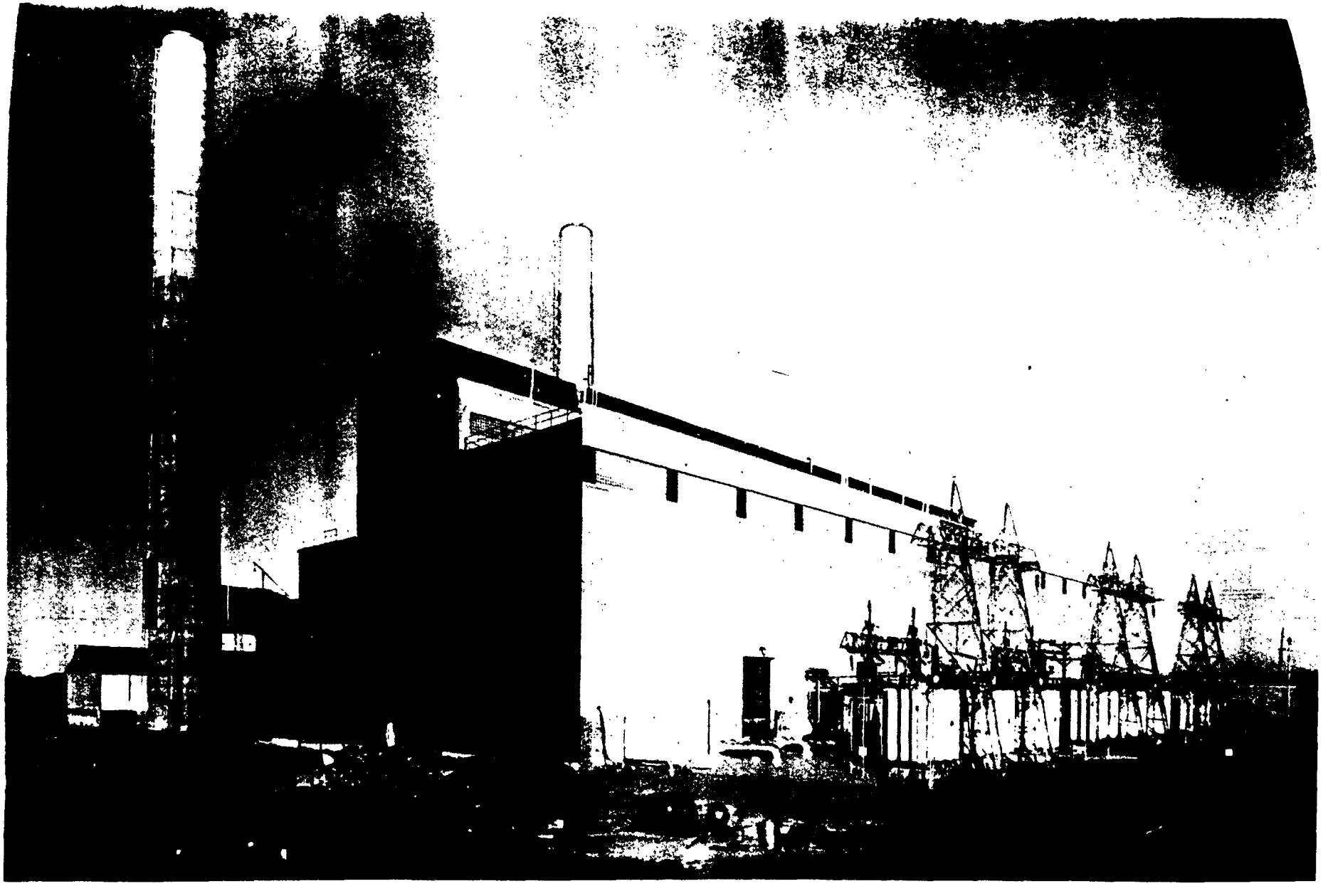
WAD01987



GENERAL VIEW LOOKING WEST

UNIT 3 PROGRESS PICTURE 89 NOVEMBER 3, 1951

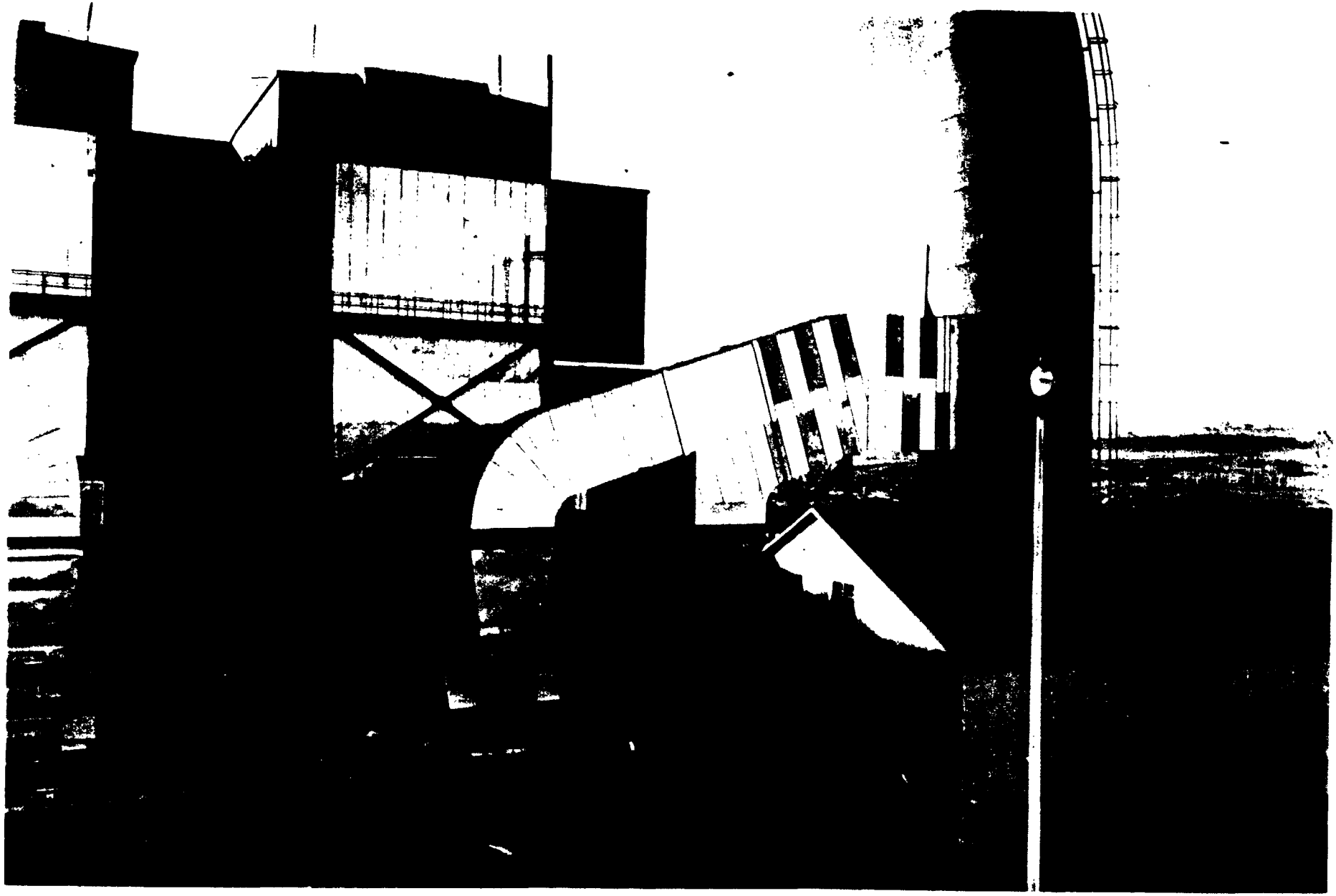
WAD01988



GENERAL VIEW LOOKING NORTH-WEST

UNIT 3 PROGRESS PICTURE 90 NOVEMBER 30, 1951

WAD01989



BOILER AND BREECHING

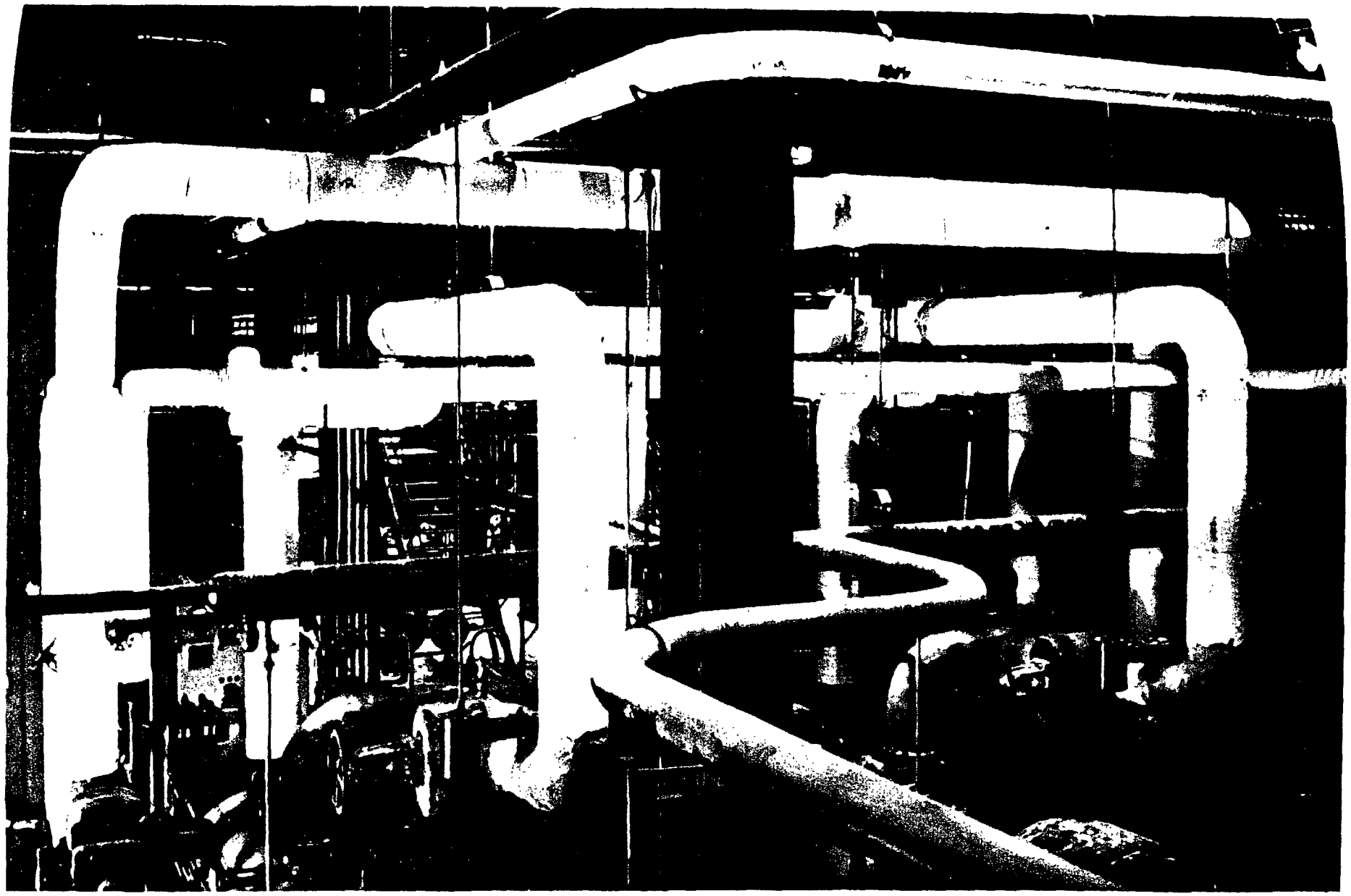
UNIT 3 PROGRESS PICTURE 92 NOVEMBER 30, 1951

WAD01990

CIRCULATING WATER PUMPS

UNIT 3 PROGRESS PICTURE 94 NOVEMBER 10, 1951

WAD01991



BOILER FEEDWATER PIPING

UNIT 3 PROGRESS PICTURE 95 NOV. 10, 1951

WAD01992

COAL PIPING AND FEEDERS AT TURBINE LEVEL
UNIT 3 PROGRESS PICTURE 97 NOVEMBER 30, 1951

WAD01993

TURBINE ROOM

UNIT 3 PROGRESS PICTURE 98 NOVEMBER 30, 1951

WAD01994

WAD01995

SECTION I
PROJECT OUTLINE

SECTION I

PROJECT OUTLINE

PUBLIC SERVICE COMPANY OF COLORADO
ARAPAHOE STEAM ELECTRIC STATION
1950-51 88,000 KW INSTALLATION
1951 44,000 KW EXTENSION

PROJECT OUTLINE

SECTION I - GENERAL

Since the start of World War II the Rocky Mountain Area has grown rapidly in population and industrial capacity. Colorado and especially Denver, largest population center of the area, are the leading examples of this trend. Early in 1947, Public Service Company of Colorado, serving Colorado and Denver, decided to expand its facilities with a new steam-electric station.

A site on South Platte River, on the southern Denver city limits, has area for future expansion, adequate coal storage, makeup to supply cooling towers. River flow is not large enough to support a once-through cooling system for Arapahoe Station. Though present design contemplates maximum capacity of 200,000 kw, the site can accommodate about 300,000 kw.

Early in 1948 design work started on two 40,000-kw preferred-standard units to be served by single boilers with no cross-connection. Initial steam conditions of 850 psig and 900 F were chosen using high-moisture sub-bituminous coal as fuel with low-cost natural gas as a supplementary fuel when available. The third 40,000 kw preferred-standard unit was authorized in 1949 for completion in 1951.

SECTION II - SITE DEVELOPMENT

The plant site extends along the South Platte River at the southern city limits of Denver. South Platte River Drive paralleling the river bank forms two sides of the property. The west side is bounded by a branch of the Colorado and Southern Railroad which serves the Plant area. The north end of the property connects to subdivided land in which full city blocks are used for truck gardening at the present time.

Included in the area is a kidney shaped pond formed by gravel excavation at sometime past. A second gravel pit was filled in and graded for coal storage. The pond is kept at level by inflow of ground water which usually follows river level.

The main plant is situated about 400 feet north of South Platte River Drive and faces south. Immediately in front of the plant is the switchyard and immediately behind the plant is the coal storage area. The cooling towers are located along the edge of the gravel pit running generally in north-south direction.

Coal dead storage tracks are located to the west of the building paralleling C&S tracks. Live coal tracks and unloading hoppers are to the north of the main building.

WAD01998

See Plot Plan F-86800 for complete site layout.

SECTION III - STATION LAYOUT

Station layout features compactness and economy. Outdoor-type steam generators have only upper area around drum and burners and lower area around ash hoppers housed. Building has brick front on south and east walls for architectural appearance, insulated steel panels for other walls. Placing all heavy rotating equipment, like boiler feed pumps, mills, draft fans on the ground level, held down structural-steel costs. Eliminating a sub-basement reduced excavation and foundation costs.

Location of the central control room for first two units minimizes length of conduit and control-piping runs to boilers and turbines. Each pair of units will have individual control rooms, but for the present the generator controls for unit 3 are housed in control room 1-2. Only the two bunker bays separate the boilers from the turbines. Deaerators, heaters and evaporators for two units stand above the control rooms. This eliminates the usual auxiliary bay. A 100-ton turbine-room crane can handle larger future unit parts.

The turbine generators are located lengthwise with steam ends of each pair facing. The height of the turbine pedestal was held to 25 ft, a minimum for maintaining condenser hotwells above basement floor level to avoid a condenser pit.

The steam generators are separated by three 24 feet bays in which are located the condensate storage tanks, chemical feeding equipment, air compressors and machine shop on the ground floor and the switchgear room on the operating floor.

The office and service area is contained on two floors at the east or permanent end of the building. Facilities include a main lobby and reception desk, chiefs office, assistant chiefs office, conference room and first aid room on the ground floor, with laboratory, results office and locker room with showers etc. on the second floor.

For complete detail arrangement see general arrangement drawings F-100234, F-100235, and F-100236.

SECTION IV - ARCHITECTURAL AND STRUCTURAL FEATURES

Building columns, boiler columns, stack and turbine pedestal are supported by concrete pile clusters driven to an average depth of 30 feet.

Architectural treatment of the plant is largely an expression of volume requirements of major mechanical and electrical equipment. The natural surroundings were considered in selection of sand colored brick for the turbine room and office building at permanent end. The remainder of the plant utilizes steel insulated panel for low cost and ruggedness.

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The turbine room interior is treated as a continuous room for the three units. This will be continued for future units. The auxiliary area is open to the turbine room as are the bunker shells. The coal handling equipment above the bunkers is completely enclosed by steel panel partitions to keep the dust nuisance to a minimum.

The control rooms are enclosed by tile walls and glass. Windows are provvided for view of the turbine room and boiler fronts. Egg crate lighting is included for the control rooms as well as asphalt tile flooring. Since the heaters and evaporators are located immediately above the control rooms a membrane waterproofing covers the ceiling slabs and no piping, ducting or conduit is allowed to pass through these areas.

the switchgear room is enclosed by tile and steel paneling. No separate battery room is provided for station d-c supply and the batteries are located in an open area of the switchgear room.

The steam generators are mostly outdoors. Enclosure is provided at the ground level for the ash handling equipment and at the firing aisle and drum level for operating convenience. These enclosures are constructed of insulated steel panel.

Roof construction features precast concrete slab covered by bonded roofing. This type of construction is substantially cheaper than poured-in-place slab.

Concrete flooring is finished with grey hardener for appearance and durability.

Structurally of interest is the bunker construction. Bunkers are arranged in groups of four and are of the unreinforced steel silo type. This type was chosen because it offered less expensive construction and better coal flowing characteristics with less chance of coal hanging in the bunker.

SECTION V - STEAM GENERATING UNITS

Each unit is equipped with one Babcock & Wilcox Special Stirling type 3-drum steam generator capable of producing continuously 450,000 lb per hour of 905 F, 925 psig steam or 475,000 lb per hour for a four hour peak period. Steam generators are fired vertically through roof tubes with Colorado pulverized sub-bituminous coal or natural gas or the two in combination.

Burners

Eight burners are arranged across the top of the furnace near the front water wall. Coal and gas burners are of the intertube type. Automatic gas lighting is provided.

Furnace

Particular attention was given to furnace design to obtain the features

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required for burning the low grades of coal available. Furnace is completely water cooled and contains 7,794 sq ft of surface. Furnace volume is 491,900 cu ft and heat release is held to 13,500 Btu/cu ft.

Superheater

The superheater consists of 19,800 sq ft of surface and is of the pendant and horizontal continuous tube type. Steam temperature control is by two attemperators located in the bottom drum. Bailey Meter control equipment is used and maintains 905 F at superheater outlet within plus or minus 10 F with a control range from 285,000 lb/hr to 450,000 lb/hr.

Drums

The boiler is equipped with three drums, uptake steam - 36", downtake steam - 60" and mud drum - 54". All drums and boiler parts are designed for a pressure of 1050 psig. The downtake steam drum includes washers, separators and scrubbers. Feedwater is introduced directly into the downtake drum as no economizer is included.

Air Heaters

The air preheaters are of the tubular type with five air passes. The tubes are divided into two sections, 5465-2" - 14 Bwg at the hot end and 1813-3-1/4" - 11 Bwg at the cold end. The short heavy tubes at the cold end offer better corrosion resistance and are more easily replaceable. The total heating surface of the air heater is 118,370 sq ft. A recirculation duct is provided from the hot end to the forced draft fan inlets to raise incoming air temperature as a deterrent to condensation and subsequent corrosion.

Dust Collectors

Each boiler is equipped with an Aerotec mechanical dust collector between the Air Heater and Induced Draft Fans. Space has been provided for a future electrostatic collector if the surrounding area develops to a point where further consideration of the dust problem is necessary.

Draft Fans

Each boiler is equipped with two forced draft fans rated at 100,000 cfm at 13.8 in wa each driven by a 300 hp, 1200 rpm motor and two induced draft fans rated at 173,500 cfm at 12.8 in wa each driven by a 700 hp, 800 rpm motor. All fans are constant speed motor driven with inlet vane and outlet damper control. All fans are equipped with sleeve type bearings. Fans are manufactured by B F Sturtevent Co.

Soot Blowers

The Diamond soot blowing system is air blowing and air powered. A Complete automatic sequential air control system is provided. Each boiler is equipped with 18 rotary blowers, 4 long retractable blowers and 2 straight line air heater cleaners. Air supply for all boilers is provided by three

Worthington two stage air compressors each rated for 504 cfm at 5280 ft altitude. A 750 cu ft primary 500 psig receiver and a 100 cu ft secondary 365 psig receiver are used in conjunction with the system.

SECTION VI - ASH AND DUST HANDLING

The ash and dust handling systems are provided by the United Conveyor Corporation.

The wet bottom ash system will convey at a rate of 50 tons per hour and the dry dust system at 15 tons per hour.

The ash hoppers are of the flooded type sealed at the lower water wall headers by water troughs. A continuous overflow from the seals to the hopper maintains low lining temperature above hopper water levels prolonging lining life. Ash is discharged through one gate at the end of each hopper. This gate is hydraulically operated by a three way valve immediately adjacent to a sight window in the hopper front. The ash then discharges through a 3 hp crusher to a Jetpulsion Pump. The Jetpulsion Pump is a water jet device fed by 125 psig water from two 1,000 gpm vertical ash water pumps located in the gravel pit pond. These pumps also feed the jetting nozzles in the ash hoppers as well as the fly ash system. The Jetpulsion Pump discharges ash and water to the gravel pit through an 8" cast iron pipe line.

The gravel pit is divided into two parts by an earth causeway. The north side receives ash from the plant and the south side provides sluicing water to the plant. The pit should provide ash storage for many years. When it does fill up ash can be clam shelled into rail cars for transportation to remote disposal. All three boilers discharge into a common line to the gravel pit.

The fly ash system is of the dry type. Vacuum is created by two water jet Hydroveyors discharging their mixture of water air and ash to air separators located on the east side of Boilers No. 1 & 3. One hydroveyor serves boilers 1 & 2 and the second serves boiler 3 and future 4. The air separators discharge by gravity into the main 8" ash line to the gravel pit.

Each boiler has four rear pass hoppers, four air heater hoppers and four dust collector hoppers. The dust collector hoppers are equipped with automatic air operated dust intake gates actuated from a sequential control system. The control system is incorporated in ash control panels located on the ground floor between boiler 1 and 2 and between boiler 3 and future 4. These panels also mount the control switches for the ash water pumps as well as vacuum recorders for each Hydroveyor.

One 250 ft by 11 ft ID concrete brick lined self supporting stack is provided for Boilers 1 and 2. Boiler 3 and future 4 are provided with a 250 ft by 14 ft ID stack of the same construction. Each stack is equipped with a dust hopper and intake connected to the boiler collection system.

SECTION VII - PULVERIZERS

Coal for Boilers 1 and 3 is pulverized in two sets of four Babcock and Wilcox Ball Mills each equipped with a separately driven primary air fan. Each mill is driven by a 100 hp motor and each primary air fan by a 125 hp motor.

Each mill is designed for a capacity of 16,800 lb per hour when delivering a product of which 72 per cent will pass through a 200 mesh screen, 89 per cent through a 100 mesh screen and 98 per cent through a 50 mesh screen. Under the above conditions power input to mill and primary air fan will not exceed 17.4 kw per ton pulverized.

Control of the mill is accomplished by an air damper between primary air fan and pulverizer actuated by a Bailey drive from the combustion control system. The table type feeders mounted on the operating floor are controlled by two speed positions and by a gate on the table. The gate is actuated by a Bailey Drive.

Boiler 2 is equipped with four Combustion Engineering Raymond Bowl type pulverizers and exhausters. Mill and exhauster are driven by a 250 hp motor.

Each bowl mill is designed for 20,700 lb per hour when delivering a product of which 70% will pass through a 200 mesh screen and 98% through a 50 mesh screen. Under these conditions total power to mill and exhauster will not exceed 17.2 kw per ton.

The mill is controlled by a damper in the exhauster discharge from the combustion control system. The star type feeders are equipped with Reeves Variable Speed Drives for feed control by a Bailey Drive. Feeders are located in the operating floor.

Mill temperatures for all mills are controlled manually by tempering dampers located at the rear of each boiler. These dampers admit cold air directly from the F D fan discharge into the main stream of primary air going to the mills from air heater outlet.

A pyrites disposal system is provided for each set of four mills. This system is of the dry type with vacuum created by hydraulic exhauster nozzles discharging into the respective boiler hoppers. All piping from the mills is run in trenches covered with checker plate.

SECTION VIII - TURBINE GENERATOR UNITS

The Turbine-Generators for Units 1 and 3 are General Electric 40,000/44,000 kw preferred standard, 3600 rpm, 20 stage tandem compound units designed for throttle steam conditions of 850 psig and 900 F and for an exhaust pressure of 1-1/2 in. mercury absolute. Turbines are designed for five stage feedwater bleed heating. The generators are hydrogen cooled rated at 47,058 kva with .5 lb hydrogen at 0.85 power factor and 13,800 volts 60 cycle with a 0.8 short circuit ratio. Generator maximum capacity at 15 psig hydrogen is 54,117 kva.

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Number 2 unit is a Westinghouse 40,000/44,000 kw preferred-standard, 3600 rpm, 33 stage tandem compound unit designed for throttle steam conditions of 850 psig and 900 F and for an exhaust pressure of 1-1/2 in. mercury. Turbine is provided for 5 bleed feedwater heating. The generator is hydrogen cooled rated at 47,058 kva with .5 lb hydrogen at .85 power factor and 13,800 volts, 60 cycle with a 0.8 short circuit ratio. Maximum generator capacity with 15 lb hydrogen pressure is 54,117 kva.

All three units are equipped with direct connected exciters rated at 250 volts.

The turbine lube oil systems are supplemented with Bowser continuous by-pass filtering systems including a batch oil storage tank for each pair of units.

A 100 ton crane is provided to handle the largest parts of turbine generators. This crane will handle the largest parts of future larger machines.

SECTION IX - STEAM CYCLE

Flow diagrams F-86808, F-86851 and F-100206 and Heat Balance diagrams E-86807 and E-86850 show schematically the cycle arrangement with numerical values, flow rates and line sizes. At 44,000 kw load and design conditions the station heat rate is 12,510 Btu/kw hr when burning coal at 84% boiler efficiency.

Steam is delivered from the boiler to the turbine through 12" sch 100 1% chrome 1/2% moly pipe with no crossovers between units. After partial expansion through the turbine steam is bled at five points to four closed feedwater heaters, deaerating heater and evaporator. The three top heaters are vertical head up, two pass without drain coolers. The low pressure heater is horizontal and mounted in the condenser neck to save space and maintain a minimum of piping. All heaters are supplied by Struthers Wells Company. The two top heaters are drained to a flash tank where the flash is carried to the deaerator by two high pressure drain pumps, one standby. The two low pressure heaters also drain to a flash tank where flash is directed to the L P heater shell and condensate is pumped into the main condensate pump discharge by two low pressure heater drip pumps, one standby. The evaporator coil drains to the high pressure flash tank.

The condensers are two pass 30,000 sq ft arranged with divided water box. They are set in conventional manner across the axis of the turbine. The condensers for Units 1 and 2 are of Allis-Chalmers Mfg. Westinghouse supplied Unit 2 condenser.

Two 700 gpm 350 ft TDH vertical condensate pumps each driven by a vertical 100 hp motor, serve each condenser hotwell. One pump is required at full load with one pump as standby. Manual recirculation is employed back to condenser hotwell during start up.

From the condensate pump the condensate passes in turn through the steam

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jet air ejector, through the low pressure and intermediate low pressure heaters to the deaerator vent condenser. The deaerator is of the horizontal tray type manufactured by Worthington Corporation rated at 400,000 lb per hour with a 0.005 cc oxygen guarantee and fitted with a horizontal 125,000 lb storage tank.

Deaerator level is maintained during system changes by a high level float to by-pass condensate to storage from condensate pump discharge and by a low level float to admit dead storage to the condenser. An automatic overflow is provided to waste if deaerator level goes beyond control.

Three Byron Jackson Boiler Feed Pumps per unit, one of which is a spare, each rated 265,000 lb per hour at 1160 psig and driven by a 600 hp motor take their suction from the deaerator storage tank and discharge through the two high pressure heaters to the boiler drum. Main boiler feed pipe is carbon steel 8" sch 160. The two high pressure heaters are close coupled on the feedwater side and are by-passed automatically on high water in either heater.

Condensate storage is provided in vertical 11,000 gallon storage tanks located at the ground level, one per unit. Each pair of units has two condensate transfer pumps for handling large condensate changes.

SECTION X - CIRCULATING WATER SYSTEM

Since the South Platte does not supply sufficient flow for a once through circulating water system cooling towers are supplied. The cooling towers are located along the west edge of the gravel pit over concrete basins. The cooling tower for Units 1 and 2 is of Marley Company manufacture and is an eight cell induced draft, double flow type with overall size 63' x 193' x 39', capacity 62,000 gpm, 83 F water leaving tower 104.3 F to tower and 20 F approach to a design wet bulb of 63 F. Eight 60 hp motors drive the aluminum bladed fans through gear heads. The tower for Unit 3 is based on same design conditions but at half the capacity or 31,000 gpm with four cells.

Water flows by gravity from tower basin through cast in place concrete tunnel designed for four units to the pump intake located near the station. The pumps are housed in a brick building which also houses chemical treatment equipment, service water pumps and chlorine storage.

The main circulating pumps, one per unit, are vertical Allis-Chalmers mixed flow design, each sized for 31,000 gpm against a TDH of 75 ft and driven by an Allis Chalmers 800 hp vertical motor.

Chlorine and acid are injected into the system immediately ahead of pump suction.

The acid system, supplied by Permutit, automatically maintains pH by injecting continuously controlled amounts of sulphuric acid. A continuous sample is taken to the electrode of a Leeds & Northrup pH controller-recorder which automatically adjusts the stroke of two Milton Roy proportioning pumps feeding concentrated sulphuric acid to a mixing chamber. In the

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lead lined mixing chamber the acid mixes with service water and is piped through stainless pipe to the circulating water tunnel. Design calculations indicate a pH of about 8.0 is necessary for best results.

One 10,000 gallon storage tank for the strong acid is set by a rail siding alongside the pump house. Emergency shower and eyewash fountain are provided for personnel protection when handling acid. The acid pumps and controller are located in a separately enclosed room of the pump house.

The chlorine system supplied by Wallace & Tiernan Company is of the intermittent automatic desliming type. The main chlorinator and controls are in the pump house enclosed in a separate room. A chlorine storage room with a capacity of 20 one ton cylinders completes the pump house. A two ton jib crane is furnished for unloading cylinders from the cars and a two ton traveling hoist handles the cylinders in the storage room.

The three main circulators discharge through automatic butterfly valves to a common cast in place concrete tunnel feeding the three condensers in parallel. A temporary end is provided for extension to future Unit 4.

Each condenser is valved with four 30" bevel gear operated gate valves for shutdown purposes. Condenser tubes are drawn out through large openings closed by overhead rolling doors in the building front wall.

Circulating water is piped from each condenser to a common return tunnel paralleling the inlet tunnel. The return tunnel runs to the cooling towers paralleling their west sides. The top of the tunnel is maintained at grade so it can be used as a walkway during winter months. An individual valved riser serves each tower cell. Each riser is equipped with a measuring orifice so water to each cell can be apportioned. Towers for Unit 4 can be located at the end of the Unit 3 tower. Any expansion beyond this will require tower location across the gravel pit or on the east side.

SECTION XI - COAL HANDLING SYSTEM

The Coal Handling System is designed to handle run of the mine western sub-bituminous coal at a rate of 300 tons per hour. All component parts may be speeded up by drive changes to handle 600 tons per hour in the future should station capacity demand it. For general arrangement of the system see drawing F-86804.

The coal to be handled has the following proximate and ultimate analysis:

Proximate Analysis	
Moisture	24.0%
Volatile matter	28.8%
Fixed carbon	42.0%
Ash	5.0%
Total	100.0%

Ultimate Analysis	
Carbon	55.24%
Hydrogen	3.08%
Oxygen	10.78%
Nitrogen	1.14%
Sulphur	0.61%
Ash	5.15%

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Softening temperature - 2090 F
Ash fluid temperature - 2230 F
Grindability (Hardgrove) 45
Heating value (high) 9280 Btu

Ultimate possible plant capacity indicates that a car dumper could be necessary to unload the required coal tonnage. Therefore receiving layout provides space for a car dumper pit. For the present, however, no car dumper or shakeout is provided and side and bottom dump cars are emptied by hand over the four track hoppers arranged three in a line on one track and one on a parallel track.

Two of the hoppers are equipped with apron feeders and two with reciprocating plate feeders. All feed to 42 inch inclined conveyor No. 2 to the crusher house. The head pulley of No. 2 belt is magnetic to take-out tramp iron before coal reaches the crusher.

From No. 2 belt coal may be directed at operators choice either to No. 5 storage belt at right angles to No. 2 or through the crusher to the vibrating screen. No. 5 runs out either side of the crusher house to dump coal on the storage pile. Coal is reclaimed to the track hoppers by a bulldozer. No. 5 belt is 36 inch and the galley is uncovered.

The crusher is of Pennsylvania Crusher Company manufacture sized for 300 tons per hour. A by-pass chute is provided around the crusher to the vibrating screen.

The vibrating screen feeds No. 3 inclined conveyor carrying coal from the crusher house to the bunker level. A weightometer is installed near the tail end of belt No. 3.

The coal enters the plant between boilers 1 and 2 at right angles to a traveling shuttle feeding the three sets of bunkers. The shuttle mounts a shuttle conveyor No. 4 and two airplane type conveyors 4A and 4B at either end to feed the two lines of bunkers. The bunker floor is cast in place concrete slab containing slots for coal feed. The slots are sealed by a Robbins belt sealer to keep dust nuisance to a minimum. Rotoclones are provided to maintain a vacuum in the bunkers to further hold down dust.

The entire system is completely interlocked to protect personnel, equipment and installation. All conveyors are sequentially protected from their discharge point back to the feeders. All flopper gates are equipped with metal clad mercury switches to assure the desired flow sequence. Hand cable operated, manually reset emergency stop switches are located paralleling each belt which permit stopping a conveyor at any point along its run. The normal interlocks then stop all preceding units. Complete control of the system may be had at the bunker level. Partial control of the system is located at the crusher house for storage operation. Feeders are selected by the track hopper operator but are started and stopped by the man at the bunkers.

All conveyors and supporting steel are supplied by the Webster Manufacturing Company.

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SECTION XII - CONTROLS AND INSTRUMENTATION

The control systems are designed for supervision of each pair of units from a centralized control room. Local controls are held to a minimum consistent with the nature of the equipment being controlled. Included in the control rooms are boiler board and turbine board for each unit, common control board for control of common auxiliaries and electric switch board for supervision of switchyard and electric end of main machines.

The boiler controls are designed to hold steam pressure over specified range when burning 100% coal, 100% gas or any combination of these two. Controls are pneumatic and supplied by the Bailey Meter Company. The basic control varies air and fuel in the most efficient ratios to hold constant steam output pressure at varying steam flow rates. All dampers, control valves and other devices regulating flow of air or fuel are controlled automatically by the system or remote manually from the central control room at the discretion of the operator.

A Bailey three element feedwater control system is provided to hold boiler drum level. The system utilizes drum level, feed flow and steam flow as the three elements of control. The flow is regulated by a 6 inch Bailey piston operated valve located in the main feed line ahead of the high pressure heaters.

A record of all important functions of the steam cycle and electric cycle is maintained by recording instruments on the boiler and turbine boards. The continuous recorders not only give operators trends of the value being measured but provides data for plant performance analysis.

Deviations from normal operating conditions of level, temperature, pressure, etc. are indicated by a visual and audible annunciator system. On each board is mounted a set of indicating windows usually connected with functions performed on that particular board.

Motor operation, with controls in the central control room, is provided for feedwater control shutoff and bypass valves, H P heater shutoff and bypass valves, boiler feed pump discharge valves, deaerator emergency make-up valves and main steam block valves. The more important services are 125 d-c operated while the rest are 440 volt a-c. The feedwater bypass valves and deaerator emergency feed valves are provided with inching type control, the rest with open or close control.

Supplementing indications on the main control boards various local indications are provided, where required, for checking performance. Among these local devices are pressure gages, industrial type thermometers and gage glasses.

SECTION XIII - WATER SUPPLY AND TREATMENT

There are six principal requirements for water including boiler feed, cooling, tower makeup, sanitation, fire protection and ash handling. These

can be classified under the sources that supply them.

City Water	River and Well Water
Boiler Feed	Service Water
Sanitation	C. W. Cooling Tower Makeup
Fire Protection	Ash Handling

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City Water

The city water supply enters the plant site through a 14" cast iron main. The water to fire hydrants, hose connections and automatic transformer spray protective system is unmetered. Water to boiler makeup and sanitation is metered as it enters the station building.

Water for boiler makeup passes through manually operated Permutit zeolite softeners, one set per pair of units, where it is softened at a maximum rate of 60 gpm. The evaporator feed pumps pump this water to the Griscom Russell bent tube evaporator, one per unit, where it is distilled at a maximum net output rate of 13,500 lb per hour. The vapor passes to the individual deaerators and the brine is blown to waste. The evaporators are equipped with a deaerator preheater through which the softened water passes on its way to the evaporator shell. Steam for the evaporator coils is taken from the second extraction point on each unit. Manual coil inlet regulation is utilized for control of the evaporators..

Internal boiler treatment is provided in the form of dissodium phosphate injected into the drum by two Milton Roy positive displacement pumps per pair of units. Sulphite is injected into the boiler feed pump suction as an oxygen scavenger by two additional Milton Roy positive displacement pumps. Each pump will handle two units leaving one as a spare. Chemical storage, mixing tanks and pump suction tanks are located at ground level between each pair of boilers.

Sanitary water is supplied to office and locker room facilities and to drinking fountains throughout the plant.

River and Well Water

To supply cooling and service water to the various requirements in the plant including hydrogen and oil coolers, boiler feed pumps, bearings, ash hopper seals etc. two shallow wells and three river wells have been provided. The river wells are located in the bank of the river to draw in the better quality river water. The shallow wells (50-55 ft), located away from the river, take water from the natural aquifier of lesser quality requiring more treatment than the river water.

All river and well pumps discharge to a common settling basin in the C W pump house. An automatic system maintains level in this settling basin by cutting in and out well pumps as required. Preference is given to the river water because of the better quality.

Three vertical 2000 gpm service water pumps are mounted in the settling basin to supply the plants requirements. The common discharge of these pumps

is metered in the pump house. Since this water is to be passed through the plant coolers, a polyphosphate inhibitor such as Calgon is injected to the stream. This is accomplished with a proportioning pump located in the acid treatment room with its combination storage-mixing tank.

An underground pipe line carries service water to the main plant where it passes through a twin strainer and a regulating valve set to hold a constant pressure in the plant service and cooling headers. The water, after passing once through the plant coolers is piped back to the C W pump suction where it is introduced to the circulating water system as makeup. This makeup water replaces water lost by tower evaporation and windage and by deconcentration blowdown.

SECTION XIV - MAIN SWITCHING, CONTROL AND PROTECTIVE EQUIPMENT

Generator Leads

The generator leads are 3" IPS copper tubes supported on 23 kv porcelain insulators mounted on steel frame work. They are covered with 1/8" thick formica having a dielectric strength of 650 volts per mil. This additional insulation extends from the terminals of the generator to a point 21 feet beyond the south wall of powerhouse. The leads pass through this wall by means of 23 kv Lapp porcelain wall bushings. Generator leads indoors are spaced on 2 foot centers and enclosed in expanded metal enclosure as protection to personnel. Generator leads outdoors are spaced on 4 foot centers and the delta connection to the three single phase step-up power transformers are spaced on 2 foot 6 inch centers.

In the leads between wall and each transformer bank is mounted a 23 kv 3000 ampere, gang operated disconnect switch for isolating generator, so that insulation readings can be taken without disconnecting main bus. This disconnect switch also permits energizing the unit auxiliary power transformer if desired without the generator running.

The auxiliary power transformer is fed by means of 1-1/4 inch IPS copper bus. It can be isolated from main power transformers and generator leads by means of a 23 kv 400 ampere gang operated switch. See Main One Line Diagram Drawing No. E-100362.

Generator Neutral

The generator neutral is formed at the terminals of the generator and grounded through 25 kva, 13,200-120/240 volt, single phase pyranol insulated distribution transformer connected on 12,210 volt tap. The neutral connection is metal enclosed. The transformer limits ground current to such a low value as to practically guarantee no burning of generator laminations during a ground fault. The voltage type ground detector relay across secondary of transformer can accurately detect ground faults within less than 5% of the neutral of the generator.

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Potential Transformers

The potential transformers are in a metal cubicle located on mezzanine floor of generator pedestal. They are connected to generator leads by means of current limiting primary fuses, so sized as to prevent a faulted potential transformer from acting as a bus fault, but not to provide thermal overload protection for the potential transformer.

Secondary circuits are fused for metering and unfused for relays and automatic voltage regulator supply.

Lightning and Surge Protective Equipment

Lightning and surge protective equipment includes one 12 kv lightning arrester and one 0.25 mfd capacitor per phase for protection of each generator. This equipment is mounted underneath generator leads on a steel platform outside south wall of powerhouse.

They are enclosed in housing of expanded metal to prevent accidental contact by birds or animals with possibility of resultant grounds or shorts. The housing also prevents the danger from flying of broken porcelain in the event of destruction of lightning arrester, while permitting the escape of gases. The protective equipment can be easily isolated by means of three hook stick operated 23 kv - 400 ampere disconnect switches.

Current Transformers

Two current transformers are located on each generator terminal bushing. Those on generator neutral, are one each for generator differentail type protection and transformer protection, while one of those on line side is for other side of generator protection and remaining sets is for metering and line drop compensation of automatic voltage regulator.

Generator Excitation

Excitation for each generator is supplied by a shaft driven separately excited exciter rated 145 kw, 250 volts and direct connected pilot exciter rated 4 kw, 250 volts. A generator field cubicle, mounted on generator pedestal mezzanine floor, houses generator field circuit breaker, discharge resistor, and shunts for field ammeter and rotor temperature recorder.

Generator Control Switchboard

The generator control switchboard is a part of the main electrical switchboard and controls generators, exciters, auxiliary power supply, and 115 kv feeder circuits. Unit load controllers are used to proportion load between all three present machines and can be easily expanded to care for any additional machines in the future. There is also flat frequency control, flat tie line control or tie line bus control.

Control Wiring

The control wiring is 19/#22 Awg multi-conductor 600 volt tinned copper cable. Control cables are installed in galvanized expanded metal cable trays in the station wherever multiplicity of runs permit, or in conduit where individual runs are required.

Protective Relays

The protective relaying for the main electrical circuits consists of time delay overcurrent relays connected in a current summation circuit for each generator, each main power transformer bank and each unit auxiliary transformer. The start-up auxiliary power transformer is protected by 15 kv fused disconnect switches. A voltage type ground relay is connected in parallel with a 27 kw loading resistor, across the 240 volt winding of neutral grounding transformer. The voltage of operating coil of this relay is low enough to detect a ground fault within approximately 4% of the generator neutral. By means of voltage limiting network the relay coil can withstand the voltage that would be impressed on it with a phase lead solidly grounded.

SECTION XV - AUXILIARY ELECTRICAL EQUIPMENT

Unit Auxiliary Transformers

The unit auxiliary power transformers are located outdoors adjacent to main generator leads and just south of powerhouse wall. They are rated 6000 kva OISC 13,200 volts delta to 2400 volts delta with two approximately 2-1/2% full capacity taps above normal voltage and same below, and have approximately 8% impedance. Transformers have provision for future forced air cooling to increase rating to 8000 kva. High voltage bushings are rated 25 kv and low voltage 8.66 kv. A flanged throat is provided on the top of the transformer for bolting on the metal enclosed bus to be used for the 2400 volt connections.

Main Auxiliary Switchgear

For each generator and one common the main auxiliary switchgear consists of one metal-clad, 5 kv switchgear group arranged as a single bus. Large motors are supplied directly from this switchgear. Remote electrically operated non-automatic emergency tie connections are provided between the four different transformers and 2400 volt switchgear groups. Circuit breakers are rated 1200 amperes except the Incoming and Tie breaker in each group which are rated 2000 amperes. All breakers have an interrupting capacity of 100 mva at 2400 volts. This switchgear, as well as station service transformers and 480 volt power centers, is located in two separate rooms. One between the first two boilers and other west of the third boiler. The rooms are isolated from all steam lines, water lines, etc, for maximum reliability and minimum maintenance.

480 Volt Power Centers

WAD02013

480 Volt Power Centers

The 480 volt power centers are used to supply motors from 75 to 150 hp inclusive and several 480 volt motor control centers. Generators No. 1 and No. 3 each have two of these power centers. Generator No. 2 and Common each have one. These power centers are of metal-clad construction each with dry type, air cooled, 2400-480 volt, 3 phase, 1000 kva transformer, throat connected to 600 volt drawout breakers. The 1000 ampere main and 1200 ampere tie breakers have 50,000 ampere interrupting capacity. The motor and feeder breakers have 25,000 ampere interrupting capacity. The motor control centers are all fed through a total of seven (7) 400 ampere (4% on 1000 kva base) reactors in order to limit the possible short circuit current to not over 15,000 amperes.

480 Volt Motor Controller Centers

The 480 volt motor control centers are fed from the power centers through air cored current limiting reactors as mentioned in previous paragraph. This limitation of fault current is required because of the use of circuit breaker type combination starters for the control of all motors up to 60 hp. The control centers are distributed at strategic locations throughout the plant, each approximately near the center of the group of motors controlled by it. Short circuits in motor leads or windings is to be cleared by the air circuit breakers, while sustained locked rotor current and thermal overloads on non-essential motors is cleared by thermal type overloads tripping the magnetically operated contactor. On essential drives the thermal overloads sound an alarm only and it is up to the operator to ascertain the cause and remove trouble or stop the motor before it fails.

Cooling Tower Control Centers

Each unit has a unit substation type of control center for cooling tower fans. Each center consists of 500 kva, 2400-480 volt, three phase outdoor type OA transformer ,throat connected to outdoor type motor control center. Each cooling tower cell fan starter is for two speed two winding motor and is capable of reversing the fan on low speed in order to blow warm air out through inlet louvers for melting ice accumulation. The unit substations for first two units is a double ended unit with transformer sized so that either transformer can supply the fan motors for two units. The substation for third unit is single ended to which can be readily added the transformer and starters for fourth unit to make a double ended unit. One section of each group of starters is devoted to a single phase transformer and small lighting panel for lights on cooling tower and local yard areas. The transformers are protected against faults and heavy overloads by relays in 2400 volt switchgear, one breaker feeding each transformer.

Coal Handling Control Center

There is a single system of belts etc. for feeding coal from railroad cars or storage to bunkers or storage. All coal handling motors, including crusher, receive power and are controlled from a unit substation type of control center. It consists of a 500 kva, 2400-480 volt, three phase outdoor

WAD02014

type OA transformer throat connected through building wall to indoor type motor control center, located in control room on first floor of crusher building. All starters are combination type with manual circuit breaker for short circuit protection and magnetic contactors, d-c operated for magnetic separator pulley and contactor type for 150 hp crusher motor. The transformer is so sized and space is available for enough starters to double the present rate of coal handling. The transformer is fed from 2400 volt switchgear through its own breaker, on the front panel of which are mounted necessary instruments and relays.

Motor Control

Motor control stations for the majority of motors are located in the central control room, with remaining motors controlled from local stations, such as coal handling from control station above bunkers, in crusher house and at track hoppers, and cooling tower fans from top of cooling tower. Except for motors started by circuit breakers, the control stations are generally of the maintaining contact control switch type.

Power Wiring for Station Auxiliaries

For the station auxiliary power wiring an oil base rubber compound insulation, rated 5000 volts for the 2400 volt circuits and 1000 volts for 480 volt a-c and 250 volt d-c excitation circuits is used. Indoor power cables are generally run in exposed galvanized steel conduits and conduits in the sand fill of the basement floor. Power and control wiring from the main plant to the cooling towers, circulating water pump house, coal handling power transformer and switchyard is run in Korduct conduits encased in concrete envelope. Minimum power cable size is No. 3/0 Awg for 2300 volt circuits and No. 12 for 440 volt circuits.

Control Wiring

Conduits and galvanized expanded metal cable trays carry the control wiring. Access platforms suspended from floor beams of operating floor serve all cable trays and make them easily accessible. Thus there is a very high degree of flexibility in arranging the control circuits, a maximum ease of installation and ready accessibility for maintenance or rearrangement.

Station Grounding System

The station grounding system consists of a ground bus of 3" by 1/4" galvanized steel strap. In order to secure the lowest possible resistance ground the ground loop was connected to the metallic casings of river well pumps, two ash water pumps in gravel pits, two shallow well pumps and two deep wells 710 feet and 1700 feet deep respectively. Also to increase the ground surface available for dissipation of large ground currents, as well as minimize ground resistance in the high resistivity soil of gravel and/or clay the metallic shells of not less than 40 Raymond concrete piles under the building foundations and 16 or more under the concrete stacks are all connected to the grounding grid.

WAD02015

SECTION XVI - COMMUNICATION EQUIPMENT

Communication comprises three individual systems:

1. Bell System

This system is entirely independent of other systems, having its individual conduit and wire. There is one instrument located in each control room and the rest are in office area.

2. Intrasite Telephone System

This is a completely automatic, selective talking, selective ringing dial type system equipped for 50 lines with a code calling machine and code call single stroke bells. The telephone system is for operation on a 24 volt battery complete with charger, used exclusively for this purpose. There are 30 code call bells which are operated on 120 volts d-c supplied from the station battery. The initial installation consists of 36 instruments located strategically about the plant, cooling tower, transformer and switchyard, pump house and main gate location and equipped for five simultaneous conversations. Instruments at noisy locations are equipped with loud ringing bells. Special features of the system include an executive right-of-way selector, and conference call.

3. General Emergency Alarm System

Due to the limited number of operating personnel and relatively large operating area covered, experience demonstrated the need of a general emergency alarm system so that all personnel can get to their assigned stations as soon as possible on a "Unit" emergency. The type of equipment to fulfill the necessary requirements is essentially a non-interfering fire alarm type, actuated by code box located near each boiler gage board. When initiated the code will be sounded on all horns and repeat four times, which cycles is repeated if the box is pulled again. In the event that two boxes are pulled almost simultaneously, the box which is pulled first will complete its four rounds, and the second box shall then go through its complete operation, designating that there is an emergency in both locations. The boxes operate in conjuction with a closed circuit central station control panel, through which any required number of signals may be operated. The present system consists of a total of four signals, two of which are electric resonating horns and two are six inch compressed air horns with an electrically operated air valve.

SECTION XVII - SWITCHYARD

Main Power Transformers

Each main transformer bank consists of 3 - 16,667 kva, single phase, 60 cycles self cooled transformers with provision for future forced air cooling to increase the continuous rating to 22,250 kva. They are 13,200 volts delta to 110 kv wye with two approximately 2-1/2% full capacity taps above

WAD02016

normal and two same below normal voltage, operated by external hand operated no load tap changer. The system operates with solidly grounded neutral so the high tension winding has graded insulation and neutral bushing is duplicate of low tension bushings. The high voltage bushings are high altitude type. The transformer tank is so constructed that it can be removed at the base and avoid lifting core and coils. It is of the welded joint construction throughout except for gasketed joints for manholes, bushings and radiators.

Oil Circuit Breakers

The 115 kv oil circuit breakers in the switchyard are rated 800 ampere, 115 kv, 2500 mva interrupting capacity and are arranged for switching generators and lines from a split operating bus.

See Drawing E-100416.

Lightning Protection

Lightning protection is provided by complete shielding of all electrical equipment by shield wires extending over the switchyard from all the incoming lines to the turbine room south wall. In addition station type lightning arresters are installed on each incoming line.

Switchyard Structural Design

The switchyard is of the low-open structure design using 2" SPS copper tube on pedestal insulators for both the main operating bus and inspection bus on seven foot phase spacing, and located approximately 17 feet above the ground. Steel supporting towers of continuous "A" frame type are located between the two buses. The incoming transmission lines and connections to main power transformer banks are terminated on these towers. The main switchyard for first three units is arranged in 40 foot bays, occupying an area of approximately 340 feet by 187 feet inside the fence. This allows room to move the inspection bus south to provide space for the installation of oil circuit breakers in the circuits from this bus, if ever desired.

Relay Protection

Relay protection in the 115 kv switchyard consists of two sets of potential (from CTs) type bus differential protection, one on each bus section; current summation inverse time overcurrent relays on the power transformer banks; zoned distance impedance type, current polarized directional ground relays and pilot wire directional ground protection on the four outgoing feeders.

The instruments, control switches and all relays are a part of the main control board for Units No. 1 and No. 2 and is located in the control room common to these two units.

WAD02017

SECTION XVIII - D-C CONTROL SYSTEM

A 125 volt d-c control system is used for both the main plant and the switchyard, consisting of one 60 cell storage battery rated 560 ampere hours on the six hour discharge rate to 1.75 volts per cell and each cell has six positive plates and seven negative plates. The battery is continuously floated on a 10 kw diverter pole charging generator driven by a 15 hp motor. Its design is such as to absorb the most of suddenly applied control current requirements and thus increase the life of the battery.

This system provides for the installation of three units and must be supplemented by a similar duplicate system with interconnecting tie for any future expansion.

See Drawing No. E-100411.

SECTION XIX - LIGHTING

A two wire 115 volt, single phase lighting distribution system, with its midpoint solidly grounded is used for the station building, switchyard, pump house, cooling tower, coal handling and yard lighting. The turbine bay uses a combination of hi-pressure mercury vapor lamps and incandescent lamps. The control room is illuminated by fluorescent fixtures above a louvre-all ceiling and they can be switched to give any one of three levels of illumination.

SECTION XX - CATHODIC PROTECTION

A cathodic protection system to protect all underground steel, such as piping, conduit and steel ground grid. The ground grid is 1/4" x 3" or 1/4" x 2" steel bar or 3/8" stranded steel cable since it is well protected by cathodic protection and bare copper would have drained protection from steel equipment.

The anode ground bed consists of 31 anodes at an average of 15 foot spacing. It is located 40 feet east of the West property line.

WAD02018

SECTION II
GENERAL FEATURES

SECTION II
GENERAL FEATURES

PUBLIC SERVICE COMPANY OF COLORADO
ARAPAHOE STEAM ELECTRIC STATION
1950-51 88,000 KW INSTALLATION
1951 44,000 KW EXTENSION

SECTION II - GENERAL FEATURES

General

Early in 1947 it became evident that additional electric generating capacity would be required in the Denver area in the near future. Also at this time, it was realized that the expected recession in business after the war years was not to take place, and that the continuation of the growth of electric load throughout the entire system would require a planned program covering quite an extended period of time. As a result of this realization, Ebasco Services, Incorporated, of New York City, was invited to make a preliminary survey of the system for purposes of discussions prior to making final recommendations. These discussions were held in Denver, beginning July 14, 1947, and conclusions reached at that time resulted in recommendations for new construction for 1950 and 1951. However, later, a more extensive study of the power supply for the central system was made, resulting in a report issued in September of 1947 covering a planned program to and including the year 1955.

Previous to the completion of the Arapahoe Steam Electric Station, the central system of the Public Service Company of Colorado comprised units with total generating capabilities of 237,000 kw. The three units installed at the Arapahoe plant added a generating capability of 144,000 kw, bringing the total capability to 381,000 kw for the central system at the time of the completion of the Arapahoe station.

On August 21, 1947, Ebasco Services, Incorporated, negotiated a contract with the Public Service Company of Colorado to provide design engineering, and construction services for the initial installation of one 40,000/44,000 kw turbine generator at a new site to be known as the Arapahoe Steam Electric Station. This site had been determined by the power supply study heretofore mentioned. On January 30, 1948, a supplement to the contract was issued covering an extension to the Arapahoe Steam Electric Station for a second 40,000/44,000 kw unit designated No. 2, and on September 1, 1950, another supplement to the original contract was issued, covering a further extension to the Arapahoe Steam Electric Station for a third 40,000/44,000 kw unit, designated No. 3.

Although the contract called for one installation and two extensions, it was decided that since no design or construction was started before the issuance of the supplement authorizing the second unit, to designate both Units No. 1 and 2 as the original installation, and Unit No. 3 as an extension.

No ground breaking ceremonies were held; however, the specific date of August 2, 1948, was set as the official beginning of construction of this project, namely the date on which the excavation for the circulating water tunnels was started.

The original installation consists of two Babcock and Wilcox steam generators, each with rated capacity of 450,000 lb/hr, designated as Nos. 1 and 2; one 40,000/44,000 kw General Electric turbine generator unit, designated as No.

1; one 40,000/44,000 kw Westinghouse turbine generator unit, designated as No. 2; three Westinghouse 16,667 kva, 115,000 volt power transformers, designated as 1A, 1B and 1C; three General Electric 16,667 kva 115,000 volt power transformers, designated as 2A, 2B and 2C; and all necessary auxiliary equipment and structures for both units. The extension consists of one Babcock and Wilcox steam generator with rated capacity of 450,000 lb/hr, designated as No. 3; one 40,000/44,000 General Electric turbine generator unit, designated as No. 3; three General Electric 16,667 kva, 115,000 volt power transformers designated as 3A, 3B and 3C; and all necessary auxiliary equipment and structures for this unit.

This plant is designed for 850 psig and 900° F. steam conditions and for the use of pulverized coal as the primary fuel, and natural gas as a secondary fuel. Although coal is the primary fuel, there are extended periods during warm weather when large quantities of gas are burned. Considerable coal storage area with rail track hoppers is provided. A conveyor type system with crusher and screening facilities is provided for either moving coal from track hoppers to storage area without preparation, or moving coal from hoppers through the partial preparation equipment to the station bunkers. In addition to the coal storage area, considerable trackage is provided for live storage of coal cars to provide for a three-day holiday when only a skeleton crew for handling coal is available.

Marley cooling towers are provided to dissipate the heat picked up by the turbine surface condensers. Make up water for these towers is derived from shallow wells and river wells.

The turbine generator units and most of the auxiliary equipment are housed in a reinforced concrete, steel and brick structure. The steam generators are of the semi-outdoor type with an enclosed firing aisle near the top of the boiler and an enclosure at ground level housing the ash hoppers, the forced draft fans and drivers, and portions of the ash sluicing system.

No conventional auxiliary bay is provided to house auxiliary equipment as considerable space, available at ground level and on the turbine operating floor elevation between bunkers, and at several elevations between boilers, was utilized to house the auxiliaries.

The power and station service transformers, with their steel structures, are located just outside and south of the building in an area designated as the transformer yard, which is not fenced. The surface of this yard is covered with granite chips for maintaining better conditions in winter.

An eight bay 115,000 volt switchyard is provided with steel structures, bus work, air break switches, oil circuit breakers, instrument transformers, and necessary conduit and control wiring, all of which is enclosed by an eight-foot chain link type fence with access gates. The surface of this switchyard is covered with granite chips similar to those furnished for the surface of the transformer yard.

Trial operation of Unit No. 1 was initially scheduled for May 1, 1950. However, due to a three months, Denver Area, strike by the carpenters, and delay in delivery of boiler tubes which, in turn, brought erection into the bad weather period, causing further delay, trial operation was not realized until October 7, 1950. Trial operation of Unit No. 2 was scheduled for March 1, 1951,

and construction progress was such that this date was expected to be met with little difficulty; however, because of seasonal inclement weather, it was necessary to practically enclose the entire boiler with a heated weather housing, and because necessary additional unexpected tests on both the boiler and turbine generator were required, trial operation was delayed until March 15, 1951. Trial operation of Unit No. 3 was scheduled for November 1, 1951, but delivery of boiler material was such that it became necessary to work two shifts if trial operation was to be accomplished in November. Trial operation was actually realized November 17, 1951.

Construction Plant Facilities

Shortly after the construction starting date it was decided, as a job economy factor, to purchase as much of the construction equipment as was required throughout the job, and use rental equipment only as a fill-in for short periods of work; therefore, construction equipment was purchased from time to time as required for proper prosecution of the work. Eight pieces of heavy equipment and approximately 77 pieces of light equipment, including trucks, but not including the conventional small tools, were acquired during the construction period.

Temporary construction buildings consisted of an office, warehouse, general construction supervisor's office, and timekeepers' office, all of structural steel frame with corrugated aluminum sidings and roof (Butler buildings), and additional buildings for use as change houses, contractors' offices and storage rooms, erector's tool rooms, and workmen's toilets, all of which were obtained by purchase of wood barracks at Buckley Field, near Denver. These barracks, which were approximately 20 feet by 100 feet, were cut into two parts and hauled to the job site. The field office was a 20 foot by 70 foot building with necessary facilities for the personnel employed therein. This building was placed on a temporary reinforced concrete slab. The warehouse was a 40 foot by 100 foot building similar in structure to the office building. Necessary bins and facilities for storing material were provided as well as a small inside office for the warehouse personnel. All of these temporary construction buildings were first located southeast of the building site during the construction of Units No. 1 and 2, and later with the exception of the office and warehouse, were moved approximately 500 feet west when Unit No. 3 construction started, for proximity to the new construction area.

No provisions were made for a concrete mixing plant on the job. A contract was made with Colorado Premix Concrete Company to provide ready mixed concrete as needed. Only equipment grouting and other small requirements were mixed on the job.

The usual temporary walkways, ladders, platforms, hand railings and barricades were provided as required during construction.

Two 1948 Chevrolet sedans and a 1948 Chevrolet station wagon were purchased by the Ebasco Services, Incorporated, during the early part of the construction program. The sedans were assigned to the construction superintendent and the general construction supervisor, and the station wagon was assigned to the resident engineer until April 29, 1949, after which date the station wagon was unassigned and used for the purpose of picking up small field purchases, and for other transportation. On April, 1951, this station wagon was transferred to the Public Service Company for assignment to Mr. A. P. Vail. On September 1,

1950, a new resident engineer arrived on the job, and the sedan being used by the construction superintendent was reassigned to the resident engineer, and a new 1950 Ford sedan was purchased for the construction superintendent.

Necessary power and light transformer facilities for construction purposes were provided by the operating company and the power consumed billed to the field office through their regular monthly charge letter. To provide these necessary power and light facilities, the Public Service Company of Colorado constructed a 13 kv overhead line from their distribution system to the north edge of the plant site. From this point, a temporary overhead line was strung to the construction bank of transformers where switching and metering equipment was provided on the primary side. These transformers remained in this position until September 28, 1950, when the area was needed for coal storage, at which time the bank was moved to the south side of the station building adjacent to the 13 kv standby station service transformer, where it remained until released on January 29, 1952.

Three telephone trunk lines and the necessary extensions were provided in the field office. One line was limited to the Superintendent's office, and the other two were on a rotary system which added flexibility to the limited number of lines.

All calls were received by the receptionist and referred to the proper persons.

Labor Policy

The great majority of the work on this project was performed by Ebasco forces, the exceptions being pile driving, plant piping, heat insulation, stack and cooling tower erection, electrical work, roofing and painting.

The piping contract was on a cost plus basis. The pile driving, heat insulation, roofing, electrical work and painting contracts were on a unit price basis, and stack erection and cooling tower erection were on a lump sum basis. On cost plus work, payrolls were kept by the various contractors and foremen's daily reports submitted, which were checked by the field office time checker, classified by the cost department, and approved by the Resident Engineer. Both Ebasco Services and contractors used local union field labor exclusively. This did not include office employees.

The Superintendent, Resident Engineer, Construction Accountant, and Cost Engineer were carried on the Ebasco New York payroll. An Ebasco field payroll was set up to take care of all field employed personnel. Details of this payroll are expanded in the accounting section of this report.

The project as a whole was operated on a 40-hour per week schedule except for brief periods when a 48-hour schedule was maintained to expedite completion of certain phases of the work, especially at a time just prior to placing in service of a turbine generator unit.

The local union wage scale for the various crafts was employed at all times.

Overtime for all crafts was paid for on a basis as shown in the following schedule.

	Over 8 Hours	Saturday	Sunday
Boilermakers	2	2	2
Bricklayers	2	2	2
Carpenters	2	2	2
Cement Finishers	1½	1½	2
Electricians	1½	1½	2
Insulators	1½	1½	2
Ironworkers	2	2	2
Laborers	1½	1½	2
Mason Tenders	1½	1½	2
Millwrights	2	2	2
Oilers	1½	1½	2
Operating Engineers	1½	1½	2
Pipefitters	2	1½	2
Plumbers	2	1½	2
Sheet Metal Workers	2	2	2
Truck Drivers	1½	1½	2
Warehousemen	1½	1½	1½
Welders	2	1½	2

Wage rates of practically all the crafts were increased from time to time during the approximately three-year construction period.

The following is a tabulation showing classes of labor and rates paid during the major portion of the project.

Boilermakers	Welder	Helper	Craft	Foremen	Gen. Foremen
Oct. 1, 1948	2.25	2.00	2.25	2.50	2.625
Oct. 18, 1949		2.10	2.35	2.60	2.725
April 1, 1951		2.25	2.50	2.625	2.75
August 3, 1951	2.50	2.25	2.50	2.75	2.875

Bricklayers	Craft	Foremen	Gen. Foremen
July, 1949	3.00	3.50	3.75

Carpenters	Craft	Foremen	Gen. Foremen
April 30, 1948	2.10	2.365	
July 1, 1950	2.35	2.6437	2.75

Concrete Finishers	Craft	Foreman
June, 1948	2.25	2.50
May 1, 1950	2.32	2.57
Jan. 1, 1951	2.40	2.65
July 1, 1952	2.475	2.725

Electricians	Craft	Foreman	Gen. Foreman
June, 1948	2.25	2.40	
May 1, 1950	2.41	2.60	
Nov. 1, 1950	2.50	2.70	2.90
March 1, 1951	2.65	2.86	3.07
Oct. 8, 1951	2.75	3.00	3.25

Truck Drivers	Craft
June, 1948	1.50
May 1, 1950	1.55
Sept. 1, 1950	1.60
Feb. 1, 1951	1.65

Glaziers	Inside	Outside	Foremen
June, 1948	1.72	1.89	25¢
July, 1949	1.75	2.00	Additional
July, 1950	1.82	2.10	Per
June 7, 1951	1.92	2.20	Hour

Ironworkers	Craft	Foremen	Gen. Foremen
June, 1948	2.00	2.25	
June 4, 1949	2.10	2.35	2.60
June 4, 1950	2.20	2.45	2.70
Jan. 1, 1951	2.25	2.50	2.75
Apr. 1, 1951	2.30	2.55	2.80
Sept. 17, 1951	2.35	2.60	2.85

Operating Engineers	Winch Trucks Compressors & Pumps Tractors Air Tuggers	Oiler	Crane Operator
June, 1948	2.00	1.45	2.15
June 4, 1949	2.10	1.55	2.25
June 4, 1950	2.15	1.60	2.30
Sept. 1, 1950	2.20	1.65	2.35
Jan. 1, 1951	2.25	1.70	2.40
July 1, 1951	2.31	1.70	2.48

Laborers	Air Tools	Craft	Pusher	Foremen
June, 1948	1.75	1.40	1.65	1.90
May 1, 1950	1.80	1.45	1.70	1.95
Sept. 1, 1950	1.85	1.50	1.75	2.00
July 1, 1951	1.955	1.575	1.825	2.075

Lathers	Craft	Foremen
June, 1948	2.25	2.50
July, 1949	2.50	2.75
July, 1950	3.00	3.25

Mason Tenders	Craft	Foremen
June, 1948	1.75	2.00
May 1, 1950	1.80	2.05
Sept. 1, 1950	1.85	2.10

Millwrights	Craft	Foremen
April 30, 1948	2.10	2.365
July 1, 1950	2.35	2.6437

Painters	Craft	Foremen
June, 1948	1.925	2.175
July, 1949	2.05	2.30
July, 1950	2.125	2.375
July 1, 1951	2.34	2.59

Pipefitters	Craft	Foremen	Gen. Foremen
June, 1948	2.24	2.365	2.615
July, 1949	2.40	2.525	2.775
April 1, 1951	2.65	2.915	2.9812

Plasterers	Craft	Foreman
June, 1948	2.25	2.50
July, 1949	2.50	3.00
July, 1950	3.00	3.25

Plumbers	Craft	Foremen	Gen. Foremen
June, 1948	2.24	2.365	2.615
July, 1949	2.40	2.525	2.775
April 1, 1951	2.65	2.915	3.0475

Roofers	Craft	Foremen
June, 1948	2.10	2.225
July, 1950	2.25	2.50
April 1, 1951	2.35	2.60

Sheetmetal Workers	Craft	Foremen
June, 1948	2.00	2.25
July, 1949	2.125	2.375
July, 1950	2.325	2.575

Tile Setters	Craft	Foremen
June, 1948	2.25	2.50
July, 1949	2.375	2.625
July, 1950	2.50	2.75
Dec. 18, 1950	2.60	2.85

Ebasco Services at all times were particularly careful in assigning work to various crafts to eliminate as much as possible jurisdictional disputes. The few strikes or differences of opinion which did occur were in most cases the results of area, rather than job, disputes.

During the greater portion of the construction period, the labor relations department of Ebasco Services, New York Office, was aware of, and greatly assisted in the handling of labor disputes requiring decisions by the unions' international boards.

Purchasing

The procurement of all major equipment and some miscellaneous material and supplies was made in New York by the Purchasing Department of the design and construction division of Ebasco Services, Incorporated, as agent for the Public Service Company of Colorado. Requisitions were issued by the design division to Ebasco Purchasing Agent, who also furnished factory inspection and expediting services. At first 3, and later 5, copies of all purchase orders, and all supplements thereto, were furnished the field construction office.

Local purchases were made by the field purchasing agent located in the field office at the job site. For items of any consequence, regular written inquiries were sent out to various vendors asking for formal quotations, which were assembled on a comparison of bid form for selection and placing orders. The price and delivery usually governed placing of the order.

Local orders were issued by the field purchasing agent on authority from requisitions approved by the construction superintendent and the resident engineer.

Special purchase order forms printed by Ebasco Services in New York for Public Service Company of Colorado were used and designated for the project by the initials SD, starting with the numeral 1 and running consecutively. No attempt was made to give a separate series of numbers for each of the three units. Order numbers were used as the need required, regardless for which unit the material was to be ordered.

The State of Colorado and the City of Denver assess a use and sales tax of 2% and 1% respectively, which are not applicable to transportation; therefore, all orders possible were placed on a basis of F. O. B. shipping point or F. O. B. shipping point with freight allowed to destination.

Five (5) copies of all invoices were furnished the field office on both local and New York orders and were carefully checked for price, terms, and extensions against the order. The invoices on New York orders were sent by the vendor directly to the Ebasco purchasing department in New York, which forwarded them to the field office after their approval. Payments were made according to the terms of the orders, except that final retention payments were not made until approval was received from Mr. R. F. Throne, or Mr. W. D. Hardaway, of Public Service Company, and Mr. R. B. Chase, of Ebasco Services, New York. All purchase orders issued for this project noted that material was to be shipped to Public Service Company of Colorado, Arapahoe Steam Electric Station, Denver, Colorado, care of Mr. B. A. Snow, Construction Superintendent.

Accounting

Standard Ebasco forms were used for all accounting purposes. Books of account used on this project were: General Ledger, form A-1; Check and Voucher Register, form A-2; Job Control Ledger, form A-4; and Detail Cost Ledger, form A-5a Rev. Books were closed at the end of each calendar month and a Trial Balance, form A-10 Rev., prepared from the balances as reflected in the control accounts. A detailed Statement of Construction Accounts, form A-10a Rev., was prepared from balances as reflected in the detail cost ledgers. Five copies of each of these reports were submitted to Mr. D. P. Roberts, Property Accountant, of Public Service Company, and three copies to Mr. G. P. Redden, Assistant Treasurer of Ebasco, New York. This procedure was followed until March 31, 1952, when a decision was reached by Ebasco, in collaboration with the Client Company, whereby the Statement of Construction Accounts would henceforth be prepared quarterly.

An Estimate of Cash Requirements, form 505 Rev., was prepared by the Accountant as of the last Thursday of each month. Two copies were submitted to Mr. Roberts, one copy to Mr. Throne, and two copies to Mr. Redden.

Immediately following the production of the monthly Statement of Construction Accounts, and upon receipt of the monthly letter of transmittal from Public Service Company incorporating charges to the construction project accumulated by them, a so-called Interest Report, Field Office form, was compiled, showing the allocation of total expenditures to date to Units 1, 2 and 3. Six copies of this report were submitted to Mr. Roberts.

Work orders were issued in numerical sequence, covering the accumulation of costs of work performed for the account of sub-contractors, vendors, etc. At the time of completion of work order, an invoice was prepared and transmitted to the vendor or sub-contractor concerned. A "Status of Work Orders" was prepared monthly, showing the work order number, vendors' names, Ebasco purchase order number, Unit to which the work order applied, our field invoice number, when billed, and the amount involved. Distribution of this report was the same as distribution of work orders, five copies to Public Service, three copies to Ebasco, New York, and four copies to Ebasco Field Office.

General Account (Working Fund): An initial advance of $10,000 was deposited in the First National Bank of Denver, Colorado, July 28, 1948. Subsequent deposits, $15,000, September 22, 1948, $25,000, October 13, 1948, $25,000, December 14, 1948, $75,000, March 22, 1949, and $50,000, February 7, 1950, brought the General Account to a total of $200,000.

Payroll Account: An initial advance of $500 was deposited in the American National Bank of Denver, Colorado, August 5, 1948. Subsequent deposits, $1,000, October 14, 1948, $8,500, March 4, 1949, and $5,000, September, 1949, brought the Payroll Account to a total of $15,000. This account was built from funds withdrawn from the General Account and was a part thereof.

Petty Cash Account: A Petty Cash Fund of $750 was established by funds withdrawn from the General Account. Initial withdrawal of $100 was made October 21, 1948, with subsequent withdrawals of $150 May 10, 1949, and $500, June 1, 1949. This account was also an integral part of the General Account.

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Withdrawals from the General Account were by regular Ebasco Voucher Check, form A-7, which required any two (2) of the following signatures: B. A. Snow, Construction Superintendent; E. Rans, General Construction Supervisor; W. I. Milburn, Resident Engineer; M. Whitmore, Accountant; and R. C. Booth, Construction Manager, whose signature was later superseded by that of F. S. Sawyer, Construction Manager. Restoration of withdrawals from this account were by regular voucher checks of the Public Service Company of Colorado in payment, upon presentation, of Ebasco Reimbursement Requests, form A-17,

Withdrawals from the Payroll Account were by regular Ebasco payroll checks, form T-12A, requiring one (1) of the aforesaid signatures. Restoration of withdrawals from this account were made through an Ebasco voucher check in payment of an Account Payable Voucher, form A-6, supported by a copy of the approved field payroll.

Petty cash disbursements were made by the Accountant. This fund was kept in cash in the vault of the field office, and was used for payment of photographs, blueprints, postage, express, drinking water service, office supplies, and small items of construction materials not warranting the issuance of a Field Purchase Order. In most cases, a numbered "Teller's Slip", was issued by the Field Purchasing Agent, coded, approved by the Construction Superintendent, Resident Engineer, or the Accountant and signed, as cash received, by the person actually making the payment. This slip was then attached to the paid invoice or delivery ticket. Restoration of expenditures of this fund was made by Ebasco Voucher check to the Accountant through an Account Payable voucher supported by Petty Cash Reimbursement Sheet, form A-12.

Monthly Bank Statements, covering the general and payroll accounts, were secured from the respective banks by the auditing department of the client company each month and reconciled to construction funds advanced as reflected in their ledgers against Ebasco Services, Incorporated. The statements were then forwarded to the Ebasco field office, where they were reconciled to book balances. These reconciliations, form A-13, were then transmitted to Mr. G. P. Redden, Ebasco, New York, and to Mr. D. P. Roberts, Public Service Company, Denver, Colorado.

Contracts

Practically all of the major field office contracts were on either a lump sum or unit price basis. The lump sum type contract required very little supervision, but close inspection was necessary to make certain that the proper materials were used and that first-class workmanship was provided. Material furnished by the contractor was received and reported on form T-5, and approved by the proper supervisor and the warehouseman.

The unit price contracts required Ebasco supervision and inspection. Material for this type contract was almost entirely furnished by the owner; however, after recording by Ebasco Services, Incorporated, it was the responsibility of the contractor to receive and care for this material until installed.

Sub-Contracts

Contractors on cost plus work were required to furnish Contractor's Daily Labor Reports, form T-6b, which were checked, approved, extended, coded and filed to substantiate billings when made. Ebasco time checkers made daily checks of all subcontractor's employees on both Contract and Cost Plus work.

Payment to the lump sum contractor was made in full at the completion of the contract, and after approval by the owner.

Payment to the unit price contractor was made monthly or periodically on a contractors estimate, form 502, which was made up by the cost department, checked by the Resident Engineer and the Accountant, and approved by the Construction Superintendent. Payments to cost plus contractors were made periodically on billings which were backed up by the daily approved time sheets. Final payment to all contractors was made after quantity checks and determination that the work was satisfactory, and approved by the Public Service Company of Colorado, the Resident Engineer, the Accountant, and the Construction Superintendent. A form letter was used for these final payments.

Insurance coverage carried by the contractor was set and approved by the Public Service Company of Colorado legal department, and certificates of validity were furnished the owner from the contractor's insurance company.

Each contractor was required to carry insurance as follows:

1 - Workman's Compensation

2 - Bodily Injury and Property Damage
  (a) PL & PD
  (b) Contractors contingent liability
  (c) Automotive liability

Payrolls

Payrolls were prepared weekly and payment made by check. Payroll periods originally were from 12:01 AM Thursday through 12:00 midnight Wednesday, and payment made to employees Friday afternoon each week. As of October 14, 1948, a new payroll period was established, 12:01 AM Monday through 12:00 midnight Sunday, and payment made to employees Wednesday afternoon each week. Field employees were checked in each morning by picking up their brass numbers corresponding with the numbers on celluloid buttons issued to the individual. Time checkers made two field checks daily, one in the middle of the forenoon and one during the afternoon. A final night check was made when employees turned in their brass checks before leaving the property. Regular Ebasco forms were used in the timekeeping department: Employment Card, form T-1; Change of Rate Notice, form T-3; Notice of Discharge - Quittance, form T-4; Daily Check Sheet, form T-5; Foreman's Daily Report, form T-6a; Employee Time and Tax Record, forms T-8b and T-8d; Construction Payroll, form T-9; Payroll Distribution Ledger, form T-10a; and Payroll Check, form T-12a. Foreman made up and turned in a report each day which was checked against the Time Checker's daily check sheet, turned over to the Cost Department for coding, and then given to the timekeeper for extending and posting to the Time and Tax Record. Foreman's Reports were then handed to the Payroll Distribution Clerk, who made a daily recap of hours and money to each coded account and posted to the Payroll Distribution ledgers. The Foreman's reports became a permanent part of the voucher payable, and the time checker's check sheets were filed for future reference. Construction pay-payrolls were typed from Employee Time and Tax forms in quadruplicate. One copy each for the original and two copies of the Account Payable Voucher and the quadruplicate filed in a post binder for ready field office reference. All labor was engaged by and considered employees of Ebasco.

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On January 7, 1952, Employee Time and Tax Records were split into two (2) payrolls. One payroll consisted of crafts only, and the second payroll consisted of all office personnel, supervisors and field engineering crews. This second payroll was kept strictly confidential and all checks sealed in window envelopes before delivery to the individual. This confidential payroll was discussed with Mr. John Connell, Auditor, of the Client Company, before it was actually put into operation and, with his concurrence, was formally adopted on the above date.

Payroll deductions from employee's earnings consisted of: Federal Old Age Benefit - 1% of earnings up to and including $3,000 through December 31, 1949; 1-1/2% of earnings up to and including $3,000 for the year 1950; 1-1/2% of earnings up to and including $3,600 from January 1, 1951, to the conclusion of the project; Federal Withholding Tax - withheld in accordance with Circular E, as revised each year and supplement issued October, 1951, by the Commissioner of Internal Revenue, Washington, D. C. Amounts withheld from employees for Federal Income Tax and Old-Age Benefit, along with the employer's contribution for Old-Age, Federal Unemployment and State Unemployment, were reported on forms T-16 Rev., T-17a Rev., and T-17b Rev., and remitted to Ebasco New York Office for transmittal to the Governmental Authorities.

Insurance

Ebasco Services, Incorporated, New York Office, furnished the following insurance:

Workmen's Compensation and Employer's Liability

Policy Number	Insurance Company	Term
ELUB 2541252	Travelers Ins. Co.	12/31/47-48
ELUB 90345	Travelers Ins. Co.	12/31/48-49
ELUB 535370	Travelers Ins. Co.	12/31/49-50
ELUB 1169799	Travelers Ins. Co.	12/31/50-51
ELUB 2046705	Travelers Ins. Co.	12/31/51-52

Coverage -
Statutory in accordance with Colorado Workmen's Compensation and Occupational Disease Law. Employers' Liability - Limit $100,000 each accident for injuries other than Occupational Disease; $50,000 each person, $100,000 each accident for Occupational Diseases.

Primary Public Liability and Property Damage

Policy Number	Insurance Company	Term
SLG 2541253	Travelers Ins. Co.	12/31/47-48
RDS 403109	Travelers Ins. Co.	12/31/48-49
SLG 90346	Travelers Ins. Co.	12/31/48-49
RDS 535373	Travelers Ins. Co.	12/31/49-50
SLG 535371	Travelers Ins. Co.	12/31/49-50
SLG 1169800	Travelers Ins. Co.	12/31/50-51
SLG 2046706	Travelers Ins. Co.	12/31/51-52

Coverage -
Third party liability for personal injury and property damage. Limits $5,000 each person, $10,000 each accident for personal injury; $5,000 each accident, $25,000 aggregate for property damage.

Automobile Public Liability and Property Damage (Owned Cars)

Policy Number	Insurance Company	Term
A-846900	Hartford Accident and Indemnity Company	1/1/47-48
AB-289200	Hartford Accident and Indemnity Company	1/1/48-49
AE-192300	Hartford Accident and Indemnity Company	1/1/49-50
AE-768200	Hartford Accident and Indemnity Company	1/1/50-51
AH-244300	Hartford Accident and Indemnity Company	1/1/51/52
AH-710600	Hartford Accident and Indemnity Company	1/1/52/53

Coverage -
Third party liability for bodily injury and property damage arising out of the use of listed owned automobiles.

Limits:
Up to 12/31/51 -
$5,000 each person, $10,000 each accident for bodily injury; $5,000 each accident for property damage.

After 12/31/51 -
$10,000 each person, $10,000 each accident for bodily injury, $10,000 each accident for property damage.

Automobile Public Liability and Property Damage
(Hired and Non-Owned Equipment)

Policy Number	Insurance Company	Term
MS 23357	Sun Insurance Company	6/30/47-48
MS 25930	Sun Insurance Company	6/30/48-49
MS 25995	Sun Insurance Company	6/30/49-50
MS 26485	Sun Insurance Company	6/30/50-51
MS 26798	Sun Insurance Company	6/30/51-52

Coverage -
Third party liability for bodily injury and property damage arising out of the use of hired and non-owned automobiles.

Limits -
$100,000 each person, $300,000 each accident for bodily injury; $50,000 each accident for property damage.

Excess Public Liability and Property Damage

Policy Number	Insurance Company	Term
48421	Lloyd's	12/31/47-48
67461K)	Lloyd's	12/31/48-49
68636K)	Lloyd's	12/31/48-49
68637K)	Lloyd's	12/31/48-49
76627K)	Lloyd's	12/31/49-50
76628K)	Lloyd's	12/31/49-50
76629K)	Lloyd's	12/31/49-50
K5446)	Lloyd's	12/31/50-51
K5447)	Lloyd's	12/31/50-51
K5448)	Lloyd's	12/31/50-51
CN117052)	Lloyd's	12/31/51-52
CN117053)	Lloyd's	12/31/51-52
CN117054)	Lloyd's	12/31/51-52
CN117055)	Lloyd's	12/31/51-52

Coverage -
Third party liability for personal injury and property damage.

Limits:

1947-48	-$ 200,000
1948-51 Incl.	-$1,000,000
After 12/31/51	-$2,000,000

This coverage is in amounts in excess of the coverage provided under the primary policies including those covering owned and hired automobiles).

Fidelity Insurance

Bond Number	Insurance Company	Term
5262954 AS	National Surety Co.	6/1/45-51
5340893 AS	National Surety Co.	6/1/51-54

Coverage -
Loss of money or other property caused by dishonesty of any employee(s).

Limit: -
$1,000,000 each loss

Flat Premium charged covering all operations.
No specific project segregation.

Inland Marine-Transportation Insurance

Policy Number	Insurance Company	Term
TPX 723097	National Fire Ins. Co.	7/29/48-49
1TFX 718442	National Fire Ins. Co.	7/29/49-50
1TFX 735202	National Fire Ins. Co.	7/29/50-51
1TFX 718447	National Fire Ins. Co.	7/29/51 to 9/1/51
CM 15537	Lloyd's	9/1/51 to 7/1/52

Coverage -
Insured against all risks of loss on material and equipment during transit and loss during loading and unloading including hoisting, rigging, or installation operations, caused by breaking and or parting of tackle and equipment limited to $100,000 in any one casualty.

Public Service Company of Colorado, Denver, furnished the following insurance:

Automobile - Fire and Theft (Broad Form)

Policy Number	Insurance Company	Term
AN 41705	Niagara Fire Ins. Co.	12/4/47/48
AN 25299	Niagara Fire Ins. Co.	12/4/48/49
AN 13496	Niagara Fire Ins. Co.	12/4/49/50
D184300	Planet Ins. Co.	12/4/50/51
D184574	Planet Ins. Co.	12/4/51/52

Coverage -
Fire, lightning, transportation and theft (broad form).

Construction Equipment

Policy Number	Insurance Company	Term
AN 41705	Niagara Fire Ins. Co.	12/4/47-48
AN 25299	Niagara Fire Ins. Co.	12/4/48-49
AN-13496	Niagara Fire Ins. Co.	12/4/49-2/20-50
SP 55139	Planet Ins. Co.	2/20/50-51
SP 88805	Planet Ins. Co.	2/20/51-52
SP 138819	Planet Ins. Co.	2/20/52-55

Coverage -
Fire, Lightning, derailment or overturning.

Fire - Blanket Form

Policy Number	Insurance Company	Term
209727	Nat'l Fire Ins. Co.	12/1/49-52

Coverage -
100% of actual cash value at time of loss.

Turbine Explosion

Policy Number	Insurance Company	Term
193-4269	The Hartford Steam Boiler Insp. & Ins. Company	From 10/1/50

Coverage -
Explosion - Limit per accident $10,000. Excess in amount of $1,500,000 with Lloyd's of London.

Boiler and Boiler Piping Explosion

Policy Number	Insurance Company	Term
193-3868	The Hartford Steam Boiler Insp. & Ins. Company	9/11/50
"	" " "	2/9/51
"	" " "	10/5/51
193-5899	" " "	From 2/1/52

Coverage -
Explosion - Limit per accident $2,000,000.

Organization

Ebasco Services Incorporated provided the services of their New York Office design and construction departments, the latter including the services of Mr. R. C. Booth and Mr. F. S. Sawyer as construction managers. The latter replaced the former, who was reassigned to the Project in Greece, on August 31, 1950. The Construction Manager organized the field office staff and exercised general supervision over the entire functions performed by the New York Office engineering and construction staff relative to this project including preparations of specifications, outline of proposals, and contracts for field contion and assisted in co-ordinating engineering and purchasing with the construction program. This service functioned through contact with the following personnel of the Public Service Company; with Mr. M. M. Koch, Vice President Electrical Operations, on matters of policy; with Mr. R. F. Throne, Superintendent Steam Production, on mechanical construction; with Mr. W. D. Hardaway, Superintendent Hydro-Electrical Production and Transmission, on electrical construction; with Mr. John Connell, Auditor, on accounting; with Mr. D. P. Roberts, Property Accountant, on cost accounting; and with Mr. Roy T. Blanchard, Purchas-Agent and Traffic Manager, on traffic and purchasing.

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Ebasco supplied the following field personnel:

Title	Name	Date of Termination
Construction Superintendent	B. A. Snow	
General Construction Suprvsr.	Ernest R. Rans	
Resident Engineer	A. L. Peterson	April 29, 1949
	Wm. I. Milburn	
Construction Accountant	M. Whitmore	
Mechanical Supervisor	E. Curtis	April 27, 1951
Mechanical Engineer	Bruce W. Bates	
Asst. Mechanical Engineer	L. F. Keegan	January 11, 1952
Boiler Supervisor	R. L. Wright	November 16, 1951
Mechanical Inspector	Lou J. Poulos	
Electrical Engineer	James M. Morris	March 14, 1952
Electrical Inspector	Richard C. Dutton	January 12, 1951
	James E. Ratcliff	March 20, 1951
	Robert C. Hinsey	April 6, 1951
	James S. Marsh	June 4, 1951
	Paul M. Brebrick	December 14, 1951
Office Engineer	Charles G. Anderson	
Draftsman	Harold L. Rivers, Jr.	May 5, 1950
	Robert Crist	April 9, 1951
	M. D. VanWormer	
Cost Engineer	Nelson P. Harpold	January 15, 1951
	Frank L. Ulmer	September 19, 1950
	John E. Walker	December 15, 1950
	Charles E. Lott	November 16, 1951
	Stewart Keith	
Cost Clerk	Charles W. Ellson	April 21, 1950
	Orrin J. Stransky	February 20, 1951
	Lewis A. Cota	November 17, 1950
	John D. Norris	March 23, 1951
	Benjamin T. Watkins	February 22, 1952
	Kenneth N. Kinney	October 19, 1951
	David W. Cox	June 11, 1951
	Ralph F. Ostrom	August 3, 1951
	Chester R. Dow	December 7, 1951
	L. W. McDonough	April 11, 1952
	L. R. Bowen	
	Elmer H. Goetzinger	

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Title	Name	Date of Termination
Field Engineer	William H. Thomas	
Chief-of-Party	Emmett J. Connell	September 22, 1949
	Joseph Riggs	May 12, 1950
	Leo S. Fisher	November 24, 1950
	Charles H. Conlin	
Junior Engineer	Barton K. Leslie	July 10, 1951
	James M. Egan	October 24, 1951
Instrument Man	Maynard J. Bonesteel	October 21, 1948
	Carleton Whitehead	September 16, 1949
	William M. McMecham	October 13, 1949
	Allison H. Stocker	February 3, 1950
	James Covey	May 18, 1951
	Clyde Miller	April 13, 1951
	Glen D. Rohlf	March 28, 1952
	Palmer H. Moen	July 20, 1951
	Hazen H. Hunter	August 10, 1951
	Gwinn E. McCuistion	April 18, 1952
	Robert C. D'Urso	December 7, 1951
Chainman	Dudley C. Brewster	October 16, 1951
	Alfred A. Covey	February 1, 1952
	E. C. Graebing	
	Virgil R. Paine	
Rodman	Louis R. Soderburg	July 20, 1951
	W. H. R. McCormack	September 27, 1951
	Paul H. Miller	June 6, 1951
Field Inspector	Frank J. McInroy	June 3, 1949
	Marion S. Morrison	September 8, 1949
	Steven Hordinski	April 21, 1950
	Lawrence J. Dolan, Jr.	March 27, 1950
	Gerald E. Harnden	April 13, 1951
Nurse	Robert N. Sailer	February 19, 1951
	Gurney Hinshaw	
Receptionist	Elizabeth A. Clary	December 26, 1948
	Kathryn A. Nance	December 29, 1948
	Ellen S. Neeley	June 24, 1949
	Olive M. Jones	February 1, 1950
	Elizabeth M. Lefferdink	March 31, 1950
	Samuel F. Wagle	September 30, 1950
	Bernice K. Urbanczyk	January 15, 1951
	Connie M. Boyer	
Purchasing Agent	Martin M. Gilbert	April 15, 1949
	John W. Johnson	May 19, 1951
	Donald P. Durkee	

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Title	Name	Date of Termination
Purchasing Stenographer	Christmar I. Berg	June 15, 1951
	Geraldine V. Pettis	March 28, 1952
	Lonnie D. Wood	
Storekeeper	Curtis C. Lanphear	December 5, 1949
	Edgar H. Hayes	June 30, 1950
	Willis E. Tice	
Warehousemen	Joel E. Starnes	August 31, 1950
	Ronald A. Lebrecque	September 9, 1950
	Rudolph Sams	
	Carl Gagliano	
Chief Clerk	Albert H. Stahl	May 11, 1951
	Joseph M. Spaulding, Jr.	
Timekeeper	Paul A. Walter	November 18, 1949
	James P. Smith	January 25, 1952
	Darwin E. Welch	May 18, 1951
	Roger O. Williams, Jr.	
Time Checker	Joseph G. Keithline	September 1, 1950
	Harry R. Mossey	
Clerk	Marjorie L. Lindeman	January 5, 1950
	William R. Flynn	December 15, 1950
	Donald L. Staggs	June 30, 1950
	Nona M. Jones	June 29, 1951
	William G. Gaiser	May 15, 1951
	Morris L. Dennis	June 27, 1950
	Vincent J. Poe	February 23, 1951
	Raymond C. Wachter	April 27, 1951
	Herman Settle	March 30, 1951
	George Menzak	
	Leonard Crandall	April 13, 1951
	James Urich	May 16, 1952
	Shirley E. Kemper	September 25, 1951
	Clay W. Ritchey, Jr.	February 1, 1952
	Louise Fugate	March 28, 1952
	Veronica M. Harrison	December 19, 1951
	Sarah Lee	December 19, 1951
	Amalia Sivic	
	Kenneth Shaffer	February 22, 1952
	H. A. Mereness	
Stenographer-Typist	Ruth M. Webster	April 15, 1949
	Ruth J. Riggins	May 4, 1951
	Phyllis M. Honea	March 29, 1950
	Anne M. Jones	March 31, 1950
	Patrick T. Slane	April 30, 1951
	Melvin L. Strohmaier	June 20, 1950
	Marian L. Atterbury	March 30, 1951
	Ruth N. Myers	July 18, 1950
	John M. DeGray	

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Title	Name	Date of Termination
Stenographer-Typist (Cont'd)	Georgene F. Wragge	May 23, 1951
	Ruth F. Sebastian	
	Faith L. Korbelik	August 16, 1951
	Barbara Dunmore	January 11, 1952

New York

Mechanical Engineer	Robert B. Beers
Electrical Engineer	A. W. Huseby
Plant Betterment Engineer	John H. Moore
Cathodic Protection Eng.	John H. Collins
Accountant	A. E. Moyle
Accountant	R. G. Speiker
Estimating Engineer	Fenimore Owen
Estimating Engineer	Andrew W. Wilcox

CONTRACTOR'S PERSONNEL

Allis Chalmers Manufacturing Company	(Condensers, Units 1 & 2 Transformers, Unit 2)
Dale Perkins	Erector
P. R. Pollock	District Manager
I. McNiece	Service Representative
Apex Wood Products, Inc.	(Lobby Counter)
P. Korte	Foreman
B & B Engineering & Supply Company	(Heat Insulation)
M. S. Epperson	Superintendent
E. O. McGraw	Superintendent
Babcock & Wilcox Company	(Boiler Units)
W. W. Fowler	Erector
J. Perkins	Erector (Night Shaft)
W. B. Beisel	Service Engineer (Units 1 & 2)
C. P. Pearson	Service Engineer (Unit 3)
Diamond Power Specialties Corp.	(Soot Blowers)
H. E. Curtis	Service Engineer
C. Robb	Service Engineer
G. H. Stickford	Service Engineer
National Boiler Casing Company	(Boiler Casing)
C. Frost	Erector Units 1 - 2
M. Hrubic	Erector Unit 3

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Babcock & Wilcox Company (Cont'd)	
Stearns-Roger Mfg. Company	(Refractory)
W. Kelly	Foreman
Sturdevant Division of Westinghouse Electric Company	(Fans)
J. Baches	Service Engineer
Bell Plumbing and Heating Company	(Station Plumbing)
Robert Peterson	Sales Engineer
Guy Wright	Foreman
Byron-Jackson Company	(Boiler Feed Pumps)
A. A. Pechuls	Erector
W. K. Shone	Service Engineer
Collier Electric Company	(Electrical Construction)
M. D. MacGregor	Superintendent
G. Rehm	Foreman
O. Mrsny	Clerk-Timekeeper
Colorado & Southern Railway	(Railroad Spurs)
R. F. Harris	Roadmaster
Realock Fence Division of Colorado Fuel & Iron Company	(Fence)
R. A. Sutherland	Erection Superintendent
R. E. Bley	Asst. Manager
Combustion Engineering Company, Inc.	(Unit 2 Pulverizers)
Fred Howell	Erector
G. Miller	Erector, after Nov. 28, 1950
J. H. Hedditch	Erector, after April 16, 1951
Construction Specialties Company	(Sound Proofing - Control Rooms)
Ray Carson	Foreman

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Craftsman Painters and Decorators	(Painting)
R. D. Lewis	Foreman
C. McBride	Foreman, after June 5, 1951
D. W. Hamilton	Foreman, after Jan. 22, 1952
Custodis Construction Company, Inc.	(Stacks)
J. Bond	Erector (No. 1 Stack)
E. Gorelo	Erector (No. 2 Stack Concrete)
A. Pouppert	Erector (No. 2 Stack Lining)
Detroit Steel Products Company	(C-Panels)
T. W. Freeman	Erector
Flexicore Company of Colorado	(Roof Slabs)
N. Lindquist	Foreman
General Electric Company	(Unit 1 & 3 Turbines)
H. Andrews	Locomotive Service Engineer
J. O. Reichen	Erector (Unit 1 Turbine)
L. Meade	Start-up Engineer (Unit 1)
Earl Martin	Erector (Unit 3 Turbine)
M. I. Cleveland	Start-up Engineer (Unit 3)
Grinnell Company	(Transformers Fire-Protection)
S. Tiege	Foreman
Kansas City Structural Steel Company	(Station Building Structural Steel)
John F. Beasley Construction Company	(Erection)
C. D. Ratcliff	Superintendent (Units 1 - 2)
T. C. Koogle & Son	(Well Drilling)
George C. Koogle	Superintendent
Manning, Maxwell and Moore	(Station Crane)
F. J. Lepres	Erector

Marley Company	(Cooling Towers)
R. W. Speer	Erector (Units 1 & 2)
W. E. Grimsley	Erector (Unit 3)
R. Roble	Service Engineer
McCarty-Johnson, Inc.	(Heating, Ventilating and Air Conditioning.)
Agaton Anderson	Foreman Units 1 - 2
James Fields	Foreman Unit 3
Minneapolis-Honeywell Regulator Co.	(Controls)
D. D. Pearsall	Service Engineer
R. H. Hillbread	Service Engineer
Fox Metal Products Corporation	(Ductwork)
K. Sadler	Foreman
McMurtry Manufacturing	(Window Glazing)
Albert A. Spenst	Foreman
Merrick Scale Company	(Coal Scales)
E. D. Fivecote	Erector
Midwest Piping and Supply Company	(Plant Piping)
I. D. Lehman	Superintendent
C. Evans	Timekeeper
O. F. Rejholec	Timekeeper
Otis Elevator Company	(Elevators)
W. H. Lapean	Erector
Raymond Concrete Pile Company	(Substructure Piling)
N. G. Pastore	Foreman (Soil Tests)
R. R. Moyer	Superintendent (Units 1 - 2-3)
L. E. Dock	Clerk (Unit 1-2)
G. J. Higgins	Clerk (Unit 3)
Jerry Healy	Foreman (Unit 1)
Wm. Engelbrecht	Foreman (Unit 2)
Wm. Guth	Foreman (Unit 3)
John C. Reeves & Company	(Floor Covering)
L. A. Bott	Foreman

Peter Seerie, Inc.	(Initial Site Grading)
Rondal McGlivery	Supervisor
R. J. Tipton	(Preliminary Surveys)
J. Osborn	Engineer
Webster Engineering Company	(Coal Handling System)
W. J. Schneider	Erector
Western Elaterite Roofing Company	(Building Roofs)
M. E. Wille	Foreman
Westinghouse Electric Corporation	(Unit 2 Turbine-Generator, Condenser & Units 1 & 3 Transformers)
W. H. Bagley	Erector (Condenser)
R. Kaley	Erector (Turbine-Generator)
G. A. Ratcliffe	Erector (Turbine-Generator)
L. Woods	Service Engineer (Transformers)
W. W. Wilmore Nurseries	(Landscaping)
S. Wilmore	Proprietor

MANUFACTURER'S REPRESENTATIVES

The Autocall Company	(Annunciators)
I. A. Klein	Representative
F. E. Seaton	Service Engineer
Automatic Electric Sales Company	(Intrasite Telephone)
O. E. Ragsdale	Service Engineer
Bailey Meter Company	(Instruments)
A. Danielson	Service Engineer
L. F. Monohan	Service Engineer
Edwards Valve, Incorporated	(Valves)
S. S. Dunn	Service Engineer
J. S. Weltey	Service Engineer
Flexicore Company of Colorado	(Roof Slabs)
G. F. Bettcher	Representative

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Grinnell Company	(Transformer Fire Protection)
P. W. Menlengracht	Representative
Leeds and Northrup Company	(Instruments)
R. L. Wham	Service Engineer
J. E. Casey	Service Engineer
Manning, Maxwell and Moore, Inc.	(Valves)
F. Redel	Service Engineer
McCarty-Johnson, Inc.	(Heating, Ventilating and Air Conditioning)
E. L. Potarf	Representative
W. F. Rogers	Representative
McMurtry Manufacturing	(Window Glazing and Paint)
A. G. Barr	Sales Engineer
Mountain States Telephone & Telegraph Company	(Telephone System)
A. W. Frisch	Representative
L. N. Crispelle	Representative
Henry Pratt Company	(C. W. Valves)
R. B. Saar	Service Engineer
John C. Reeves & Company	(Floor Covering)
T. W. Keeton	Representative
United Conveyor Corporation	(Ash Sluicing System)
C. A. Crouch	Service Engineer
Worthington Pump and Machinery Corporation	(Compressors)
Ray Keys	Service Engineer
Fred L. Ellis	Sales Engineer
P. F. Robbins	Sales Engineer

EBASCO SERVICES INCORPORATED
PAYROLL INSURANCE RATES

Carpentry NOC	WC & EL	PL	PD
1948	2.809	.350	.155
1949	2.853	.210	.090
1950	2.580	.210	.090
1951	2.539	.020	.019
1952	1.851	.016	.019
Grad Inc Bur & Fl			
1948	3.159	.150	.206
1949	3.212	.090	.120
1950	2.814	.090	.120
1951	2.772	.020	.019
1952	2.571	.016	.019
Conc or Cement Wk			
1949	1.192	.222	.165
1950	1.141	.312	.120
1951	1.101	.020	.019
1952	.897	.016	.019
Elect Wrg in Bldgs			
1949	1.211	.054	.113
1950	1.140	.054	.113
1951	1.100	.020	.019
1952	.881	.016	.019
Painting Steel			
1949	11.423	.444	.750
1950	11.095	.444	.750
1951	11.045	.020	.019
Plastering NOC			
1949	1.585	.072	.120
1950	1.441	.072	.120
1951	1.400	.020	.019
Sewer Const			
1949	3.829	.732	.938
Iron Brass Brnz Wk			
1950	1.793	.222	.135
Paint Dec Pap Hng			
1950	1.979	.054	.263
1951	2.013	.020	.019
1952	1.478	.016	.019
Road Construction			
1951	2.648	.020	.019
1952	2.284	.016	.019

Clerical NOC	WC & EL	PL	PD
1948	.099	.005	.0065
1949	.101	.003	.0038
1950	.090	.003	.0038
1951	.061	.010	.019
1952	.050	.008	.019
Air Cond & Vent			
1949	1.774	.060	.135
1950	1.626	.060	.135
1951	1.586	.020	.019
1952	1.276	.016	.019
Const Const NOC			
1949	2.701	.222	.165
1950	3.167	.222	.165
1951	3.125	.020	.019
1952	1.952	.016	.019
Fence Const			
1949	1.327	.222	.135
1950	1.214	.222	.135
1951	1.213	.020	.019
1952	1.005	.016	.019
Pile Driving			
1949	6.897	.492	.750
1950	6.651	.492	.750
1951	6.606	.020	.019
Railroad Const			
1949	2.915	.192	.188
1950	2.777	.192	.188
1951	2.736	.020	.019
Water Mains or Coons			
1950	2.584	.732	.938
Sheet Metal Work			
1950	1.626	.060	.135
1951	1.586	.020	.019
Roofing			
1951	4.434	.020	.019
1952	3.528	.016	.019
Tank Erect or Rep			
1952	1.914	.016	.019
Executive Suprvrs			
1948		.090	.0323
1949		.054	.0188
1950		.054	.0188

Elect Apparatus	WC & EL	PL	PD
1948	1.739	.160	.258
1949	1.771	.096	.150
1950	1.695	.096	.150
1951	1.655	.020	.019
1952	1.531	.016	.019
Boiler Inst & Rep			
1949	2.459	.096	.150
1950	2.360	.096	.150
1951	2.318	.020	.019
1952	1.914	.016	.019
Conduit Const			
1949	2.026	.258	.338
1950	1.938	.258	.338
1951	1.897	.020	.019
1952	1.580	.016	.019
Gas Mains or Conns			
1949	2.719	.732	.938
1951	2.543	.020	.019
1952	2.106	.016	.019
Masonry			
1949	2.097	.168	.120
1950	1.952	.168	.120
1951	1.911	.020	.019
1952	1.314	.016	.019
Steel Frm Structrs			
1949	11.423	1.020	.563
1950	11.095	1.020	.563
1951	11.045	.020	.019
Elevator Erect			
1950	1.533	.228	.270
Metal Sash & Doors			
1950	1.703	.222	.135
1951	1.662	.020	.019
1952	1.372	.016	.019
Fur & Fix Inst			
1951	.777	.020	.019
Stairs Rails Balcs			
1952	9.391	.016	.019
Independent Contrs			
1948		.040	.026
1949		.024	.015
1950		.024	.015

Exc Excl Rock	WC & EL	PL	PD
1948	3.159	.820	1.290
1949	3.212	.492	.750
1950	2.814	.492	.750
1951	2.772	.020	.019
1952	2.571	.016	.019
Chimney Inc Fdn			
1949	7.038	.168	.120
1950	6.826	.168	.120
1951	6.780	.020	.019
1952	5.676	.016	.019
Drilling NOC			
1949	3.618	.222	.135
1950	3.470	.066	.133
Irn or Stl Er NOC			
1949	7.076	.564	.450
1950	6.836	.564	.450
1951	6.791	.020	.019
1952	5.643	.016	.019
Plumbing NOC			
1949	1.070	.084	.150
1950	1.222	.084	.150
1951	1.182	.020	.019
1952	.908	.016	.019
Drainage Ditches			
1949	2.446	.090	.225
1951	2.292	.020	.019
Telephone System			
1950	2.202	.336	.338
Millwright Work			
1950	1.695	.096	.150
1951	1.655	.020	.019
1952	1.531	.016	.019
Steam Mains or Conns			
1951	2.543	.020	.019

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FORM IN-1

EBASCO SERVICES INCORPORATED

FINAL

FIRE INSURANCE SCHEDULE

PREPARED BY J. M. Spaulding, Jr. Public Service Company of Colorado (COMPANY)

APPROVED M. Whitmore Arapahoe Steam Electric Station (PROJECT) MONTH OF October 1951

ITEM	DESCRIPTION	PREVIOUSLY REPORTED	INCREASE THIS MONTH	TOTAL TO DATE
	PRODUCTION PLANT			
2	Fire Protection and Service Water Systems	28,670	148	28,818
3	Station Building	1,241,029	14,695	1,255,724
6	Fuel and Ash Structures	111,670		111,670
7	Coal Equipment	1,077,466	8,716	1,086,182
9	Boiler Equipment	3,244,611	(144,798)	3,099,813
10	Boiler Plant Auxiliaries	664,817	23,176	687,993
11	Plant Piping	1,234,657	27,031	1,261,688
12	Turbogenerator Equipment	3,240,068	(11,053)	3,229,015
13	Condensers and Auxiliaries	1,070,111	(28,986)	1,041,125
14	Turbine Room Auxiliaries	117,755	2,180	119,935
15	Main Sw Control & Protective Equipment	972,564	29,722	1,002,286
18	Miscellaneous Power Plant Equipment	30 350	87	30,437
	TRANSMISSION PLANT			
20	Outdoor Structures	44,656		44,656
21	Transformer Equipment	446,079	537	446,616
22	High Voltage Sw Control & Prot Equipment	355,103	9	355,112
	OTHER			
25	Office and Warehouse Building	71,785		71,785
26	Craft Buildings and Contents	2,522		2,522
27	Portable Buildings	12,266		12,266
32	Lumber and other materials on yard	12,077		12,077
33	Indirects and Overheads	3,329,280	(19,634)	3,309,646
	Total Project	17,307,536	(98,170)	17,209,366

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SECTION III
SPECIFIC HISTORY

SECTION III
SPECIFIC HISTORY

PUBLIC SERVICE COMPANY OF COLORADO
ARAPAHOE STEAM ELECTRIC STATION
1950-51 88,000 KW INSTALLATION
1951 44,000 KW EXTENSION

SECTION III - SPECIFIC HISTORY

STRUCTURES AND IMPROVEMENTS

IMPROVEMENTS TO SITE

As this was a completely new project, considerable grading and area preparation was necessary. As mentioned in the General Feature section of this report, the site was chosen and purchased as a result of the power supply study made by Ebasco Services and issued September, 1947. Almost at the beginning of the grading, a situation developed which caused considerable legal action. In attempting to level one of the high mounds of earth, there was uncovered on August 24, 1948, what appeared to be an old cemetery containing three skeletons, one adult and two children, which were removed and re-interred in Riverside Cemetery by court order. After this incident, grading continued with good progress. The excavation for switchyard foundations was carried on at the same time with the site grading, the excavated material being used as backfill in low areas. Backfill required at a later date around the switchyard foundations was secured from the circulating water tunnel excavation.

As the subsurface material consists almost entirely of gravel to a considerable depth, no great amount of weather surfacing was required; however, the transformer and switchyard areas were surfaced with granite chips for appearance and improvement to walking conditions. Asphalt topped roads with approximately 6" rock base were built as access roads from the South Platte River Drive to the southeast corner of the building (main entrance), thence along the east side of the building to the line of induced draft fans, thence west along the north side of these fans to the west end of the warehouse. In addition to this road, asphalt paving was provided in the area between the induced and forced draft fans at each boiler and from the warehouse to the building along the railroad spur. The entire area blacktopped amounted to approximately 90,000 square feet.

Adequate yard drainage facilities consisting of catch basins, manholes, concrete and steel piping were provided where necessary around the building, coal storage and switchyard areas.

Shortly after the completion of the grading of the area just outside and along the east wall of the offices, an attempt was made to landscape this space by planting shrubs and flowers, but due either to the lateness of the season, or poor planting, these died, but were replaced at no additional cost by the nurseryman the next spring, 1951. Further landscaping was not begun until the spring of 1952, when planting of trees between the cooling towers and the South Platte River Drive was done to prevent vapor from interfering with motor vehicle driver's visibility. Also, shrubs and other plants were planted along the entrance road.

Considerable fill was required to provide sufficient elevation to bring in the railroad spur track and to provide track storage without undue grades. Approximately 152,375 cubic yards of earth fill was used and 8961 feet of track laid from the northwest entrance gate to and beyond the track hoppers in four tracks. Included in this line of tracks are two spurs, one through the turbine room between Units 2 and 3, and one to the east side of the pump house. 2396 feet of additional railroad track was built in two tracks along the west site fence as part of Unit No. 3 extension, making a total of 11,357 linear feet of railroad track within the site fence.

The entire site area of approximately 58.5 acres was fenced during the very early stages of construction. Ten thousand feet of fence material was purchased on local order SD-15, which provided also for erection on a footage basis when required. In February, 1952, it became necessary to close out the old order and issue a new order (SD3939) because of increased costs of material and labor; therefore, the fence purchased for and erected around the building was at an increase of slightly over 5%.

Yard lighting was provided for the immediate areas surrounding the plant, for the cooling tower area, coal storage area, the switchyard area and the main entrance roadway. High boulevard standards using mercury vapor lanps were used for roadway lighting. Flood lights were also used to advantage at strategic points on building and structure roofs. These lighting facilities consisted of various types of fixtures furnished on orders NY-77124, 77156, 77196 and 77198 and installed as described below.

The station area roadways are lighted by 15 standards and two sets of double flood light standards. The roadway lights consist of General Electric Company No. 79D, 400 watt mercury vapor lamps with General Electric harp to brackets, form 83D, and No. 207 globes, set on Pfaff and Kendall Catalogue No. C-395 standards, each 33' 3" high. The two track hopper standards each consist of one 1000 watt and 750 watt flood light fixture with wide beam reflectors, Crouse Hinds type ADE-16, Catalogue No. 42742 plain lens.

Concrete enclosed ducts were installed underground for use by the Bell Telephone Company in providing outside telephone services to the plant site. These ducts provided entrance to the site from both the north and south property lines and terminated at the building wall from whence the circuits were continued in steel conduits to control rooms No. 1-2, and 3.

Fire protection in the yard area consists of 15 strategically located fire hydrants. Eleven hydrants,located in the cooling tower, coal handling, and transformer areas are 6" pipe size with one 4½" pumper connection, and two 2½" hose connections. Four hydrants located in the switchyard area are 4" pipe size with two 2½" hose connections. Hydrants in the cooling tower area are tapped direct from the incoming 12" city water main, thereby eliminating the fire pump feature from them. All other hydrants are tapped from the 8" fire protection ring header that makes a complete loop inside the station building. Fourteen fire hydrants were purchased from the R. D. Wood Company on NY-77120, and three from the Board of Water Commissioners, City and County of Denver, on local orders SD-752 and SD-1552. A fire pump, purchased on NY-77165, is provided to assure ample water pressure at all times, being controlled by a pressure switch tapped into the fire protection ring header. Also, a fire truck pumper connection is provided at the east wall of the station building in case of complete power failure.

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A private 8 inch sanitary sewer was constructed from the plant site, north along South Lipan Street to West Evans Avenue, tying in at that point to an existing private sewer of the D. C. Burns Realty and Trust Company. Local order SD-80 was issued to the W. G. Rhodus Company to furnish all labor and material on a price basis of $1.70 per foot for 8 inch pipe and $1.40 per foot for 4 inch pipe. Manholes, of which 13 were constructed, were priced at $155.00 each. Work started on the sanitary sewer November 4, 1948, and was completed November 29, 1948. During construction of the discharge tunnel for the No. 3 cooling tower, it was determined that sewer manhole 10 would interfere with the tunnel. Local construction forces relocated manhole 10 and also ran the 4 inch sanitary sewer to the crusher house from manhole 11. Temporary toilet facilities for construction forces were provided by a 4 inch line from manhole 12 to the temporary construction office. A field toilet was also tied into this line.

Service Water System (Outside)

The securing of a water supply in the state of Colorado is rather unique in that it is one of only four states whose entire water supply was subscribed to and granted as early as 1850, so that at this date the only way water can be obtained is to either buy existing rights or buy water from those holding these rights. Considerable care must be exercised in securing either water or rights as apparently more rights have been granted than there is water to fulfill these rights. This makes rights valued in the order of standing and also it makes water available in the same order; therefore, it is possible to secure rights, but no water.

The city water supply was brought in from the north property line in a 12 inch pipe to a meter located at the ground floor of the building, just east of column line 6 and south of column line G. An underground extension to this line was installed along the north side of the building to Unit 3 for future installation of metering facilities.

A deep well was drilled in an attempt to reach a 1700 foot depth but just before this depth was reached the casing collapsed and this drilling was abandoned; however, two other deep wells were completed, one to a depth of 700 feet, and the other to a depth of 1700 feet. A deep well pump was purchased from the Layne Western Company for the 1700 foot well, but was not installed because sufficient water was obtained from the other sources. These two deep wells are capped for future use. Two shallow wells and three river wells were provided which now supply all of the service and make-up water required for the three units. Shallow well pump No. 1 of 850 gpm capacity, is provided with 30 hp motor driver, and shallow Well Pump No. 2, of 700 gpm capacity, is provided with a 15 hp motor driver. The river wells, each of 1,000 gpm capacity, require 20 hp motor drivers. The shallow well pumps were supplied by Layne Western Company on order NY-77102 and were first placed in service in August, 1950. Two of the river well pumps were furnished by Layne Western Company on order NY-77102 and were placed in service on December 1 and 2, 1950. The third river well pump was furnished by the Layne Western Company on order NY-77518 and was placed in service on November 16, 1951. Some difficulty was encountered in obtaining sufficient water from the river wells through the original casing, and it was decided to add a collector piping system into the river. This added feature consisted of approximately 120 feet of 36" perforated concrete pipe laid in a horizontal position several feet below the surface of the river bed and extending from the wells 94 feet west to center-line of manhole, and then 36 feet south, of which 21 feet is perforated pipe and 15 feet is Massey type

Cribbing and 10" minimum rock fill to center of river.

Piping from all wells was brought underground to the pump house where the water discharged into a large sump from which it was pumped into the plant service water system by three service water pumps. Two service water pumps were installed for the original construction. These pumps, each with a capacity of 2,000 gpm cold water against a total dynamic head of 100 feet, were furnished by Worthington Pump and Machinery Corporation on order NY-7742 and went into operation in October, 1950. A third service water pump (having the same capacity) was furnished by the same vendor on order NY-77456 for installation with Unit 3. This third pump was placed in service on November 7, 1951. Inside of the pump house and east of the service water pumps a control panel was located which contained the controls for well and service water pumps for Units 1 and 2. Also included on this panel were necessary gauges and instruments for these pumps. A second similar panel was installed adjacent to and north of the original panel for mounting controls and instruments for service water pump No. 3 and future pump No. 4.

Service water piping, for all Units, between the pump house and station building, is grouped in a common trench approximately 25 feet north of the East West Base Line. One ten inch line is provided for Units 1 and 2 and a second ten inch line is provided for Unit 3 and future Unit 4.

Service water for hydrogen and lube oil cooling is a "closed" system and is returned through an 8" line under pressure, to the circulating water system intake tunnel at the acid and chlorine feed pit. All other Service Water used as cooling water is an "Open" system. Funnels are provided in the discharge piping at the various pieces of equipment to allow visual checking of water flow, and hand testing of temperatures. The water is returned to the circulating water pump pit by gravity through a slightly pitched 10" line, entering at the southeast corner of the circulating water pump pit at elevation 5257'-0".

A six inch line running from the city water main in the station building to the pump house, provides emergency circulating water makeup. The line leaves the station building 9'4" east of column line 3 and follows the service water piping to the pump house.

Erection of Service Water Piping in the Pump House area started May 10, 1950, in order to take advantage of previous excavation required for Pump House construction. Piping from the Pump House Area to the Station Building started June 26, 1950, and was completed August 15, 1950, for Units 1 and 2. Unit 3 Service Water Piping was run from the Pump House to Column Line 5 along with Unit 1 and 2 piping in order to use the same trench excavation. The remainder of the Unit 3 Service Water piping was started July 12, 1951, and was completed August 7, 1951.

Station Building

Excavation for the building foundation for Units 1 and 2 was started on September 29, 1948. Work was stopped shortly afterwards, however, pending a change in basic foundation design from a mat type to piling. With a decision reached to use piling, excavation work commenced again January 31, 1949, and was completed March 18, 1949, with 4650 cubic yards excavated. Backfill to top of pile caps which was completed on February 16, 1951, amounted to approximately 3750 cubic yards. The installation of piling for Units 1 and 2 was started

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on January 31, 1949, and completed April 7, 1949, by the Raymond Concrete Pile Company under Order NY-7741. 562 step taper piles averaging in length from 25 feet to 35 feet and containing a total of 512 cubic yards of concrete were installed. Piling for supporting the turbine pedestal Nos. 1 and 2was installed at the same time. The placing of concrete pile caps began April 19, 1949, and was completed July 1, 1949, with a total of 667 cubic yards of concrete. Base plates for building columns for Units 1 and 2 were set and grouted between July 1, 1949, and August 5, 1949.

Excavation for the building foundation for Unit No. 3 was started on February 8, 1950, and completed on February 16, 1950, with 2250 cubic yards excavated. Backfill to top of pile caps which was completed on July 13, 1951, amounted to approximately 1860 cubic yards. The installation of piling for Unit No. 3, by the Raymond Concrete Pile Company under Order NY-77409, was started on February 28, 1950, and completed April 7, 1950. 289 step taper piles averaging in length from 25 feet to 35 feet and containing a total of 252 cubic yards of concrete were installed. Piling for supporting the turbine pedestal No. 3 was installed at the same time. The placing of concrete pile caps began April 21, 1950, and was completed August 26, 1950, with a total of 289 cubic yards of concrete. Base plates for building columns for Unit No. 3 were set and grouted between August 10, 1950, and September 1, 1950.

Reinforced concrete grade beams were installed between column foundations for supporting and providing finished appearance for the insulated steel "C" panel building enclosure. These grade beams extended under the west temporary wall and around machine shop and boiler areas. In addition concrete walls were built along the east and south sides from substructure depth to 10 feet above grade for appearance and to support the brick walls above elevation 5272.

The station building for all three units consists of thirteen bays, each of 24 feet, making a total building length of 312 feet. The width of the building, 140'6", is comprised of a turbine bay 40 feet wide between columns A and B, of a bunker bay 42 feet wide between columns B and D, and a firing aisle 10 feet wide between columns D and E. Additional areas, such as the switchgear rooms, fan rooms number 2 and 3, and the machine shop, are located between boilers, thus utilizing available space for station auxiliaries and eliminating a conventional auxiliary bay.

Structural steel framing for the station building was furnished by the Kansas City Structural Steel Company on order NY-7731 for Units 1 and 2, and on order NY-77408 for Unit 3. Erection for Units 1 and 2 was by Kansas City Structural Steel Company who, in turn, sub-contracted to John F. Beasley Construction Company, and was started on August 24, 1949, and completed on December 19, 1949, with approximately 1260 tons of steel set. Erection of steel for Unit 3 was by Ebasco forces, and started on August 31, 1950, and was completed on June 29, 1951, with approximately 750 tons of steel set. Miscellaneous steel for stairways, platforms, etc., was furnished on NY-77113 for Units 1 and 2 and NY-77442 for Unit 3. This miscellaneous steel aggregated approximately 14.4 tons for each unit.

Hand railing is of 1¼ inches steel pipe, all welded construction, using weld pipe fittings for turns and angles. Material was furnished fabricated by United Steel and Iron Works Company on Order NY-77125 for Units 1 and 2 and on Order NY-77443 for Unit No. 3. Some additional handrailing was purchased fabricated on local orders. All erection was by Ebasco forces. Erection was

started shortly after the first setting of stairways and walkways and continued throughout the construction period as needed.

Reinforced concrete floors of 9 inch thickness were placed throughout the entire building enclosure at the ground level in which were built the necessary concrete trenches for running the ash sluice piping and the pyrite piping around the coal mills. All of these trenches were provided with angle iron framework and checker plate covers. Sumps were provided on the ground floor for installation of sump pumps, one each in the center of each group of pulverizers. Floor drainage boxes with necessary piping to sumps were provided at necessary points in the ground floor.

Spacious office, locker, laboratories, first aid and conference rooms were provided at the east end of the main building. These rooms occupied two floors in a space 24'-0" feet wide by 83'-6½" long. A ladies toilet was provided on the first floor. Toilet facilities were also provided in the chief engineer's office, and shower baths and toilet facilities were provided in the second floor locker room. A small area was provided for a kitchen in which a sink was installed with room for range and refrigerator to be installed at some future date.

The east and south walls of the building above elevation 5272' are buff-colored brick. The laying up of these brick walls was started on November 21, 1949, for Units No. 1 and 2, including the offices, and was completed on April 21, 1950. Brick walls for Unit No. 3 were started on November 14, 1950, and completed on March 9, 1951. Ebasco forces were used in this work, which included the laying of glass blocks for windows in the south wall at elevation 5316 and 5338. Parapet walls with precast concrete coping were built along the east and south roof lines. All partition walls in the office area are of plaster finish and the ceilings are a suspended type with plaster finish and flush type fluorescent lighting fixtures. In an effort to make the control room reasonably soundproof, hollow glazed tile was used for its outside walls. In this tile wall along the south side is inserted thermopane windows to enable the operators to see into the turbine room. The ceiling is covered with sound-absorbent celotex and the side walls from about one-half way up to the ceiling are covered with perforated transite with accoustical material backing. A special drop ceiling of plastic material similar in shape to egg crating is suspended beneath the fluorescent lighting fixtures both for diffusion of light and aiding in preventing sound reverberations. For all outside walls which are not brick, insulated steel panels are used. These panels are made up of #18 USS gage steel plate with about 3 inches of insulation and are approximately 18 inches wide by 10 feet long. They are welded to an angle iron framework, except the temporary west end of the turbine room where they are bolted. These panels were furnished by Detroit Steel Products Company on Order NY-77107 for Units 1 and 2, and NY-77444 for Unit 3.

Reinforced concrete floors are at elevation 5287 (turbine operating level), at 5302 (evaporator level), at 5315 (deaerator level), and 5341 (shuttle coal conveyor level). The turbine operating floor is made up of three parts, each of approximately 7265 square feet for Units 1, 2 and 3. These areas include portions of the bunker bays between column lines B and D. The floors at the evaporator level for Units 1, 2 and 3 cover three areas of approximately 1978 square feet each. The floor at the deaerator level for Units 1, 2 and 3 also covers three areas of approximately 1402 square feet each; and the floor at the shuttle conveyor level covers an area of approximately 7066 square feet total area for Units 1, 2 and 3. In addition to these areas, there are, between

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boilers, two floor areas at elevation 5287, of approximately 3271 square feet each, on which are located the switchgear rooms for Units 1 and 2, 3 and 4, and three areas at elevation 5302 of approximately 816 square feet each on which the air conditioning and ventilating equipment is located for Units 1, 2 and 3. These latter are designated as fan rooms 1, 2 and 3.

Floor grating was installed at elevations 5287', 5402', 5317.33', 5328.17', 5325.42' in the building, which include walkways leading out to the turbine room roof. This grating was furnished by Blaw-Knox Company on Order NY-77114 for Units 1 and 2 and NY-77431 for Unit 3. All stair treads and nosings were of cast "Feralun" type and were furnished by the American Abrasive Metals Company on Order NY-77115 for Units 1 and 2, and NY-77432 for Unit 3. The turbine operating floor area bounded by columns A1-B1-B9 and A9 which is essentially for Units 1 and 2, is surfaced with approximately 2 inches of cement topping which includes 2 feet square by 1/2 inch deep imbedded aluminum frames, gray masterplate finish steel trowelled and waxed to a polish. This topping, except for waxing which was done by Ebasco forces, was furnished and applied by John C. Reeves and Company on local order SD-2867. The turbine floor area for Unit 3, which is bounded by columns A9-B9-B14-A14, is surfaced by 8"x8"x½" thick cement tile of gray color to match the surface of Units 1 and 2, and was furnished and installed by John C. Reeves and Company, on Order SD-4147. Asphalt tile floor covering was installed in the offices, control rooms, and on the observation platform in the east end of the turbine room at elevation 5302.02'. Approximately 7522 square feet of asphalt tile was installed for the three units, which was furnished by John C. Reeves and Company on local orders SD-2043 for Units 1 and 2, and SD-2706 for Unit 3.

Precast concrete slabs, 6 inches thick by 12 inches wide and ranging in length from 6 feet to 12 feet, were installed as the base roof material. These slabs were anchored to the building steel and supported the built-up 20-year bonded roof which consists of five layers of 15 pound felted roofing paper with gravel topping. The precast slabs were furnished by Flexicore Company of Colorado on order NY-77106 for Units 1 and 2 and NY-77463 for Unit 3. Cast in place concrete roof slabs were installed over the switchgear and fan rooms for all units. The built-up roofing was furnished and applied by Western Elaterite Roofing Company on local orders SD-1659 for Units 1 and 2, and SD-2696 for Unit 3. Approximately 38,817 square feet of this built-up roofing was applied to the three units.

The major portion of the hinged doors was of the hollow metal type and furnished by the Richmond Fireproof Door Company on order NY-77167 for Units 1 and 2, and NY-77482 for Unit 3. Rolling doors were installed in the wall at eachcondenser, in the north and south walls at the railroad track, and in the north wall of the pump house. These doors were furnished by the R. C. Mahon Company on order NY-77123 for Units 1 and 2, and NY-77441 for Unit 3.

Steel sash is of the Fencraft intermediate projected type with outside glazing. Approximately 2246 square feet of window sash were furnished for Units 1 and 2, and 730 square feet for Unit 3, by the Detroit Steel Products Company on order NY-77161 for Units 1 and 2, and NY-77466 for Unit 3.

Glazing for all windows, including the thermopane glass for the main entrance and control rooms, was furnished and installed by the McMurtry Manufacturing Company on local orders SD-1623 for Units 1 and 2, and SD-2957 for Unit 3.

The station crane was installed immediately upon its arrival on October 6, 1949. It is a Shaw Box Type "S", four motor, electrically operated, with main hook of 100 tons and auxiliary hook of 10 tons capacity. It was furnished by Manning, Maxwell and Moore Inc. on order NY-7748, and was placed in operation November 2, 1949, for use for construction purposes.

Other Buildings

A reinforced concrete, brick and steel structure was built to house the circulating water and service water pumps. Also included in this building are rooms for circulating water treating equipment and gas metering equipment. This structure, designated generally as the pump house, is 47'-0½" wide by 70'-3" long with an addition on the west side of 25'-0½" by 29'-3" which isolates and houses the gas metering equipment. Glazed tile partitions inside the pump house proper provide individual rooms for separating the various types of water treating methods. A large room in the northeast corner is used for chlorine cylinder storage. Two smaller rooms in the southeast corner are for acid, polyphosphate, and chlorine-treating equipment. The portion of this building which houses the circulating water and service water pumps is built over the well section of the circulating water tunnels. Steel beams are installed for supporting the roof which has precast concrete slabs as a base for the built-up 5-ply 20-year bonded roof. A lighting panel with necessary conduit, wiring, and fixtures is installed to provide general and specific lighting service. Unit heaters are installed for building heating.

This building, including all its services, was built by Ebasco forces starting on March 22, 1949, and finished on February 1, 1952. Rolling doors and conventional type doors, steel window sash, heating units, lighting fixtures, roof ventilators and built-up roofing were furnished by the same vendors and on the same orders as similar equipment for the main building. Description of the various pieces of equipment contained within this building is expanded under the appropriate heading for each service under the general head of Condensers and Auxiliaries.

Fuel and Ash Structures

An appropriate structure was required to house the various pieces of coal-crushing equipment. Therefore, a building was erected 27'-2" by 25'8" by 53'-4" high, with concrete foundations and floors, structural steel framing, insulated steel panel siding, precast concrete roof base with built-up roof, and necessary lighting, heating and toilet facilities.

Very little excavation was required for the crusher house and this was done along with site grading. 28½ cubic yards of concrete had been placed for the foundation mat when it was discovered that it was 4 feet off proper location. This concrete was removed and formwork and placing of reinforcing steel was started again on February 23, 1950, and 69½ cubic yards of concrete was placed therein, completing the mat on March 1, 1950. Formwork, reinforcing steel and 4 cubic yards of concrete were placed for the column footings on March 3, 1950. Steel erection was delayed because of late delivery; however, erection began on June 9, 1950, and was completed on August 10, 1950. All of the structural steel, window sash and reinforcing steel for floors, was furnished by the Webster Manufacturing Company as part of their coal-handling equipment on order NY-7768. The lighting, heating, ventilating, toilet facilities and "C" panel siding were

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furnished by the same vendors and on the same orders for similar equipment supplied for the main building. All erection and installation was by Ebasco forces.

BOILER PLANT EQUIPMENT

Coal Handling Equipment

A complete integrated coal handling system is installed for removing coal from cars, transporting to yard storage or to bunkers, via conveyor belts. This system, which included coal crushing and screening, was designed and furnished by Webster Manufacturing Co. on order NY-7768, and erection was by Ebasco forces under the direction of a Webster Manufacturing Company's supervisor.

The system is arranged essentially as follows: A two track hopper pit located north of the station building contains four hoppers, three under the south track and one under the north track. Two hoppers contain reciprocating plate feeders and two contain apron conveyor feeders. All feeders discharge into a central hopper from which coal drops onto a 42-inch belt conveyor No. 2 carrying coal to the crusher house. The head pulley of No. 2 belt is of the magnetic type to take out tramp iron. The coal drops off the head pulley into a series of chutes controlled by flapper gates. The coal is either directed onto reversible cross conveyor No. 5 depositing either east or west to storage or continues down through the crusher and screen to 36-inch belt conveyor No. 3 traveling up to the station building. The bunker filling system is located on elevation 5342 in the main building and consists of a traveling shuttle on which is mounted a 36-inch reversible shuttle belt No. 4 discharging either east or west onto reversible wing conveyors 4A and 4B which empty into the bunkers. Four bunkers of the "silo" type, each of 240 tons capacity serve each boiler. The initial capacity of the coal handling system is 300 tons per hour. Provision has been made to increase this to 600 tons per hour by increasing the speed of all conveyors at some future date. A merrick Weightometer is furnished and mounted on belt conveyor No. 3 to measure tonnage handled into the bunkers only.

Work began on the track hopper November 1, 1949, with machine excavation. Excavation was carried on intermittently due to bad weather through this period until completed February 10, 1950. Hand excavation began on this date. Different soil conditions were encountered than anticipated and excavation was halted until an investigation could be undertaken. After investigation, construction was released as planned with the concurrence of the Client's engineers, and excavation was resumed March 3, 1950, and completed for forming March 10, 1950. Erection of forms and placing of reinforcing steel for the base slab of the track hopper began on March 10, 1950, and was completed with 56 cubic yards of concrete placed therein on March 17, 1950. Formwork, placing of reinforcing steel and placing of concrete continued on the upper portions until completed on August 26, 1950, with 385 cubic yards of concrete placed. Conveyor No. 2 tunnel leading up from the track hopper was excavated in conjunction with the track hopper. Formwork and placing of reinforcing steel began August 23, 1950. The first concrete was placed the following week and continued being placed until completion on September 30, 1950, bringing the total concrete for the tunnel to 232½ cubic yards.

To facilitate erection, conveyor gallery steel was assembled on the ground in as long lengths as fabrication and handling permitted. Assembly of this steel started on June 8, 1950, and with erection, continued until completed on September 23, 1950. A number of miscellaneous items of steel were omitted to

permit the installation of machinery, which started early in August. On September 13, 1950, Webster Manufacturing Company's erection supervisor arrived on the job to supervise final setting and alignment of machinery and to put the equipment into operation.

Work continued on concrete slabs, gallery walls and roofs, crusher house siding and other structural features which could not be started until after the machinery was in place. A considerable period of adjustment was required for all conveyors and crusher house equipment. Conveyors No. 2 and No. 5 were first operated on October 18, 1950, together with the four feeders. Coal was unloaded to storage October 19, 1950. Conveyor belt No. 3, shuttle conveyor No. 4, and wing conveyor No. 4A were first operated on November 10, 1950, for filling the bunkers for Units No. 1 and 2.

From the bottom of the coal bunkers raw coal is fed through piping down to the coal feeders located on the turbine operating level. These coal feeders, furnished by Babcock and Wilcox for Units 1 and 3 and by Combustion Engineering for Unit 2, are designed to work in conjunction with the coal mills and feed sufficient coal to satisfy the mills, which are of the ball type for Units 1 and 3 and are Raymond Bowl Mill type for Unit 2, and each having a capacity of 16,800 lbs. per hour. Tempering air is supplied through ducts from the air preheater to the primary air fans, which in turn supply air to the mills and the coal piping to the burners.

One set of 4 pulverizers including feeders, controls and piping were supplied for each boiler. Those for boilers 1 and 3 were furnished by Babcock & Wilcox on orders NY-773 and NY-77402 respectively. Those for boiler 2 were furnished by the Combustion Engineering Company on order NY-7727.

There are two 18" pipes from each coal mill for supplying pulverized coal to the burners for Units 1 and 3, and one 22" pipe from each coal mill for supplying pulverized coal to the burners in Unit 2. These pipes reduce to 14" for all three units at the burner operating level.

Ash Disposal Equipment

To provide for the removal and handling of ashes, a complete sluicing system was installed for all units. This system consisted of two vertical sluice pumps installed on a concrete foundation located in the sluice pond east of the plant; necessary piping from these pumps to the several boiler ash hoppers and hydroveyors and return to the pond; ash hoppers, including clinker grinder, hydraulically operated lifting doors, sluice trough, jet nozzles, internal water piping and refractory lining; hydroveyor exhausters; necessary piping from hydroveyor exhausters to mud drum hopper, to dust collector hopper, and to stack hopper; and control panels with switches, gages, etc., mounted thereon. All of this equipment and material except sluice pumps was furnished by the United Conveyor Corporation on order NY-7766 for Units 1 and 2 and on order NY-77415 for Unit 3. The ash sluice pumps are 7 stage vertical turbine type pumps each capable of handling 1,000 gpm sandy cold water against a total dynamic head of 340 feet with minimum submergence of 1 foot above lowest impeller and driven by a 100 hp, 3 phase, 60 cycle, 1800 rpm, G. E. drip-proof motor, furnished on order NY-77102 by Layne-Western Company. These pumps are mounted on two wells of 48" perforated concrete pipe sump to a depth of 30 ft. or el. 5224.5. A coarse rock fill surrounds these wells and a concrete and steel walkway and platform provide access from the pond bank. Installation of the ash sluicing equipment was begun

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on May 21, 1950, and completed on December 15, 1950, for Unit 1, on May 8, 1951, for Unit 2, and on December 19, 1951 for Unit 3.

Boiler Equipment

The steam generators are Babcock and Wilcox special three-drum sterling type with tubular air heater and submerged attemporator steam temperature control, purchased on order NY-773 for Units 1 and 2, and NY-77402 for Unit 3. Gas and pulverized coal are fired together or separately, down between the roof tubes. Each boiler is capable of evaporating continuously 450,000 pounds of water per hour. The boiler manufacturer supplies all appurtenances, including automatic Diamond air soot blowers, gages, water columns, safety valves including Consolidated power control valve, complete setting with steel casing, two induced and two forced draft fans per boiler, air preheater, air and gas ducts, dust collector, breeching to I. D. fans and all insulation and lagging.

A two stage superheater is supplied with each boiler. Superheat is maintained at 905° F., between 290,000 pounds per hour and 480,000 pounds per hour when the boiler is supplied with 408° F. feed water by means of two submerged attemporators located in the mud drum. A portion of the steam passing from the primary to the secondary superheater is directed through the attemporators by two proportioning valves controlled by Bailey air power drives furnished as part of the combustion control equipment.

The forced draft fans are of B. F. Sturtevant Manufacture, type 135 TV, capable of delivering 100,000 cfm, 105° F. air against 11.8 inches of water, test block conditions. Each fan is driven by a 300 hp, 1160 rpm, 2300 volt, 3 phase, 60 cycle Allis Chalmers splashproof motor and is controlled by inlet and outlet vanes driven by Bailey air power drives furnished as part of the combustion control equipment. The induced draft fans are of B. F. Sturtevant Manufacture, type 1010 TVID double inlet, capable of delivering 173,500 cfm, 380° F. air at minus 12.8 inches of water, test block conditions. Each fan is driven by a 700 hp, 705 rpm, 2300 volts, 3 phase, 60 cycle Allis Chalmers splashproof motor and is controlled by inlet vanes and outlet dampers, each driven by Bailey air power drives furnished as part of the combustion control equipment.

The principal data on the steam generators are as follows:

a.	Boiler water-heating surface, excluding water-cooled furnace surface	25,299 sq. ft.
b.	Superheating surface	19,800 sq. ft.
c.	Water cooled furnace projected area	7,794 sq. ft.
d.	Air heating surface	118,370 sq. ft.
e.	Attemporator surface	1,026 sq. ft.
f.	Furnace volume	41,900 cu. ft.
g.	Heat release per cubic foot of furnace at maximum load	13,500 btu

Motors for driving all boiler auxiliaries were furnished by Allis Chalmers Manufacturing Company on orders NY-779 for Unit 1, NY-7724 for Unit 2 and NY-77411 for Unit 3.

All equipment, gages, controllers, transmitters, etc., for combustion and feed water control systems were furnished by the Bailey Meter Company on order

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NY-7770 for Units 1 and 2 and NY-77451 for Unit 3. Description of this equipment is expanded under the appropriate heading.

Excavation for boiler foundations for Units 1 and 2 was started October 1, 1948. Work was stopped shortly afterwards, however, pending a change in basic foundation design from a mat type to piling. With the decision reached to use piling, excavation work commenced again on February 25, 1949, and was completed March 25, 1949, with 656 cubic yards excavated. Excavation for boiler No. 3 was started on February 15, 1950, and was completed on February 16, 1950, with 426 cubic yards excavated. Piling for boilers 1 and 2 foundations was started February 14, 1949, along the "E" column line and was completed on March 11, 1949, with 101 piles driven for boiler No. 1 and 101 piles for No. 2. Driving was intermittent during this period as boiler piling was driven in conjunction with the station building piling. Piling for boiler No. 3 foundation was started March 3, 1950, and completed March 17, 1950, with 101 piles driven. These pilings were also driven in conjunction with the station building for Unit 3. Placing of concrete for pile caps for boilers 1 and 2 began May 20, 1949, and was completed June 10, 1949, with a total of 257 cubic yards placed. Placing of concrete for pile caps for boiler No. 3 began April 21, 1950, and was completed July 28, 1950, with a total of 122 cubic yards placed.

Base plates for boiler structural steel were set and grouted during the following periods: for boiler No. 1, the week of July 25, 1949; for boiler No. 2, the week of August 1, 1949; and for boiler No. 3, the week of December 13, 1950. Boiler structural steel erection by Ebasco forces was started and completed in the following sequences: For boiler No. 1, started on August 15, 1949, and completed on September 30, 1949; for boiler No. 2, started on August 26, 1949, and completed on December 2, 1949; and for boiler No. 3, started on December 26, 1950, and completed on February 23, 1951. Riveting was included in this erection; however, some miscellaneous steel, such as walkways and stairways was erected later.

The Babcock and Wilcox erection superintendent arrived on the job September 12, 1949, and a few days later received and started placing the rigging for hoisting boiler drums. The uptake steam drum for boiler No. 1 was raised to place October 11, 1949; the main steam drum, October 18, 1949; and the mud drum, October 31, 1949. The uptake steam drum for boiler No. 2 was raised to place December 1, 1949; the main steam drum was raised to place December 5, 1949; and the mud drum December 21, 1949. The uptake steam drum for boiler No. 3 was raised to place February 26, 1951, the main steam drum February 28, 1951, and the mud drum March 26, 1951. The installation of water wall headers and tubes for boiler No. 1 was begun on October 24, 1949, and completed including superheater tubes, on June 30, 1950. Similar work for boiler No. 2 was begun on June 1, 1950, and completed on February 1, 1951, and that for boiler No. 3 was started on March 2, 1951, and completed on August 31, 1951. Hydrostatic test at 1575 pounds for 8 hours were completed on July 1, 1950, for boiler No. 1, on February 2, 1951, for boiler No. 2, and on September 9, 1951, for boiler No. 3. Dryout and boilout of boilers consumed approximately 8 to 10 days per boiler, and was accomplished during the periods September 7, 1950, to September 15, 1950, for boiler No. 1, February 17, 1951 to February 28, 1951, for boiler No. 2, and October 21, 1951, to October 31, 1951, for boiler No. 3. The blowing out of main steam lines and the setting and testing of safety valves were completed on September 30, 1950, for boiler No. 1, on March 11, 1951, for boiler No.2, and on November 10, 1951, for boiler No. 3, after which each of the boilers was ready for load, which was placed on boiler No. 1 on October 7, 1950,

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on boiler No. 2 on March 17, 1951, and on Boiler No. 3 on November 16, 1951. These first loads were, of course, comparatively small. However, they were increased from time to time as the turbine and boiler were in condition to accept increased load.

Each boiler is provided with a fully automatic, sequential type soot blowing system. The soot-blowing equipment was manufactured by the Diamond Power Specialty Corp. and furnished by the Babcock and Wilcox Company under orders NY-773 and NY-77402. Blowing equipment for each boiler consists of twenty A2E rotary type and four IK retractable type blowers installed in the boiler, plus 2 straight line type installed in the airheater. Two of the A2E rotary type blowers were added to each boiler after initial operation and were furnished by the Diamond Power Specialty Corp. under order NY-77526. Blowing and control air is provided by three air compressors furnished by the Worthington Pump and Machinery Corporation under Orders NY-7714 and NY-77423. Compressors are 15/6 X 12, type DC-2, horizontal, duplex, two stage, double acting; each direct connected to a 150 HP, 300 RPM, 3 phase, 60 cycle, 2300 V, synchronous motor. Blowing air is stored in a primary air receiver at 500 psi, then reduced to 365 psi through a pressure reducing valve and stored in a secondary air receiver until used in the soot-blowing cycle. Control air is taken from the 365 pound blowing air through pressure reducing valves to two control and one driving systems; the control system for the IK blowers operates at 100 psi and the control system for the A2E blowers operates at 40 psi and the driving air system for all drivers operates at 250 psi, making the entire soot-blowing system dependent only on its own compressors. The primary and secondary air receivers were furnished by Graver Tank and Manufacturing Company, Incorporated, on order NY-7778. The primary air receiver is 72" I. D. X 24'-6" long end to end of heads, with a shell thickness of 1-15/32", complete with necessary nozzles and mounting pads. The secondary air receiver is 48" I. D. X 7'-3" long end to end of heads, with a shell thickness of 11/16", complete with necessary nozzles and mounting pads. Erection of the soot blowers in the boilers and the installation of control tubing was accomplished during the last phase of boiler erection due to the need of a completed boiler casing in order to hang the control tubing alongside the boiler. Operation of the soot blowers on Unit #1 during the winter of 1950-51 proved the necessity of weather protection for the IK retractable type soot blowers due to icing up of the equipment. A protective housing of sheet aluminum was therefore provided on each side of all three boilers for each pair of IK type blowers.

From the induced draft fans a steel breeching, 16 feet by 7 feet, carries flue gas to the stack for each boiler. This breeching with supporting steel for Units 1 and 2 was furnished by the American Steel and Iron Works on order NY-77158, but was erected by Ebasco forces. Insulation was furnished and applied by B & B Engineering Company on order NY-77163 and lagging of 20 gage sheet metal was furnished and applied by National Boiler Casing Company under direct contract with B & B Engineering Company. The installation of Unit No. 1 breeching was started on June 30, 1950, and completed, including insulation and lagging, on September 5, 1950. Similar work for Unit 2 was started October 10, 1950, and completed on January 25, 1951. Breeching of the same size was furnished for Unit 3 by the same company, but on order NY-77487. Erection by the Ebasco forces was started on March 16, 1951, and completed, including insulation and lagging, on November 2, 1951. Insulation was furnished and applied by B & B Engineering Company on order NY-77504 and lagging was applied by National Boiler Casing Company under direct contract with B & B Engineering Company.

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Stack No. 1, serving boilers 1 and 2, is of reinforced concrete construction, standing 250' above elevation 5262. It includes an independent free standing, hard burned radial brick lining for the full height with an inside diameter of 13'-10". The inner lining is separated from the concrete stack by a ventilation space. A steel beam supported brick baffle wall divides the lower portion of the stack lining at the breeching openings. A concrete-lined hopper is provided at the stack bottom for collection of fly ash. This hopper is emptied via vacuum line into the boiler fly ash system. Stack No. 2 serving boiler No. 3 and future boiler No. 4 is also 250' high, but is 14' internal diameter. Excavation for Stack No. 1 was begun on March 31, 1949, and completed on April 12, 1949. The driving of piling by Raymond Concrete Pile Company on order NY-7741 was started on April 12, 1949, and completed on April 18, 1949, with 97 piles driven to a depth ranging from 32.5 to 36.2 feet. Excavation for stack No. 2 was begun on March 30, 1950, and completed on March 31, 1950. The driving of the 97 pile furnished by Raymond Concrete Pile Company on order NY-77409 was started on April 3, 1950, and completed on April 10, 1950, with piles driven to a depth ranging from 31.5 to 36.1 feet. The building of forms and placing of reinforcing steel for the foundation base of stack No. 1 was completed on July 15, 1949, and 323 cubic yards of concrete were placed therein. The plinth for this foundation was formed and reinforcing steel was placed complete on July 18, 1949. 48.5 cubic yards of concrete were placed in this form July 19, 1949. The building of forms and placing of reinforcing steel for the foundation base for stack No. 2 was completed on August 21, 1950, and 327 cubic yards of concrete were placed therein. The plinth for this foundation was formed and reinforcing steel was placed complete on August 26, 1950. 43.5 cubic yards of concrete were placed in this form August 29, 1950.

The erection superintendent, Mr. J. Bond, for Alphons Custodis Chimney Construction Company, arrived on the job August 12, 1949, and began immediately the erection of Stack No. 1, (order NY-7746), which was accomplished in approximately 10 foot lifts. Construction continued with approximately three lifts per week for the first three weeks increasing to a maximum of 5 lifts the sixth week. The outer concrete shell was completed, except for trim, on October 4, 1949. The brick lining was started on October 18, 1949. About 40 feet of tile was laid per week in the first few weeks, increasing to nearly 60 feet per week until the lining was completed on December 7, 1949. Miscellaneous trim was installed, completing Stack No. 1 on December 14, 1949. Mr. E. Gorelle, erection superintendent for Custodis Construction Company Incorporated, arrived on the job May 14, 1951, to start erection of stack No. 2. Good progress was made, averaging approximately 3 lifts of 10 feet each per week to August 17, 1951, at which time the outer concrete shell, except for trim, was completed. At this time, Mr. A. Pouppert replaced Mr. Gorelle as erection superintendent. Work started immediately on the construction of the tile lining. About 40 feet of tile was laid per week, increasing to 50 feet per week near the half-way mark. Completion of the lining and the placing of the top trim was accomplished on October 12, 1951, thus completing stack No. 2.

The combustion control equipment was furnished by Bailey Meter Company on order NY-7770 for Units 1 and 2 and order NY-77451 for Unit 3. These orders include instruments and controllers required for automatic control of the boilers. Also included are all boiler and turbine gage boards on which are mounted a considerable portion of the control devices for the combustion control system. This system is of the master pressure type biased by a steamflow/airflow meter and a gasflow/airflow meter. Also included are furnace draft controller; induced draft flow limit control; windbox to furnace to burner ratio controller;

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a two element steam temperature controller-recorder based on steam temperature and steam flow; a complete three element feed water control system based on water level, steam flow and water flow; and the various remote devices such as fan damper and vane drives, attemperator valve drives, primary air damper drives, gas control valve and feed water control valve. The automatic gas shutoff valve, a Ruggles-Klingeman, was also furnished as part of the combustion control equipment. This system functions to trip all gas fuel supply on (a) loss of induced draft fans or both forced draft fans, (b) loss of furnace draft, (c) loss of windbox to furnace differential, or (d) loss of gas pressure when burning gas. It also provides a timer to release fuel circuits only after a sufficient purge of the boiler.

Gage boards were received completely piped and wired with the majority of the instruments mounted. Instruments not supplied by Bailey Meter Company, but which were shipped to Bailey for mounting included gages on order NY-7796 to Manning, Maxwell and Moore Company, temperature recorders on order NY-77100 to Leeds and Northrup, all for Units 1 and 2 and instruments on order NY-77485 to Manning, Maxwell and Moore and recorders on order NY-77454 to Leeds and Northrup for Unit 3.

Boiler gage board No. 1 and common gage board were set on June 20, 1950; boiler gage board No. 2 was set on October 27, 1950. Boiler gage board No. 3 and common gage board for Unit No. 3 were set on September 28, 1951. Work continued on each of these boards until the trial operation date of each boiler. All boilers were operated remote manual during the first few months of operation for all units. Considerable adjustments, tests and settings were required after operation date before these boilers could be put on automatic control which was released on June 22, 1951, for Unit 1, April 20, 1951 for Unit 2, and February 1, 1952 for Unit 3.

Boiler Plant Auxiliaries

The feedwater cycle for each unit is entirely separate, operating with no interconnections except for stored condensate and evaporator makeup. Five extraction points are utilized on each turbine. These serve one high-pressure heater, one intermediate high-pressure heater with evaporator take off, one deaerating heater, one intermediate low-pressure heater and one low-pressure heater. The points are numbered respectively as follows: For the General Electric Units 1 and 3 - 4th, 7th, 12th, 15th, 18th stages, and for the Westinghouse Unit 2 - 7th, 15th, 22nd, 26th and 29th stages. The heaters and other equipment were bought identical for all units as the pressures and temperatures of the corresponding stages are identical. All extraction heaters were purchased from Struthers Wells Corporation for Units 1 and 2 on order NY-7728 and for Unit 3 on order NY-77422. The three higher stage shells are vertical, headup, with a two-foot section below the tubes for a hotwell. The low pressure heaters are horizontal and mounted in the condenser neck to shorten piping and to conserve space.

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principal data for the heaters including operating dates are as follows:

Fourth Stage - Units No 1 & 3
Seventh Stage - Unit No. 2

Effective heating surface	- sq. ft.	1211
Number Tubes		224
Size Tubes	- in. - Bwg	5/8 - 16
Tube Material	- Cupro - nickel	70 - 30
Feedwater Flow	- lbs/hr	402,700
Temperature Rise	- Degrees - "F"	347.9 - 408.2
Tube Design	- psig - "F"	1800 - 450
Shell Design	- psig - "F"	400 - 750
Fourth Stage - Unit 1	- Placed in operation	October 19, 1950
Seventh Stage - Unit 2	- Placed in operation	March 24, 1951
Fourth Stage - Unit 3	- Placed in operation	November 30, 1950

Seventh Stage - Units No. 1 & 3
Fifteenth Stage - Unit No. 2

Effective heating surface	- sq. ft.	1140
Number Tubes		224
Size Tubes	- in. - Bwg	5/8 - 16
Tube Material	- Cupro - nickel	70 - 30
Feedwater Flow	- lbs/hr	402,700
Temperature Rise	- Degrees - "F"	291.6 - 347.9
Tube Design	- psig - "F"	1800 - 400
Shell Design	- psig - "F"	250 - 800
Seventh Stage - Unit 1	- Placed in operation	October 19, 1950
Fifteenth Stage - Unit 2	- Placed in operation	March 16, 1951
Seventh Stage - Unit 3	- Placed in operation	November 30, 1951

Fifteenth Stage - Units No. 1 & 3
Twenty-sixth Stage - Unit No. 2

Effective heating surface	- sq. ft.	1014
Number Tubes		163
Size Tubes	- in. Bwg	5/8 - 18
Tube Material	- Arsenical Copper	
Feedwater Flow	- lbs/hr	333,200
Temperature Rise	- Degrees - "F"	168.6 - 233.4
Tube Design	- psig - "F"	190 - 300
Shell Design	- psig - "F"	75 - 300
Fifteenth Stage - Unit 1	- Placed in operation	October 17, 1950
Twenty-sixth State-Unit 2	- Placed in operation	March 16, 1951
Fifteenth Stage - Unit 3	- Placed in operation	November 30, 1951

Eighteenth Stage - Units No. 1 & 3
Twenty-ninth Stage - Unit No. 2

Effective heating Surface	- sq. ft.	1214
Number Tubes		145
Size Tubes	- in. Bwg	5/8 - 18
Tube Material	- Arsenical Copper	
Condensate Flow	- lbs/hr	300,000
Temperature Rise	- Degrees - "F"	111.6 - 168.6

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Tube Design	- psig - "F"	190 - 300
Shell Design	- psig - "F"	50 - 300
Eighteenth Stage - Unit 1 - Placed in operation		October 7, 1950
Twenty-ninth Stage-Unit 2 - Placed in operation		March16, 1951
Eighteenth Stage - Unit 3 - Placed in operation		November 17, 1951

The deaerators and their storage tanks were furnished by Worthington Pump and Machinery Company on order NY-777 for Units 1 and 2 and on order NY-77426 for Unit 3. They are of the horizontal type mounted on a horizontal storage tank. Each deaerator was furnished with the usual accessories including gages, gage glasses, thermometers, alarms and a Bellfield automatic overflow valve. They are designed to deaerate 400,000 pounds per hour to a residual oxygen content of .005 cubic centimeters per liter. Steam for this purpose is taken from the twelfth stage bleed of turbines 1 and 3 and from the twenty-second stage bleed of turbine No. 2. Drains from the two high pressure heaters and from the evaporator coil also enter the deaerator adding to the heat effect. The storage tank has an approximate capacity of 110,000 pounds which gives approximately 16½ minutes capacity at normal delivery to the feedwater pumps. The two storage tanks for Units 1 and 2 were raised and set on the steel November 25, 1949, and the storage tank for Unit 3 was set February 20, 1951. The storage tanks were used throughout the initial boilout of each boiler to supply the boiler feed pumps. Steam was introduced into Unit 1 deaerator on October 7, 1950, into Unit 2 on February 17, 1951, and into Unit 3 on November 16, 1951.

An evaporator is furnished for each unit and each is equipped with an independently mounted preheater. Order NY-7730 placed with the Griscom-Russell Company covers both evaporators and preheaters of Worthington Manufacture for Units 1 and 2 and Order NY-77414 with the same company covers the evaporator and preheater of Worthington Manufacture for Unit 3. Each evaporator was furnished with all appurtenances such as gages, water glasses, level controller, Bellfield control valve, blowoff valve, alarms, and thermometers. Each evaporator is fed with softened city water, and is designed for a net vapor output of 13,500 pounds per hour with total solids in vapor leaving the shell limited to 1.7 ppm when solids in shell water is limited to 3250 ppm. Steam is fed to the coils from the seventh stage bleed on Units 1 and 3, and from fifteenth stage bleed on Unit 2 at a maximum pressure of 149 psig. The evaporators are of the bent tube design with provision for cold water scale cracking. Evaporators No. 1 and 2 were set November 23, 1949, and evaporator No. 3 was set February 23, 1951. The evaporator preheaters, one for each of the evaporators described above, are of the deaerating type designed for shell pressure of 75 pounds and coil pressure of 150 pounds. Each preheater is guaranteed to heat up to 20,000 pounds per hour of 100% raw water from 70° F to saturated temperature of steam at operating pressure of 45 psig, with effluent oxygen content not exceeding .03 cubic centimeters per liter. The placing in service of all evaporators was delayed because of press of other work and also the need of them was not urgent. Evaporator No. 3 with its preheater was placed in service on September 25, 1952 and Evaporators No. 1 and 2 with their preheaters were placed in service on October 27, 1952.

Water is supplied to each boiler by three 70% capacity Byron-Jackson 3 inch by 10 inch nine stage, type HSB, double case boiler feed pumps. These pumps are capable of delivering 260,000 pounds per hour of 285° F feedwater against a

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total dynamic head of 2900 feet. A complete spare rotor was purchased for use in any one of the nine pumps. All pumps were furnished with Republic automatic recirculating control which is actuated by main flow, to bypass through silencer orifice to the deaerator at 23,000 pounds per hour, which is considered the minimum safe operating design for each pump. During normal load operation two pumps are utilized per unit. Pumps for Units 1 and 2 were furnished by Byron-Jackson Company on order NY-7716 and for Unit 3 by the same company on order NY-77403. Each pump is driven by an Allis Chalmers 600 hp, 2300 volt, 3600 rpm, 3 phase, 60 cycle, drip-proof motor, furnished on orders NY-779 for Unit 1, NY-7724 for Unit 2 and NY-77411 for Unit 3. The date of operation for each of these pumps is as follows:

BF Pump 1A	9-15-50
BF Pump 1B	9-13-50
BF Pump 1C	9-12-50
BF Pump 2A	2- 5-51
BF Pump 2B	2- 7-51
BF Pump 2C	1-27-51
BF Pump 3A	9- 7-51
BF Pump 3B	9- 7-51
BF Pump 3C	11-30-51

The reason for the unusual lapse of time before pump 3C was placed in operation was due to electrical failure of the motor on pump 2C some months after installation and which was replaced with the motor from pump 3C which had not been installed complete at that time, After rewinding the motor from pump 2C it was installed on pump 3C rather than move both motors since both were of the same size and characteristics.

Stored distilled water is pumped from the condensate storage tank and the deaerator heater storage tank by either of two type 2½/2CNE-82 centrifugal condensate transfer pumps, furnished by Worthington Pump and Machinery Corporation on order NY-7742 for Units 1 and 2, and NY-77456 for Unit 3. Each pump is designed to deliver 50,048 pounds per hour of 100° F water at 275 feet, total dynamic head, with 0 feet submergence. Piping between condensate transfer pumps and condensate storage tanks is such that either pump can be used for either Unit 1 or 2. A similar arrangement is made for the condensate transfer pumps for Unit 3 and future Unit 4. Each pump is driven by an Allis Chalmers 40 hp, 440 volt, 3 phase, 60 cycle, 3600 rpm, drip-proof motor. The condensate transfer pumps also serve as boiler cold fill pumps. The pumps for Units 1 and 2 were run initially on 9-12-50, 10-5-50, and for Unit 3 on 11-9-51.

Makeup water is pumped from the evaporator preheater into the evaporator by either of two type 1½ CNE62 centrifugal evaporator feed pumps furnished by Worthington Pump and Machinery Corporation on order NY-7742 for Units 1 and 2, and NY-77456 for Unit 3. Each pump is designed to deliver 32,500 pounds per hour of 50°-75°F water at 150 feet total dynamic head, with 55 feet submergence. Each pump is driven by an Allis Chalmers 5 hp, 440 volt, 3 phase, 60 cycle, 3600 rpm, drip-proof motor.

Each unit is provided with two low pressure drip pumps for discharging condensed steam from the low pressure heater drip receiver into the condensate piping ahead of the intermediate pressure heater. These pumps also handle condensed steam from the intermediate pressure heater and from the trap after the deaerator heater reducing station, which steam is flashed into the low pressure

flash tank, with the residual water entering the pump suction piping together with the low pressure heater drip. These low pressure heater drip pumps, size 2-LIC-1 and type horizontal centrifugal were furnished by Worthington Pump and Machinery Corporation on order NY-7742 for Units 1 and 2 and NY-77456 for Unit 3. These pumps are designed to deliver 46,015 pounds per hour of 175° F water at 350 feet total dynamic head, with 14 feet submergence. Each pump is driven by an Allis Chalmers 20 hp, 440 volt, 3 phase, 60 cycle, 1750 rpm, drip-proof motor. These pumps for Unit 1 were first operated on October 7, 1950, for Unit 2 on March 20, 1951, and for Unit 3, on November 11, 1951.

Each unit is provided with two high pressure drip pumps, for discharging condensed steam from the high pressure flash tank into the deaerator. These pumps also handle condensed steam from the evaporator coil, the 7th stage heater shell, and from traps before and after the high pressure reducing stations. These pumps, furnished by Worthington Pump and Machinery Corporation on orders NY-7742 for Units 1 and 2 and on NY-77456 for Unit 3, are horizontal centrifugal, 2-HL-IO, designed to deliver 75, 024 pounds per hour of 275° F water at 70 feet total dynamic head, with 30 feet submergence. Each pump is driven by an Allis Chalmers 5 hp, 440 volt, 3 phase, 60 cycle, 1740 rpm, drip-proof motor. These pumps were first operated on October 17, 1950, October 18, 1950 for Unit 1, on March 23, 1951, July 16, 1951, for Unit 2, and on January 7, 1952, November 30, 1951, for Unit 3.

Two condensate storage tanks each of 10,933 gallons capacity are furnished for each two units. These two tanks are connected in such a manner that they can be used in common or as individual tanks for supplying water to the condensate transfer pumps. Water from these tanks also is fed to the condenser hot wells and is automatically controlled by water elevation in the deaerator storage tank. Boiler water, deaerator, and gland seal tank overflow drain into these tanks together with the condensate pump discharge. These tanks were furnished by Eaton Metal Products Company on order NY-7779 for Units 1 and 2, and on order NY-77434 for Unit 3. After treating the inside surface of these tanks with special paint furnished on order NY-77489 by the Amercoat Corporation, they were placed in operation on September 12, 1950, for Units 1 and 2 on November 4, 1951, for Unit 3.

The high and low pressure flash tanks were furnished by Midwest Piping and Supply Company on their piping contract covered by order NY-7721 for Units 1 and 2, and NY-77407 for Unit 3. The high pressure flash tanks are designed to withstand 200 psi pressure at 360° F temperature and are of 25.7 cu. ft. capacity. The low pressure flash tanks are designed to withstand a pressure of 150 psig at 360° F and are of 10 cu. ft. capacity.

Feedwater flow to each boiler is regulated by a Bailey three element control system, consisting of an air actuated piston regulating valve, the position of which is determined from a controller responding to a steam flow, water flow, and boiler drum level. This equipment was furnished by Bailey Meter Company on order NY-7770 for Units 1 and 2, and NY-77451 for Unit 3. These orders also cover the combustion control equipment described previously.

Two boiler blow-down tanks were furnished, one for Units 1 and 2 by Graver Tank and Manufacturing Company or order NY-7778, and one for Unit 3 by Stearns-Rogers Manufacturing Company or order NY-77513. These tanks are 52" I.D. by 7'6" long and are designed for 750 psig at 510° F and were provided with a substantial concrete foundation. Drain from No. 2 tank connects to the drain from

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No. 1 which extends on into the ash sluice pond to the east of the plant. The tank for Units 1 and 2 was placed in operation September 16, 1950, and that for Unit 3 on December 1, 1951.

Two automatic steam pressure reducing stations were furnished by Fisher Governor Company for each unit, the four for Units 1 and 2 on order NY-7777, and the two for Unit 3 on NY-77481. One reducing station is designed for reducing saturated steam from 1010 psig to 155 psig with stable operation throughout a flow range from 0 flow to 30,000 pounds per hour. This reducing station is a 2" x 3" type 4100 DR 461-567, 900 pound RF cast steel and is used to supply low pressure steam to the evaporator shell and to the second reducing station. Also for No. 1 unit only it supplies steam for a third reducing station which in turn supplies steam for the office and locker room heating system. The second reducing station is a 2" type 4100 DR 555 T 150 pound RF cast steel for reducing saturated steam from 155 psig to 5 psig with suitable operation throughout a flow range from 0 flow to 5500 pounds per hour and is used to supply low pressure steam to the deaerator. The reducing station provided for a portion of the plant heating is a 2" type 4100 DR 555 T 150 pound RF cast steel for reducing saturated steam from 155 psig to 30 psig with stable operation throughout a flow range from 0 flow to 7500 pounds per hour. There is only one of these stations which was furnished by Fisher Governor Company on order NY-7777. All of these reducing stations are automatic air operated and provided with travel indicator, valve positioner, pilot tube, bypass and valves, gages and air filter set. They were placed in operation almost immediately after each boiler went into operation, except the reducing station for plant heating which went into operation on January 19, 1951.

A sodium zeolite water softener was provided for each unit by the Permutit Company on order NY-7759 for Units 1 and 2 and on order NY-77499 for Unit 3. These water softeners were located on the ground floor in the areas between boilers. They each have a vertical tank of 42 inches diameter by 5 feet high with shell design of 7100 psig working pressure and having a capacity of 50 gpm, based on a total hardness of 7 grains per gallon. Included with each zeolite tank is one 24 inch diameter by 48 inches high brine measuring tank and one 36 inch diameter by 48 inches high salt storage tank all complete with interconconnecting piping, control valves, and chemicals.

In addition to the zeolite water softener, chemical treating equipment for boiler water was furnished by Milton Roy Company on order NY-7760 for Units 1 and 2, and NY-77498 for Unit 3 and future Unit 4. Storage tanks for these systems were furnished on local orders SD-1750 for Units 1 and 2, and SD2875 for Unit 3 and future Unit 4 by Eaton Metal Products Company. The chemical pumps consist of one model MD 1-52-45-T Simplex with adjustable variable capacity up to 8 gph with discharge pressure at 1500 psig and suitable for pumping disodium phosphate solution, and driven by a 3/4 hp, 440 volt, 3 phase, 60 cycle, dripproof master gear head motor; and one model MD 1-24-36 Simplex pump with adjustable variable capacity up to 3 gph with discharge pressure at 100 psig and suitable for pumping sodium sulphite solution and driven by a 1/4 hp, 440 volt, 3 phase, 60 cycle, G. E. integral gear motor. The phosphate pump discharges directly into the boiler drum and the sulphite pump discharges into the line from the deaerator storage tanks to the Boiler Feed Pumps.

Station power piping was furnished, facricated, and erected by Midwest Piping and Supply Company, Inc., on order NY-7721 for Units 1 and 2, and on NY-77407 for Unit 3. High pressure piping was substantially all welded. Superheated steam piping was fabricated from seamless chrome-moly tubing, and

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essentially all other major piping is of seamless carbon steel tubing. Where required by code, preheating and stress relieving of welded joints was accomplished by means of resistance type electrical heating coils which wrap around the pipe weld and conduct controlled heat to the weld. Individual temperature charts were maintained for each preheated and stress relieved weld for submission for approval by the Hartford insurance inspector. Both shop fabrication and field welding and fabrication was also inspected and approved by the Hartford insurance inspector. The certification of qualified electric welders for this high pressure piping was furnished by Midwest Piping and Supply Company, Inc. High pressure cast steel valves were furnished by the Chapman Valve Manufacturing Company on order NY-7756 for Unit 1, NY-77144 for Unit 2, and NY-77413 for Unit 3. Low pressure cast steel and bronze valves were purchased from a number of vendors on several New York orders which are easily identifiable in the list of New York orders shown in a following section of this report. The erection superintendent for Midwest Piping and Supply Company arrived on the job on December 12, 1949, and started immediately on the piping erection which continued without undue interruption or unusual events throughout the construction of the three units. Power piping was essentially completed for each unit shortly after these units went into operation or approximately on October 7, 1950, for Unit 1, March 30, 1951, for Unit 2, and November 15, 1951, for Unit 3. The piping erector departed from the job on February 20, 1952.

Heat insulation for all piping, vessels, ducts, etc., is a Phillip Carey product and was furnished and applied by the B & B Engineering and Supply Company, Inc., on orders NY-77163 for Units 1 and 2, and NY-77504 for Unit 3. The installation for Units 1 and 2 was on a unit price measured basis for piping and lump sum prices for vessels and ducts. The installation for Unit 3 was on a lump sum firm price for all piping, vessels, ducts, etc. The furnishing, erecting and dismatling of scaffolding was included in these prices, All canvas covering was glue sized to provide a sealed body for finished painting. The erector arrived on the job on February 22, 1950, and began work immediately with a small crew which later was expanded into an average crew of about 12 men. The essential work for Units 1, 2 and 3 was accomplished in time to meet the trial operation date for each unit; however, quite a number of details were completed after these dates bringing the completion date of the application of all heat insulation to March 7, 1952, on which date the erector departed from the job.

TURBINEGENERATOR UNITS

Special Foundations

Each turbine generator unit is supported by a specially designed reinforced concrete foundation or pedestal which in turn rests upon step taper concrete piles, and is completely independent of the station building. The piles were furnished and driven by the Raymond Concrete Pile Company on orders NY-7741 for Units 1 and 2 and NY-77409 for Unit 3. The driving of these piles was carried on in conjunction with those driven for the various footings or foundations of the station building, including about 18% of the piles for future Unit No. 4 pedestal which were driven at the same time as those for Unit 3. Approximately 88 piles averaging in length from 25 feet to 35 feet and containing a total of 80 cubic yards of concrete were installed for each pedestal. Reinforced concrete mats were placed on the piles bringing the top elevation of these mats to 5258.0. Approximately 280 cubic yards of concrete were placed in these mats. Turbine pedestal No. 1, containing 54.5 tons of reinforcing steel and 503 cubic yards of concrete, was started on July 28, 1949, with reinforcing steel, and completed except for floor finish and machine grouting on October 6, 1949. Pedestal No. 2, containing 52.4 tons of reinforcing steel and 501 cubic yards of concrete, was started on October 7, 1949, with similar reinforcing steel and completed on April 7, 1950. Work on Pedestal No. 2 was intermittent during the winter because there was no urgency for this pedestal and it could be used as a fill in during inclement weather when outside work was somewhat inactive. Pedestal No. 3, containing 49.3 tons reinforcing steel and 522 cubic yards of concrete, was started on September 28, 1950, with similar reinforcing steel and completed on January 12, 1951. The grouting of turbinegenerator units and the floor finish on the pedestals were accomplished at much later dates. The turbine pedestal finish for each unit was completed with the turbine room floor as described under the building portion of this report.

Turbine Generator Equipment

Turbine generator No. 1 furnished by General Electric Company on order NY-771 and erected by Ebasco forces under the supervision of a General Electric Company erector consists of an ASME-AIEE preferred standard hydrogen cooled condensing unit, 40,000 kw rated turbine, 44,000 kw maximum turbine, .85 pf, 900° F normal at throttle, exhausting against 2.5" hg backpressure, at 3,600 rpm. Extraction steam for feed water heating is taken from the turbine at the 4th, 7th, 12th, 15th and 18th stages. Generator has capabilities of 44,000 KW at .85 pf and .5 psig hydrogen pressure to 48,000 KW, .85 pf at 15.0 psig hydrogen pressure, at 13,800 volts, 1968 amperes, 3 phase, 60 cycle, 0.8 short circuit ratio. Direct connected exciter with pilot exciter is rated 145 KW at 250 volts and 4 KW at 250 volts respectively.

The hydrogen cooling system including a sealing oil system consists of reservoir, decontamination and vacuum tanks, pumps, electrical controls, safety interlocks and alarms. A control panel, housing the hydrogen pressure and purity indicators and alarms, is set up on the turbine operating floor near the turbine generator unit. Hydrogen pressure on the turbine and system is maintained at one-half pound gage pressure; however, this pressure can be raised to 15 pounds if desired. In connection with this hydrogen system a CO_2 auxiliary system is maintained for the purpose of removing and replacing the hydrogen gas in the generator. Also this CO_2 may be used for generator fire protection.

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The generator is equipped with four hydrogen coolers, using service water as the cooling medium.

Accessories with the turbine generator unit include an oil reservoir of 2175 gallons capacity, two full duty Andale enclosed type oil coolers using service water as the cooling medium, shaft driven centrifugal main oil pump, turbine driven auxiliary oil pump, motor driven emergency bearing oil pump, motor driven turning gear and turning gear oil pump, motor driven vapor extractor, oil operated stop valve, complete oil operated control system including operating and emergency governors and vacuum and overspeed trip control, atmospheric blowout diaphragm on low pressure casing, eccentricity, vibration, and valve position recorders, GFA-4 voltage regulator, motor driven main exditer rheostat with high speed contactors, pilot exciter rheostat, generator neutral grounding transformer with resistor and a full complement of lubricating oil piping, pressure gages, and thermometers. The lubricating oil, hydrogen and gland seal piping was furnished by the General Electric Company, but was installed by the Midwest Piping and Supply Company as part of their plant piping contract with Ebasco Services, Inc. Erection of turbine generator No. 1 was started October 19, 1949. The generator stator was set in place November 3, 1949, using the station crane. No unusual difficulty was encountered during the erection of this unit; however, a two shift erection period was conducted between July 17, 1950, and September 23, 1950. Steam was admitted to the lead piping for blowout purposes on October 1, 1950, and was admitted to the turbine for the first time on October 1, 1950.

Turbinegenerator Unit No. 2 furnished by Westinghouse Electric Corporation on Order NY-772, and erected by Ebasco forces under the supervision of a Westinghouse Electric Corporation erector consists of an ASME-AIEE preferred standard hydrogen-cooled condensing turbine generator unit, 40,000 kw rated turbine, 44,000 kw maximum turbine, .85 pf, 900° F normal at throttle, exhausting against 2.5" hg. back pressure at 3600 rpm. Extraction steam for feed water heating is taken from the turbine at the 7th, 15th, 26th and 29th stages. Generator has capabilities of 44,000 kw at .85 pf and .5 psig hydrogen pressure to 48,000 kw, .85 pf at 15.0 psig hydrogen pressure, at 13,800 volts, 1968 amperes, 3 phase, 60 cycle, 0.8 short circuit ratio. Direct connected self air-cooled exciter with pilot exciter is rated 155 kw at 250 volts and 2.5 kw at 250 volts respectively.

The hydrogen cooling system including a sealing oil system consists of reservoir, decontamination and vacuum tanks, pumps, electrical controls, safety interlocks and alarms. A control panel, housing the hydrogen pressure and purity indicators and alarms, is set up on the turbine operating floor near the turbine generator unit. Hydrogen pressure on the turbine and system is maintained at one-half pound pressure; however, this pressure can be raised to 15 pounds if desired. In connection with this hydrogen system a CO_2 auxiliary system is maintained for the purpose of removing and replacing the hydrogen gas in the generator. Also, this CO_2 may be used for generator fire protection. The generator is equipped with four hydrogen coolers, using service water as the cooling medium.

Accessories with the turbine generator unit include an oil reservoir of 2000 gallons capacity, two full duty shell type oil coolers using service water as the cooling medium, shaft-driven centrifugal main oil pump, turbine driven auxiliary oil pump, motor driven emergency bearing oil pump, motor driven turning gear and turning gear oil pump, motor driven vapor extractor, oil-operated

stop valve, complete oil operated control system, including operating and emergency governors and vacuum and overspeed trip control, atmospheric blowout diaphragm on low pressure casting, eccentricity, vibration and valve position recorders, B J-30 voltage regulator, motor driven main exciter rheostat with high speed contactors, pilot exciter rheostat, generator neutral grounding transformer with resistor and a full complement of lubricating oil piping, pressure gages, and thermometers. The lubricating oil, hydrogen and gland seal piping was furnished by the General Electric Company, but was installed by the Midwest Piping and Supply Company as part of their plant piping contract with Ebasco Services, Inc. Erection of Turbine Generator No. 2 was started on October 21, 1950. The generator stator was set in place October 26, 1950, using the station crane. Steam was admitted to the lead piping for blowout purposes on March 16, 1951, and was admitted to the turbine for the first time to carry load on March 17, 1951.

Turbinegenerator Unit No. 3, furnished by General Electric Company on Order NY-77401, and erected by Ebasco forces under the supervision of a General Electric Company erector, consists of an ASME-AIEE preferred standard hydrogen-cooled condensing turbine generator unit, 40,000 kw rated turbine, 44,000 kw maximum turbine, .85 pf, 900^{0} F normal at throttle, exhausting against 2.5" hg back pressure, at 3,600 rpm. Extraction steam for feed water heating is taken from the turbine at 4th, 7th, 12th, 15th and 18th stages. Generator has capabilities of 44,000 kw at .85 pf and .5 psig hydrogen pressure to 48,000 kw .85 pf at 15.0 psig hydrogen pressure, at 13,800 volts, 1968 amperes, 3 phase, 60 cycle, 0.8 short circuit ratio. Direct connected exciter with pilot exciter is rated 145 kw at 250 volts and 4 kw at 250 volts respectively.

The hydrogen cooling system including a sealing oil system consists of resevoir, decontamination and vacuum tanks, pumps, electrical controls, safety interlocks and alarms. A control panel, housing the hydrogen pressure and purity indicators and alarms, is set up on the turbine operating floor near the turbine generator unit. Hydrogen pressure on the turbine and system is maintained at one-half pound gage pressure; however, this pressure can be raised to 15 pounds if desired. In connection with this hydrogen system a CO_2 auxiliary system is maintained for the purpose of removing and replacing the hydrogen gas in the generator. Also, this CO_2 may be used for generator fire protection. The generator is equipped with four hydrogen coolers, using service water as the cooling medium.

Accessories with the turbine generator unit include an oil reservoir of 2175 gallons capacity, 2 full Andale type oil coolers using service water as the cooling medium, shaft-driven centrifugal main oil pump, turbine driven auxiliary oil pump, motor driven emergency bearing oil pump, motor driven turning gear and turning gear oil pump, motor driven vapor extractor, oil-operated stop valve, complete oil-operated control system including operating and emergency governors and vacuum and overspeed trip control, atmospheric blowout diaphragm on low pressure casting, eccesntricity, vibration and valve position recorders, GFA-4 voltage regulator, motor driven main exciter rheostat with high speed contactors, pilot exciter rheostat, generator neutral grounding transformer with resistor and a full complement of lubricating oil piping, pressure gages, and thermometers. The lubricating oil, hydrogen and gland seal piping was furnished by the General Electric Company, but was installed by the Midwest Piping and Supply Company as part of their plant piping contract with Ebasco Services, Inc. Erection of turbine generator No. 3 was started June 6, 1951. The generator stator was set in place September 4, 1951, using the

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station crane. Steam was admitted to the lead piping for blowout purposes on November 11, 1951, and was admitted to the turbine for the first time to carry load on November 15, 1951.

Turbine Plant Auxiliaries

A 7000-gallon, two-compartment, lubricating oil storage tank was provided as a batch tank for Units 1 & 2 and will be temporarily used for Unit 3. A 50 gpm 1½" rotary oil transfer pump is provided for pumping oil between batch compartments, or to the turbine oil tanks, or to the filtering equipment. Two sets of turbine oil conditioning equipment were furnished. Each set will filter 540 gallons per hour with a clean oil holding capacity of 330 gallons, and has one 8 gpm rotary oil pump and one special sight overflow fitting. The transfer pump is driven by a three hp, 440 volt, 3 phase, 60 cycle Allis Chalmers drip proof motor. The filter pumps are each driven by a 1 hp, 440, 3 phase, 60 cycle Allis Chalmers drip-proof motor. The lubricating oil conditioning system with storage tank for Units 1 and 2 were furnished by Bowser Incorporated, on order NY-7737, and were placed in operation February 29, 1952. Duplicate equipment less the storage tank was furnished for Unit No. 3 by the same vendor, but on Order NY-77421, and was placed in operation October 24, 1951.

Turbine gauge boards 19'-10" long by 10'-9" high, and 5'-0" deep were fabricated and delivered completely assembled by the Bailey Meter Company on order NY-7770 for Units 1 & 2, and on order NY-77451 for Unit 3. These boards also had provisions for mounting instruments furnished by the turbine vendor for recording turbine generator conditions. No attempt is made to enumerate the myriad gauges, instruments, recorders, etc., mounted on these boards. These turbine gauge boards were placed in operation by sections; that is, pieces of equipment on these boards went into operation at various times. However, completion of the boards was accomplished by the time the respective turbine generators went on the line.

A gland seal water tank 3'-6" by 5'-6" by 4'-0" is provided for each unit. Each has a capacity of 575 gallons or 30 minutes supply, and is located at elevation 5331.83 for Units 1 and 2, and at elevation 5316.04 for Unit 3. Gland sealing water is normally supplied from the condensate water system, but there are emergency supplies from the treated water system and the city water system. All supplies are provided with level control valves and the tank is equipped with a low water alarm and gauge glasses which are visible from the operating floor. These tanks were furnished by the Eaton Metal Products Company on order NY-7779 for Units 1 and 2, and on order NY-77434 for Unit 3, and were placed in operation at the same time the turbine generators went into operation.

CONDENSERS AND AUXILIARIES

Condenser

The condenser for Unit 1 was furnished by Allis Chalmers Manufacturing Co., Inc. on order NY-774, for Unit 2 by Westinghouse Electric Corporation on order NY-7722, and for Unit 3 by Allis Chalmers Manufacturing Co., Inc., on order NY-77404. All three condensers are designed for condensing load of 320,000 KB per hour, and are two pass divided water box, horizontal surface, having a cooling surface of 30,000 square feet, consisting of 7/8 inch OD #18 BWG admiralty tubes, requiring a cooling water pump capacity of 30,000 gpm. The erection of condenser No. 1 started on November 14, 1949, and was completed and hydrostatically tested in July, 1950. Condenser No. 2 was started on May 18, 1950, and

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hydrostatically tested on September 15, 1950. Condenser No. 3 was started on March 28, 1951, and hydrostatically tested on August 2, 1951.

Condenser Auxiliaries

Two circulating water pumps were furnished with the Order for No. 1 condenser; therefore, no pump was furnished with No. 2 condenser. However, a third pump was furnished with No. 3 condenser. All of these pumps are of Allis Chalmers Manufacture, size 48 by 36, vertical, type YDBV FM, 31,000 gpm at 75 feet dynamic head. Each pump is driven by an Allis Chalmers 800 hp, 585 rpm, 2300 volt, 3 phase, 60 cycle motor.

Two condensate pumps were furnished for each condenser. The four pumps for condensers 1 and 3 are of vertical type CF2-VT, two stage, size 10 inch by 4 inch furnished by Allis Chalmers Manufacturing Company, Inc., on orders NY-774 and NY-77404. The two condensate pumps for condenser 2 are of vertical pit type, nine stage, size 10 inch by 4 inch, furnished by Westinghouse Electric Corporation on order NY-7722. Each of these condensate pumps for all three units is driven by an Allis Chalmers 100 hp, 440 volt, 3 phase, 60 cycle, 1750 rpm vertical motor (Exception-rpm of pumps for Unit 2 is 1170). A two stage twin element steam jet air ejector with surface type inter and after condensers is provided for each machine for the removal of air from the condenser shell during normal operation. Each ejector is designed to remove 150 pounds per hour of air vapor mixture at one inch hg absolute pressure and saturated at 71.5°F. These ejectors are designed to withstand 850 psig at 900° F. Steam consumption per element is 600 pounds per hour at 350 psig.

Six inch type S-37 primer hogging jets were furnished with each condenser for starting-up operation. These jets operate at 350 psig with steam consumption at 2380 pounds per hour. Both SJ AP and hogging jets were furnished by Allis Chalmers Manufacturing Company, Inc., on orders NY-774 and NY-77404 for Units 1 and 3 respectively, and by Westinghouse Electric Corporation on order NY-7722 for Unit No. 2.

Accessories included with the condensing plant consist of a float controlled air operated hot well level valve, pressure reducing orifices and associated piping for the main and priming ejectors, air leakage meter with nozzle and cap, high water alarm and gauge glasses for the hot well.

Circulating Water System

The circulating water system is comprised of cooling towers, concrete tunnels, fabricated steel piping and valves, concrete pump well, circulating water pumps (described under "Condenser Auxiliaries") and necessary electrical control equipment. The cooling towers furnished by the Marley Company are four-cell design for each unit. The two towers for Units 1 and 2 were furnished on order NY-7738 and were erected together as one tower with a concrete dividing wall in the basin only. The tower for Unit 3 was furnished on order NY-77425. These towers are wood filled, induced draft, double flow type, overall size each 73' X 97' X 39', with a capacity of 31,000 gpm, temperature of water entering tower 104.3° F, temperature of water leaving tower 83° F with wet bulb temperature 63° F. Each cell is provided with a reversible type fan 240" diameter, capable of delivering 635,000 cfm at 30" hg, and driven through a reduction gear by an Allis Chalmers 60 hp, 3 phase, 60 cycle, 440 volt, 1800 rpm totally enclosed motor. 20" distribution piping carries water from the tunnel

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to the top of the towers and discharges into an open water basin; four pipes per tower, or one per cell. Additional fabricated 30" steel pipe, including valves, is installed from the tunnels to each condenser. The piping was furnished by Midwest Piping and Supply Company Incorporated, on orders NY-7721 for Units 1 and 2, and NY-77407 for Unit 3, and the valves for this piping were furnished by Kennedy Valve Manufacturing Company on order NY-7750 for Units 1 and 2, and by Chapman Valve on order NY-77413 for Unit 3.

36" thimbles were installed in the west concrete wall of the pump well to which were attached butterfly valves and the discharge side of the circulating water pumps. One 42" thimble was installed for future C.W. Pump 4. Also, in this wall, were installed four 8" relief valves at each pump location to relieve tunnel pressure in the event of incorrect valve closure. Four 10" thimbles were installed for future Unit 4. The butterfly valves were furnished by Henry Pratt Company, Inc., on orders NY-7776 for Units 1 & 2, and NY-77424 for Unit 3. Some difficulty was encountered during the early operation of the control equipment for these valves. Field revamping of a portion of this equipment improved the operation; however, a considerable change in the dwsign of the controls by the manufacturer provided a more satisfactory operating condition.

Circulating Water Treating Equipment

Provisions were made in the pump house building for housing the circulating water treating equipment. Two separate rooms were built, the south one to house the chlorine equipment and the north room to house the acid and polyphosphate equipment. The chlorination equipment consists of one Wallace and Tiernan semi-automatic solution feed vacuum chlorinator having a maximum capacity of 2000 lbs. per 24 hours to correctly chlorinate cooling water flow of 62,000 gpm. Accessories for this equipment include necessary valves, diffuser, regulating valve, testing set, rubber-lined pipe, and electrically operated control panel and piping to introduce the chlorine into the circulating water tunnel.

The entire equipment described above was purchased for the original installation from Wallace and Tiernan Products, Inc., on order NY-7763, and was placed in operation on February 15, 1951. In an isolated room within the pump house, but having no passageway to the pump house proper, storage facilities are provided for large chlorine cylinders. Wood racks are built for holding the cylinders and an overhead trolley with a 4000 lb. capacity "Speedway" electric hoist is provided for handling these cylinders inside of the building. A jib crane with a 4000 lb. capacity "Speedway" electric hoist is provided for handling the cylinders outside of the building. A special heavy duty dynamometer with capacity up to 5000 lbs. is provided for attachment to the hoist hooks for weighing chlorine cylinders. These pieces of equipment were provided by the following vendors: the job crane by Industrial Equipment Company on order NY-77179; the trolley hoists, by Wright Manufacturing Division of the American Chain and Cable Company, Incorporated on order NY-77174; the dynamometer, by John Chatillon and Sons on order NY-77159.

The acid-treating equipment consists of two Milton Roy Type AMD special pumps, each to handle at maximum capacity 8.7 gph concentrated sulphuric acid against a discharge head of 50 psi. Accessories for this equipment includes one 4" diameter by 4' long rubber-lined mixing chamber, acid diffuser, an automatic acid controller including electrical indicating and recording equipment, one L & N control panel, one Jabsco Model 903 sampler pump and sufficient lead-lined steel pipe, fittings, valves, etc., to carry treating chemicals to the

circulating water tunnels. Provisions are made for the operator to deluge himself with water, in the event of accidental contact with treating chemicals. The acid treating system was purchased from the Permutit Company on Order NY-7769, and was placed in operation on December 2, 1950. In addition to the above equipment, an acid storage tank 8' OD by 30' long was provided for storage purposes by the Graver Tank and Manufacturing Company, Incorporated, on order NY-77170. The initial fill of this tank occurred on November 30, 1950.

ACCESSORY ELECTRICAL EQUIPMENT

General

All electrical construction was performed by the Collier Electric Company on a unit price contract negotiated January 25, 1950, and covered by local order SD-875, for Units 1 and 2. A second contract similar to the first was negotiated on February 26, 1951, for Unit No. 3. This second contract was covered by local order SD-2719. The contract for Unit No. 3 was almost an exact duplicate of the contract for Units 1 and 2, with the exception that unit prices for No. 3 were increased by 7½%. Electrical installation was started on July 26, 1949, and continued until November 23, 1951, when the major portion of this work was completed. However, a small crew of 1 to 3 men was necessary to complete odds and ends until June 15, 1952.

Main Switching Control and Protective Equipment

Foundations were almost wholly confined to those in the transformer yard just outside the building wall, for supporting structural steel on which were run the generator leads to the main transformers. These foundations were of reinforced concrete and extended down to firm ground. The generator leads were made up of 3" copper tubing, mounted on bus type insulators, which in turn were mounted on a steel structural frame, all of which was enclosed by a structural screen inside the building. Wall type bushings were provided for egress of the generator leads to the outside. Immediately outside the building wall, a structural steel framework was erected to house the generator surge protective equipment. This equipment consists of three Westinghouse Type "FP" capacitors and three Westinghouse Type "SV" lightning arrestors, all of which were connected through 400 amp., 15 KV, stick-operated disconnect switches to the generator leads. Between the building wall and the transformer delta bus, a three pole gang operated air break switch of 3000 amp. 23 kv capacity was installed. The generator leads from the generator terminals to a point close to the generator air break switch were covered with "Formica" tubing as an insulation. The 13 kv side of the main transformers is connected through a delta bus made of 3" copper tubing, uninsulated. A tap made up of 1¼" copper tubing is taken off this delta bus for a feed through a 400 amp. gang-operated air break switch to the station auxiliary transformer.

The material for the generator leads was furnished on orders NY-77152, and NY-77126 for Units 1 and 2, and on order NY-77448 for Unit No. 3. The wall bushings for Units 1 and 2 were furnished on order NY-7743, and for Unit No. 3 on order NY-77430. The 3000 ampere 23 kv gang-operated air break switches for Units 1 and 2 were furnished by Delta Star Electric Company on order NY-7745, and for Unit No. 3 by Delta Star Electric Company on order NY-77410. The 400 ampere, 23 kv, gang-operated air break switches for use with station auxiliary transformers 1 & 2 were furnished by Delta Star Electric Company on Order NY-7745, and for Unit 3 on order NY-77410. The lightning arrestors and capacitors

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used for generator surge protection were furnished by Westinghouse Electric Corporation on order NY-7712, for Units 1 & 2, and order NY-77452, for Unit No. 3. The generator leads, delta bus and associated equipment, after being tested, were first placed in operation at the same time that the generators themselves were placed in operation.

The main control switchboard, located in control room #1, consists of 13 cubicles for all three units and are designated as follows:

Panel No. 1, for Battery and Annunciator, and from which all DC control circuits emanate.
Panel No. 2, for Rotor temperature recorders.
Panel No. 3, for Generator and Turbine temperature recorders.
Panel No. 4, Generator No. 1.
Panel No. 5, Auxiliary Transformer No. 1.
Panel No. 6, Standby Auxiliary Transformer.
Panel No. 7, Auxiliary Transformer No. 2.
Panel No. 8, Generator No. 2.
Panel No. 9, Leetsdale Lines Nos. 1 & 2.
Panel No. 10, South Terminal Lines Nos. 1 & 2, and 115 kv bus sectionalizing.
Panel No. 11, Frequency Control.
Panel No. 12, Generator No. 3.
Panel No. 13, Auxiliary Transformer No. 3.

These panels are all in numerical order reading from east to west, except Panel No. 11, which was taken out of line and placed at the far west end when Unit No. 3 was added. In addition to these panels there is a swinging bracket at the west end of the board for mounting synchronizing equipment. Metering and relaying equipment are generally mounted on the rear of the cubicles. Panels 1 through 11 were furnished for Units 1 and 2 by Westinghouse Electric Corporation on order NY-7712, and Panels 12 and 13, and additions to the other panels were furnished for Unit No. 3 by Westinghouse on order NY-77452.

The generator field switch cubicle and the motor-operated exciter field rheostat for each unit are mounted on elevation 5272.5 in each turbine pedestal and are controlled from the main switchboard. The field switch cubicles were furnished by Westinghouse Electric Corporation on order NY-7712 for Units 1 and 2, and on Order NY-77452 for Unit 3. The motor-operated rheostat and voltage regulators were furnished as part of the turbine generators by the manufacturers. Synchronizing of generators to the system is done through the 115 KV oil circuit breakers in the switchyard.

In order to provide starting-up power, the Public Service Company installed a 13 KV underground cable system from the north property line of the site to a standby station auxiliary transformer located at the south side of the building in a position similar to the station auxiliary transformers for each unit. This circuit originated from a pole line structure and is installed underground throughout the site area, passing through two manholes and terminating on a steel structure at the standby transformer. The cable for this circuit is three conductor 500,000 CM, lead-covered and insulated for 15,000 volts, and was furnished by General Cable Corporation, and on order NY-77111. Termination is made in a three phase pothead at the standby transformer. Lightning arrestors are mounted and connected to the short section of copper tubing between the pothead and the transformer.

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The majority of the control cable used for the various auxiliaries consisted of multi-conductor Kerite or Anhydrex insulated with Neoprene jacket overall. This control cable was furnished for Units Nos. 1 & 2 by the Simplex Wire and Cable Company, Inc., and the Kerite Company on orders NY-77110 and NY-77112, respectively, and for Unit No. 3 by the same companies on orders NY-77493 and NY-77494, respectively.

One new station battery was provided and installed in the switchgear room No. 1-2 on El. 5287. This storage battery consists of 60 cells, tytex type positive plates, style EOE 29, 560 ampere hours, 8 hour capacity, complete with intercell connectors, hydrometer syringe, thermometer, and four rack sections. This battery was furnished by the Electric Storage Battery Company on order NY-7762. A motor generator set for charging this battery was furnished by the Electric Products Company on order NY-7761, and consists of one 10 KW continuous rated 140 volts, 72 amperes, diverter pole generator, driven by a 15 horsepower 480 volts, 3 phase, 60 cycle induction motor. The generator is suitable for floating the storage battery on the line continuously and capable of attaining a final battery voltage of 1.75 volts per cell.

The motor generator set was installed in the same room with the battery and both were placed in service on January 20, 1951.

Auxiliary Electrical Equipment

The station service transformers include:
Two General Electric 6000 kva, OSIC outdoor, 3 phase, 60 cycle, high voltage 13,800/13,200 Delta, low voltage 2400 volt Delta, furnished on order NY-778, one for Unit 1 and one for standby service; one Westinghouse 6000 kva, OISC, outdoor, 3 phase, 60 cycle, high voltage 13,800/13,200 Delta, low voltage 2400 Delta, furnished on order NY-7717 for Unit No. 2; one General Electric 6000 kva, OISC, outdoor, 3 phase, 60 cycle high voltage 13,800/13,200 Delta, low voltage 2400 Delta, furnished on order NY-77405 for Unit No. 3. From the 2400 volt side of these transformers, current is carried to the switchgear through a metal-enclosed 3 phase bus duct made up of 3½" IPS copper tubing insulated with slip-on Phenolic sleeving, all mounted on bus type insulators for 5000 volt service and enclosed in a sheet metal housing or duct. This bus duct was furnished by the Elpeco division of Realty and Industrial Corporation on order NY-7767 for Units 1 and 2, and on order NY-77455 for Unit No. 3.

Auxiliary Switching, Control and Protective Equipment

Power for Station Auxiliaries is obtained normally from both the 2400 volt and the 480 volt switchgear. Those auxiliaries supplied from the 2400 volt switchgear are the station auxiliary transformers for the coal-handling equipment and for the cooling tower fans, and all motors over 100 hp. capacity which include those for induced draft fans, forced draft fans, circulating water pumps, boiler feed pumps, and others. In addition to these pieces of equipment, the pulverizers for Unit No. 2 also obtain their power from the 2400 volt switchgear. All of the balance of the auxiliaries except a few very minor items receive their power from the 480 volt switchgear which in turn receives it power through transformers from the 2400 volt switchgear. All switchgear, power centers and control centers, regardless of their voltage, were furnished by Westinghouse Electric Manufacturing Corporation on Orders designated with the descriptions of each group which consist of the following:

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One 11-compartment 2400 volt switchgear, designated No. 1,
One 7-compartment 2400 volt switchgear, designated Common,
One 15-compartment 2400 volt switchgear, designated No. 2,
One 12-compartment 2400 volt switchgear, designated No. 3.

All of these switchgear are provided with type 50-DH-150 solenoid operated air circuit breakers and associated contactors and equipment, with ratings of 600 and 1200 ampere capacities. Switchgear No. 1 and 2 were furnished on order NY-7711. The common switchgear was furnished on order NY-7713, and switchgear No. 3 was furnished on order NY-77417.

The station service transformers supplying power from the 2400 volt switchgear to the 480 volt switchgear are of 1000 kva capacity, naturally ventilated, ASI, dry-type, 3 phase, 60 cycle, 2400/480 volts, Delta Delta. One transformer is mounted in each switchgear group, which is made up of and designated as follows:

One 10 compartment 480 volt power center, No. 1A.
One 9 compartment 480 volt power center, No. 1B.
One 6 compartment 480 volt common power center.
One 10 compartment 480 volt power center, No. 2.
One 10 compartment 480 volt power center, No. 3A.
One 10 compartment 480 volt power center, No. 3B.

Each compartment is equipped with one type DB-25, 3 pole, single throw air circuit breaker. Also included in these switchgear are necessary contactors, current transformer, potential transformers, current limiting reactors, key operated interlocks, metering instruments, and control switches. 480 volt power centers No. 1A, 1B and common were furnished on order NY-7732; power center No. 2 on order NY-7715; power centers 3A and 3B on order NY-77418.

In addition to the main 480 volt power centers located in the building, there were four (4) additional 480 volt power centers located outdoors as follows:

One 5 compartment 480 volt power center for cooling tower No. 1,
One 9 compartment 480 volt power center for cooling tower No. 2,
One 9 compartment 480 volt power center for cooling tower No. 3,
One 18 compartment 480 volt power center for the coal handling equipment.

Each of these power centers is provided with a 500 kva, OISC, 3 phase, 60 cycle, 2400/480 volt Delta Delta transformer, throat connected to the power centers.

In order to have more adequate control over minor auxiliaries, 12 control centers were installed at strategic points throughout the plant. These control centers are described and designated as follows:

One 13 circuit control center designated 1A,
One 13 circuit control center designated 1B,
One 21 circuit control center designated Common,
One 30 circuit ventilation control center for Units 1 & 2,
One 8 circuit valve control center for Units 1 & 2,
One 15 circuit pump house control center for all units.

These six control centers were furnished on order NY-7733.

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One 12 circuit control center designated 2A,
One 14 circuit control center designated 2B,

These two control centers were furnished on order NY-7734.

One 14 circuit control center designated 3A,
One 14 circuit control center designated 3B,
One 4 circuit valve control center No. 3,
One 15 circuit ventilation control center No. 3.

These four control centers were furnished on order NY-77439. In addition to these 480 volt AC control centers, two DC valve control centers were furnished by Westinghouse Electric Manufacturing Corporation on orders NY-7733 for Units 1 & 2, and on order NY-77439 for Unit No. 3. These are 12 and 8 circuit control centers respectively.

The station grounding system consists principally of galvanized steel bar; however, some insulated copper cable was used in places where it was necessary to bring the grounding system through concrete foundations or otherwise buried in concrete. Several sizes of grounding bar were used, 1/8" by 1", 1/4" by 2", 1/8" by 3" and 1/4" by 3". These bars were welded together as was required and given a good coat of asphaltic compound, wrapped with black insulating scotch tape and given another coat of asphaltic compound. All underground metallic systems such as pipe, structural steel, etc., were tied into this grounding system at as many points as was conveniently accessible. Also tied into this system were all structural steel towers, building frame and other structural steel supported at ground elevation. Approximately 10,200 feet of steel bar was required for this grounding system.

A complete cathodic protection system was installed for the station. This system consists of one selenium self-air-cooled, full wave, bridge connected rectifier, complete with DC voltmeter and ammeter, and AC primary circuit breaker, DC rating 2 to 30 volts at 50 amperes, AC service 120 volts, 60 cycle, single phase, all mounted in a weatherproof case for outdoor service. The rectifier is mounted in the southwest corner of the switchyard, and is served from the lighting cabinet in the same switchyard. Forty 4" diameter by 80" long graphite ground anodes, National Catalogue item No. 1851 DG, are installed in the form of an "L" near the southwest corner of the property. These anodes are spaced approximately 20 ft. apart, and each anode is completely surrounded by coke breeze to the extent of 14" in diameter. This system, furnished by Brance-Krachy Company, Incorporated, on order NY-77178, was placed in operation on December 1, 1950.

Power and control cables furnished for the 3 units were supplied by the Simplex Cable Company, The General Cable Company, and the Kerite Company, with some additions by field order from the Okanite Company, The G. E. Supply Company, Graybar Electric Company, and the Elliott Schmidt Electric Company. The majority of this cable was furnished on New York orders 77110, 77111, 77112, 77204, 77493, 77494, 77502, 77512, and local orders SD-1693, 2036 and 2367, and consists principally of the following types and sizes:

Description of Cable listed below: 1000 Volt, anhydroprene cable with anhydrex SA tape and neoprene jacket.

1/C - 750 MCM, Stranded
1/C - 250 MCM, Stranded
1/C - 3/0 AWG., Stranded
1/C - No. 1 AWG., Stranded
1/C - No. 4 Awg., Stranded
1/C - No. 8 Awg., Stranded
1/C - No. 10 Awg., Stranded
1/C - No. 12 Awg., Stranded

Description of Cable listed below: 600 Volt, anhydrex SA tape, colored braid, jute fill, enoprene jacket.

2/C - 19/22 Awg. Control Cable
4/C - 19/22 Awg. Control Cable
7/C - 19/22 Awg. Control Cable
9/C - 19/22 Awg. Control Cable
3/C - 19/25 Awg. Control Cable

Description of Cable listed below: Anhydrex SA underground, colored tape, jute fill, neoprene jacket.

2/C - No. 2 Awg., Stranded, 600 Volts
3/C - No. 4 Awg., Stranded, 1000 Volts
3/C - 3/0 Awg., Stranded, 1000 Volts
2/C - No. 8 Awg., Stranded, 600 Volts
1/C - 1/0 Awg., Stranded, 600 Volts
3/C - No. 4 Awg., Stranded, 1000 Volts
3/C - No. 2 Awg., Stranded, 600 Volts
1/C - 3/0 Awg., Stranded, 600 Volts
2/C - No. 12 Awg., Stranded, 600 Volts
4/C - No. 12 Awg., Stranded, 600 Volts

Description of Cable listed below: 5000 Volts, Kerite Insulation, ambrac tape, asbestos braid jacket.

1/C - No. 1 Awg., Stranded
1/C - 3/0 Awg., Stranded
1/C - 250 MCM, Stranded
1/C - 350 MCM, Stranded
1/C - 4/0 Awg., Stranded

1/C - No. 12 Awg., Stranded, 1000 Volt, okolite ozone resistant rubber insulation, okoprene belt.

Description of Cable listed below: 600 Volts, okolite ozone resistant rubber insulation, saturated braid jacket.

1/C - No. 12 Awg., solid
1/C - No. 10 Awg., solid

Description of Cable listed below: 1000 Volts, anhydrex ozone resistant insulation, tape, neoprene jacket.

1/C - 750 MCM, Stranded
1/C - 1,000 MCM Stranded
1/C - 500 MCM, Stranded
1/C - 250 MCM, Stranded
1/C - 3/0 Awg., Stranded
1/C - No. 1 Awg., Stranded
1/C - No. 4 Awg., Stranded
1/C - No. 8 Awg., Stranded
1/C - No. 10 Awg., Stranded
1/C - No. 12 Awg., Stranded

Other Cable:

1/C - No. 12 Awg., solid, 600 Volts, type AVA, varnished cambric, asbestos braid jacket.
1/C - No. 16 Awg., Stranded, 300 Volts, type FA, asbestos insulation, asbestos jacket.

3/C - 500 MCM, Stranded, 15000 Volts, metallized paper shielding, paper insulation, metallic shielding tape, non-magnetic binder, lead sheath
1/C - No. 2 Awg., Stranded, 14000 Volts, varnished cambric insulation, flameprood hard cover.
1/C - 350 MCM, Stranded, 600 Volts, anhydrex HR tape, neoprene jacket.

1/C - 4/0 Awg., Stranded, 600 Volts, anhydrex, underground neoprene jacket.

Although cable trays were used for a greater portion of the cable in the building, considerable steel conduit was also used in practically all sizes from 1/2 inch up to and including 4 inch. Listed below are the quantities and sizes of steel conduit used on the three units.

4,361'	Size 1/2"	Rigid Steel Conduit
46,923'	Size 3/4"	Rigid Steel Conduit
46,900'	Size 1"	Rigid Steel Conduit
380'	Size 1¼"	Rigid Steel Conduit
19,580'	Size 1½"	Rigid Steel Conduit
21,648'	Size 2"	Rigid Steel Conduit
140'	Size 2½"	Rigid Steel Conduit
9,560'	Size 3"	Rigid Steel Conduit
4,400'	Size 4"	Rigid Steel Conduit

MISCELLANEOUS POWER PLANT EQUIPMENT

Service Equipment

A vacuum cleaning system is provided for the station building on order NY-77200 and additional hose outlets were provided for Unit 3 on order NY-77509. The exhauster or vacuum pump is a Lamson-Billmyr No. E-7, heavy duty, multi-stage centrifugal type, coupled to a 20 HP, 3550 RPM totally enclosed fan-colled motor.

Dust is removed through a two stage system, consisting of a primary exhauster tank with a dust storage capacity of 36.4 cubic feet, and two secondary separators with a dust storage capacity of 36.4 cubic feet and of 7.8 cubic feet respectively. The secondary separators are equipped with 18 tubular cloth filter bags having a net filter area of 131.4 sq. ft. Three external shaker handles allow removal of collected dust from the filter bags without opening the unit. Dust collected in the storage tanks is discharged through Unit 2 pyrites piping into the No. 2 boiler wet ash hopper, thence to the ash sluicing system. Miscellaneous cleaning equipment includes necessary flexible hose for connections between the inlet valves of the piping system and the cleaning tools,

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and specially shaped cleaning tools and brushes to provide for all types of surfaces to be cleaned. A total of 46 outlets are located throughout the station building to provide easy access to the vacuum cleaning system. Concrete for the vacuum pump foundation was placed April 16, 1951, and the vacuum pump and motor was set the following week. Piping for all three units was started January 3, 1952, and was completed February 26, 1952. The vacuum cleaning system was put in operation February 18, 1952.

Station Compressed Air for all three units is supplied from a single compressor and receiver located in the Unit #1 Compressor area. The compressor, receiver, after-cooler, and a Class HD-7A Duomatic control panel were furnished by the Gardner-Denver Company on order NY-77101. The compressor is a Model WBQ, 6" x 4½" x 5", vertical, two stage, with a tubular intercooler, suction unloading valves, and driven through a multi-belt drive by a 50 hp, 1750 rpm motor. The after-cooler, Model B-134, complete with moisture trap and oil separator, is capable of cooling a maximum of 240 CFM of free air at 100 psi to within 15° F of the temperature of the incoming water. Receiver is a 36" diameter x 8'-0" high vertical tank designed for 125 psi working pressure and is furnished complete with safety valve, pressure gage, and drain valve. Concrete for the compressor and driver foundation was placed January 18, 1950, and totalled 5½ cu. yds. The compressor was set during the week of March 20, 1950. Piping started April 20, 1950, and continued throughout the remainder of the construction period as areas were available for installation. Air mains are of 2" standard pipe, while outlets consist of a 3/4" valve and "Chicago Coupling."

The station air compressor was put in service October 12, 1950.

GENERAL PLANT EQUIPMENT

Machine shop equipment installed consists of a 16" Leblond D-3023 lathe, a Western Machine Tool Step-toe 20" shaper, a Wells No. 8 Band Hack saw, a Buffalo No. 18 Pedestal Type drill press, a Cincinnati Electric Tool Company Fox 10" bench grinder, and an Oster No. 582 Tom Thumb threading machine. Tool cabinets, work benches, and small hand tools are also provided and all located in the area allocated and permanently fenced by a wire mesh partition furnished by Acron Wire and Iron Company on NY-77523.

Laboratory equipment is provided to make such necessary tests as water analysis, boiler tests, turbine generator tests, and other results tests as required. Built-in cabinets, table, etc., are provided--also certain plumging items to furnish running water.

First aid equipment is provided to administer to emergency needs of the employees. A cot with mattress, blankets and pillow; medicine cabinets, stools, chairs, therapeutic lamp and necessary bandages, and small medicinal items are installed in a room built for this purpose, and which is a part of the office section of the plant. This room is also provided with basin and running water.

A small kitchen is provided in which is installed a 7' Westinghouse Electric refrigerator, built-in cabinet around the sink and one supply locker.

Office equipment and furniture provided for the offices and other parts of the plant are as follows:

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Clerk's Office

1 Counter 36" wide x 45" high x 10' long Birch Plywood with Plastic Top.
1 Steel Desk - Brown Leather Covering
1 Wood Swivel Chair
4 Steel Armless Chairs - Brown
2 Green 3-Drawer File Cabinets
1 Typewriter

Chief Engineer's Office

1 Steel Desk - Gray Leather Covering
1 Upholstered Arm Swivel Chair
4 Steel Arm Chairs - Green
2 Gray 4-Drawer File Cabinets
1 Marchant Calculator
1 Calculator Stand

Assistant Chief Engineer's Office

1 Steel Desk - Gray Leather Covering
1 Upholstered Arm Swivel Chair
2 Steel Arm Chairs - Brown
2 Steel Armless Chairs - Brown
3 Gray 4-Drawer File Cabinets

Conference Room

1 Conference Table - Wood
7 Steel Armless Chairs - Green
2 Blue Print Files - Gray - 4 Sections per File

Results Office

2 Steel Desks - Brown Leather Covering
2 Wood Swivel Chairs - Green
1 Green File Cabinet - 4-Drawer
1 2-Door Steel Storage Cabinet
1 Work Bench 3' 6" high x 30" wide x 23' long - Masonite top - built-in sink - drawer space and cabinet space under top - entirely enclosed.

#1 Control Room

2 Steel Desks - Brown Leather Covering
2 Wood Swivel Chairs - Green
1 Steel Armless Chair - Brown
2 Stools - Step-up Type
1 Steel Foot Stand

#3 Control Room

1 Steel Desk - Brown Leather Covering
1 Wood Swivel Chair - Green
1 Steel Foot Stand

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Machine Shop Office

1 Wood Desk
1 Wood Chair

MISCELLANEOUS

3 Wood Chest Cabinets 6' high x 5' wide x 20" deep
1 Set Foot Lockers - wood - 7' high x 18" deep x 18' long - ¼" plywood

Facilities for handling and storing material in the warehouse consist of:

1 - Nutting 2-Wheel Hand Truck
1 - Metal Drum Emptying Rack
3 - Floor Bins 10' x 10' x 3'8"
1 - Fairbanks Morse Scale Ser. #G099319
Capacity 1000 lbs. Code 1124
1 - Section 60' x 6' x 8" Wood Wall Bins
1 - Section 26'6" x 7' x 8" Wood Wall Bins
1 - Section 20' x 7' x 8" Wood Wall Bins
2 - 16' A-Frame Metal Pipe Racks 6' High
1 - Ruger Model HP-3 Tri-Pod Ser #767 with
3 Ton Hydraulic Hoist

TRANSMISSION PLANT

General

To the south of the station building, an 8 bay switchyard was built to provide for switching and control of all generators and emanating transmission lines. The center six bays are for Units 1 and 2 (3 each) and the bay at each end is for Unit 3. The entire output from each generator is taken directly to a transformer bus at 13.8 kv and stepped up to 115 kv through 3 single phase 16,667 kva transformers and delivered through overhead conductors, air break switches, and oil circuit breakers to the double bus in the switchyard; thence through air break switches and oil circuit breakers to the various outgoing transmission lines. Substation construction progressed concurrently with that of the steam electric station.

Structures and Improvements

Yard grading was begun on April 20, 1949, and consisted of the removal of earth to a depth of approximately 5' throughout the entire switchyard area. After the concrete foundations were installed, backfill was accomplished to within 12 inches of the top of these foundations. From this point 6 inches of coarse rock was laid, bringing the final grade to El. 5260, which is 6 inches below the finished concrete footings. An eight-foot overall type 423-HF Realock chainlink fence was installed around this switchyard; also, the same type of fence was installed around the potential transformers within the switchyard, totaling approximately 1209.5 feet of fencing in which were installed two 12' drive gates and four 4' walk gates. Lighting facilities for the switchyard consists of 21 lighting standards of type Pemco No. 650, supported on reinforced concrete foundations. Plug receptacles are also provided at strategic points on the legs of the various towers. A 24-circuit lighting panel is

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provided for control of the various lighting and plug receptacle circuits in the switchyard. The lighting fixtures mounted on top of the standards are incandescent lighting units, 300 watt, Pemco Catl. No. 526; 7 of them with symmetric refractors and 13 of them with asymmetric refractors. In addition to the lighting standards, bracket-type fixtures are provided in the transformer yard which are mounted on the various structures. These standards, brackets, fixtures and refractors were furnished by the General Electric supply Corporation on order NY-77196 for Units 1 & 2, and by Gaffney-Kroese Electrical Supply Corporation on order 77496 for Unit 3.

Substation Equipment

Yard overhead structures consist of structural steel framework, structural steel towers, pipe structures and their concrete foundations. Nine T-towers with connecting truss are provided for transmission line deadends, six T-2 towers with connecting truss are provided for supporting deadends over the oil circuit breakers, six TT-towers with connecting truss are provided for deadends over the main transformers, twenty C-towers are provided for supporting the gang-operated air break switches, ninety-five I-beam lally columns are provided for supporting the copper tube main busses and cross-connecting busses in the generator bays, twelve B-towers are provided for supporting the lightning arrestors in the line bays, and six small A structures are provided for supporting the fused disconnect switches for each group of potential transformers. All of the yard overhead steel structures were provided by the Flint Steel Company on order NY-7798 for Units 1 and 2, and on order NY-77406 for Unit No. 3. The steel erection for Units 1 & 2 was begun February 2, 1950, and completed for all three Units on April 26, 1951. Designation of the switchyard bays reading from east to west is as follows: Bay No. 1-Leetsdale Feeder No. 2; Bay No. 2-Leetsdale Feeder No. 1; Bay No. 3-Generator No. 1; Bay No. 4-South Terminal Feeder No. 1; Bay No. 5-Generator No. 2; Bay No. 6-Bus section; Bay No. 7-South Terminal Feeder No. 2; Bay No. 8-Generator No. 3.

The concrete foundations for these overhead towers and structures extended down to El. 5255 and approximated a total of 835 cubic yards, which included foundations for the oil circuit breakers and potential transformers. Portions of the switchyard equipment were placed in operation from time to time as needed, and preceded closely the date of operation of the several units. Underground ducts extended from the building to a manhole in the switchyard designated No. 3. Conduits are extended from this manhole to the various pieces of equipment requiring control or power cables.

Eight 115 kv oil circuit breakers were provided by the Westinghouse Electric Corporation, two on order NY-775, three on order NY-7718, and three on order NY-77416. All of these oil circuit breakers are Westinghouse type GM-4 "DE-ION" grid 3 pole, single throw, 800 ampere, 115,000 volt, with electrically operated mechanically and electrically trip free mechanism. Four of them for use as line breakers are provided with potential devices. Twenty 3 pole gang-operated, 115,000 volt, 600 ampere air break switches are provided in the switchyard. These were furnished by the Delta Star Electric Company on orders NY-7745 for Units 1 & 2, and on NY-77410 for Unit 3. (All are type MK-40 air break switches). Three switches are mounted in each of the four line bays, and two switches are mounted in each of the three generator bays, and two are mounted in the bus sectionalizing bay. Four type VP 115 kv potential transformers were provided by the Westinghouse Electric Corporation, two on order NY-7712 and mounted in bay 4 of the switchyard for connection to the east section of the

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main bus, and two on order NY-77452, mounted in bay 7 for connection to the west section of the main bus. Protection for these potential transformers is provided by three type B-MMR-0, combination fuse and resistor mountings, furnished by S & C Electric Company on order NY-7744 for Unit No. 1 and on order NY-77433 for Unit No. 3. These fuse disconnect switches are mounted on small "A" type structures in the same bays with the potential transformers, in bay 4 for east section of bus, and in bay 7 for west section of bus. Twelve type SV lightning arrestors for outdoor use were furnished by Westinghouse Electric Manufacturing Company; nine on order NY-7712, and three on order NY-77452. Three arrestors are mounted in each of the line bays in the switchyard on the B towers, and are connected to the 115 kv line side of the airbreak switches.

The overhead cables carrying current from the main transformers to the switchyard bus, and also from the switchyard bus to the line pulloffs, are 4/0 stranded bare copper cable furnished by Anaconda Copper Company on orders NY-77149 and NY-77440. 10" disc type insulators for suspension and dead end assemblies were furnished by Ohio Brass Company on order NY-7743. Approximately 555 were required for use in both the transformer and switchyards. Approximately 1000 feet of 3/8" diameter galvanized double strength steel cable was required for the shielding wire over the switchyard and transformer area. This wire was furnished by Burkhardt Steel Company on order NY-7794 for Units 1 and 2 and by the same company on order NY-77459 for Unit No. 3.

Carrier current equipment consisting of wave trap, coupling capacitor, and tuning unit was provided by Westinghouse Electric Manufacturing Company on order NY-7712 for one line bay. However, this was not completely installed and was never put into operation.

The main power transformer equipment comprises the installation of three banks of three single phase transformers each, one bank for each turbine generator unit. The three transformers for Unit No. 1 and the three transformers for Unit No. 3 were purchased from the General Electric Company on orders NY-778 and NY-77405 respectively. Three transformers for Unit No. 2 were purchased from the Westinghouse Electric Manufacturing Company on order NY-7719. All nine transformers are of 16,667 kva capacity, oil insulated, self-cooled, for outdoor service. High voltage is 66,675 with full capacity taps, low voltage is 13,200. Impedience is 7½% on 16,667 kva base. Transformers are gas-oil sealed construction with provisions for future addition of fans to increase continuous rating with forced air cooling. These transformers are connected Wye on the high side and Delta on the low side. A manufacturer's representative was present during most of the assembling and all of the field testing of these transformers.

The main power transformer banks as well as the standby and station service transformers are protected from fire by a Grinnell system, comprised of a pipe framework upon which are mounted spray nozzles and temperature actuated thermostats for automatic control of the system. The system is a dry type with thermostatic control under air pressure which, when increased by temperature, releases water into the system under pressure. The systems for all units were furnished by the Grinnell Company on orders NY-77118 for Units 1 & 2, and order NY-77465 for Unit 3.

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