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ORGANIZATION, MANAGEMENT, AND CONSTRUCTION  
PROCEDURES USED IN POWER PLANT CONSTRUCTION

by

Daniel P. Maxfield

Submitted in Partial Fulfillment of  
the Requirement for the Degree of  
BACHELOR OF SCIENCE

from the  
Massachusetts Institute of Technology  
1951

Author

Department of Building Engineering  
and Construction, 18 May, 1951

Professor in Charge

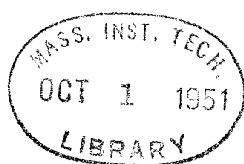
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Head of Department

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1951



Cambridge, Massachusetts

18 May 1951

Professor Joseph S. Newell  
Secretary of the Faculty  
Massachusetts Institute of Technology  
Cambridge, Massachusetts

Dear Sir:

In partial fulfillment of the requirements for the degree of Bachelor of Science in Building Engineering and Construction, I herewith submit a thesis entitled, "Organization, Management, and Construction Procedures Used in Power Plant Construction."

Respectfully submitted,

Daniel P. Maxfield

ORGANIZATION, MANAGEMENT, AND CONSTRUCTION PROCEDURES  
USED IN POWER PLANT CONSTRUCTION

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## ABSTRACT

The object of this thesis is to present the methods of organization, management and the construction used on a specific power plant project. All information is obtained from main and field office interviews with the personnel of the owner's representative, the general and subcontractors, and the working forces, and by inspection of the construction plans and specifications along with field observations and pictures of the procedures used. This information includes analysis of the job design, equipment, and layout for installation and operation.

The organization and management section includes detailed explanations of all the functioning groups on the job with reference to their manpower, duties, and services performed. The arrangements of the general contractor with each of his subcontractors are discussed with reference to the over-all plans and objectives of the owner. A detailed explanation of the trade divisions and supervision is given for all the work being performed.

The final section includes a word and picture presentation of the actual construction procedures being used on the job in an effort to give some idea of how the plant is constructed and made ready for operation.

## PREFACE AND ACKNOWLEDGMENTS

In arriving at the subject and title of this thesis the author has considered the main aspects of all building construction work that, he feels, the competent Junior Engineer should be familiar with and has chosen three main categories which will give the general over-all picture of the building construction project. These categories are Organization for construction, Management during construction, and actual procedures used in the construction which are to serve as examples for study and comparison, and to provide "food for thought" during all further study and experience in the field.

The author has chosen to apply this analysis to a specific project in preference to trying to touch slightly upon several projects, because more specific gain can be made in this way. The Power Plant has been chosen because it is one of the most complicated types of project, due to the range of units and machinery which must be compacted into an orderly functional type of building unit capable of performing efficient economical service. The problems of design and construction are complicated by the emphasis that must be placed on the mechanical and electrical aspects of the project which demand first consideration even over the building itself. The problems encountered are often



the most complex of their type and therefore should cover like problems of a simpler nature in other types of jobs.

The author is indebted to Mr. Carl Anderson and Mr. J. F. Kenney of New England Power Service Company, Mr. Frank Bell of United Engineers and Constructors Company, and to all others too numerous to list by name who are connected directly or indirectly with the Salem Harbor Project.

D. P. M.

## INTRODUCTION

It is necessary at the beginning of any such project as this to set down formally, the aims of, and the scope to be included by, the author. This has proven to be a very definite problem on this particular subject due to the complicated conditions which prevail throughout the entire construction project. The intricacies and details of the project are in many ways necessary for a clear view of the entire picture. On the other hand, however, it is quite possible to lose the object of the analysis due to the many entangling details and exacting procedures. One of the aims of this thesis is to provide an adequate reference of the three main points of Organization, Management, and Procedures, and therefore enough of the details will be included to accomplish this aim.

As to scope, the entire project that is in the construction state will be considered. This will be narrowed down by taking the time increment from the time the contract is let to the general contractor until about 1 May 1951, which date will approximate the time when all data must be terminated and the final information gathered in preparation for the final drafting of the thesis. The author will attempt to give some information to bring the thesis up to date by getting as much information as possible

on what was actually started prior to 1 October 1950. Since the author is primarily interested in construction after design has been completed, only such details of design as are necessary for a complete and clear picture of what is being constructed will be included. It is not the aim of this thesis to go into any portion of the actual design except to designate who is responsible for it in the organization section. This scope is to include the construction of unit one, through operation, although it will be impossible to separate entirely the preparation for or actual work on, the second unit within the building.

The method of analysis to be followed has been chosen so as to present the working tools for the discussion first. This is not to be considered the main topic but more of a necessary evil in order to establish common ground for the discussions on organization, management, and procedures. The analysis of the job will include all details necessary to provide a check list for further discussions and to provide a more complete picture of what is being constructed.

## ANALYSIS

### General Information

The project under consideration is located at Salem Harbor, Salem, Massachusetts. It is being constructed by the United Engineers and Constructors Company of Philadelphia, Pennsylvania, for the New England Power Company,

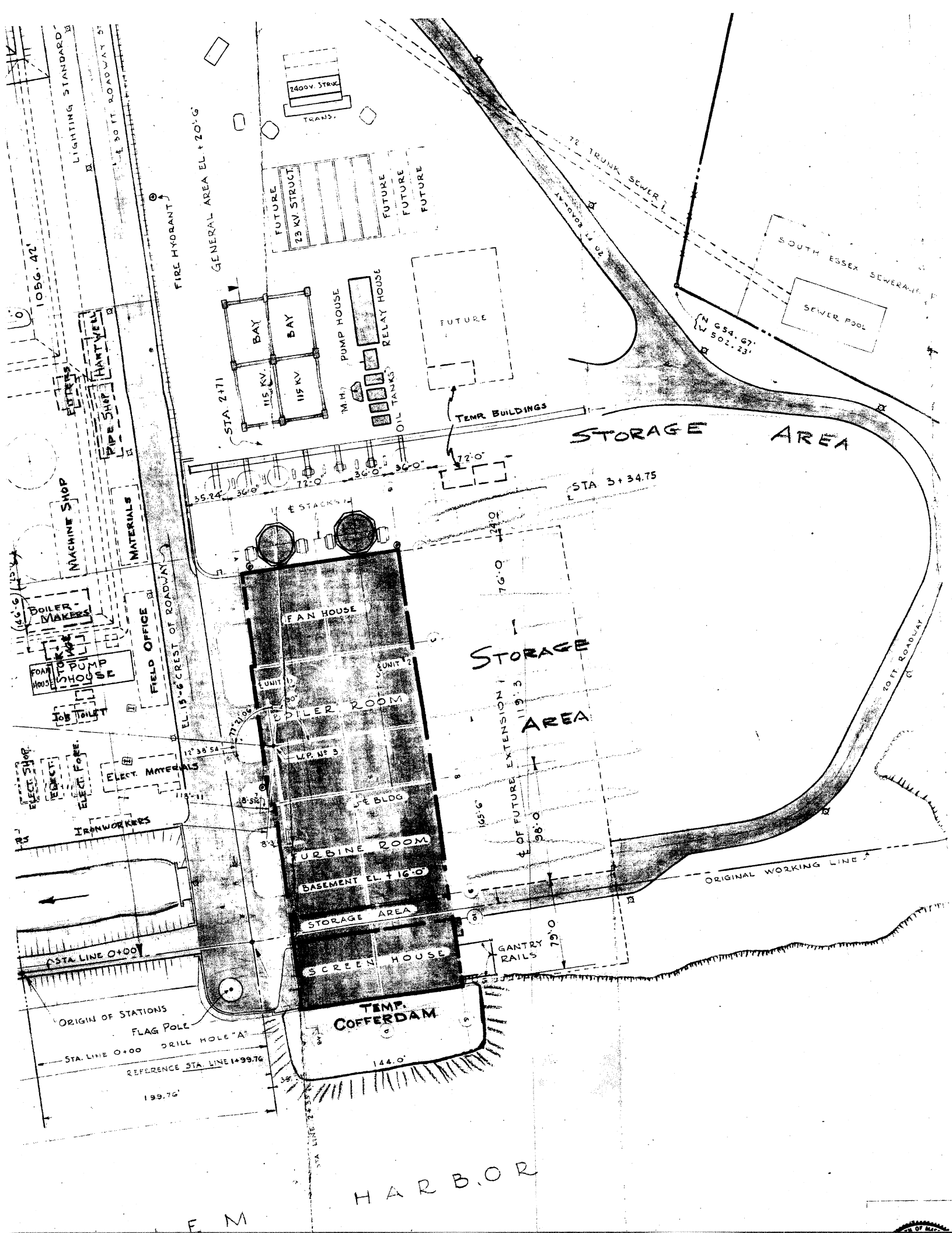
who will take over the plant upon completion of construction activities. The location is N.E. of the township of Salem and located directly on Salem Harbor.

The site chosen is on the bay or harbor and as seen from the accompanying diagrams is split into two sections by the small cove in the center. See Fig. 1. This cove is to be filled partially by rock and earth and used for oil storage and measuring tanks, and the rest will be filled with fly ash from the plant after starting operation. The plant section is located on an outcrop ledge which extends quite far out into the bay. This made it necessary to do considerable blasting in the entire area. The terminal section, which has been in operation prior to any construction revisions or additions, is located on level ground with subsurface clay layers beneath the storage areas. The terminal has been used for receiving coal from ships and handling it through storage and redistribution to railroad and trucking systems. The existing equipment at the time of the beginning of construction will be considered later. This coastal location has been chosen so that fuel can be brought in on ocean-going vessels and so that the essential supply of cooling water needed for condensing is readily available.

The total initial cost of the two-unit plant is estimated at about \$30,000,000. This includes the major portion of all new construction taking place on the entire site.

Figure 1





± ROAD FORT AVE EL. +17.19

PROPERTY LINE

FORT AVE

N 785.94'  
W 846.30'

EXISTING MANHOLE  
N 359.75  
W 827.77

± 30 FT. ROADWAY STA 1+79.31

LIGHTING STANDARD

GATE HOUSE

FIRE HYDRANT

GENERAL AREA EL. +20.6

2400V. STRUCT.  
TRANS.

FUTURE  
23 KV STRUCT.

FUTURE  
FUTURE  
FUTURE

STA 2+71  
115 KV. BAY  
115 KV. BAY

PUMP HOUSE  
RELAY HOUSE  
OIL TANKS

FUTURE

72" TRUNK SEWER  
14" DRAIN

SOUTH ESSEX SEWER

SEWER POOL

N 654.67'  
W 502.23'

TEMP. BUILDINGS

STORAGE AREA

STA 3+34.75

35.24' 36'-0" 72'-0" 36'-0" 72'-0"

STACKS

FAN HOUSE

UNIT 2

BOILER ROOM

W.P. NO. 3

STORAGE AREA

FIELD OFFICE

MATERIALS

MACHINE SHOP

PIPE SHOP HANTWELL

FIXTURES

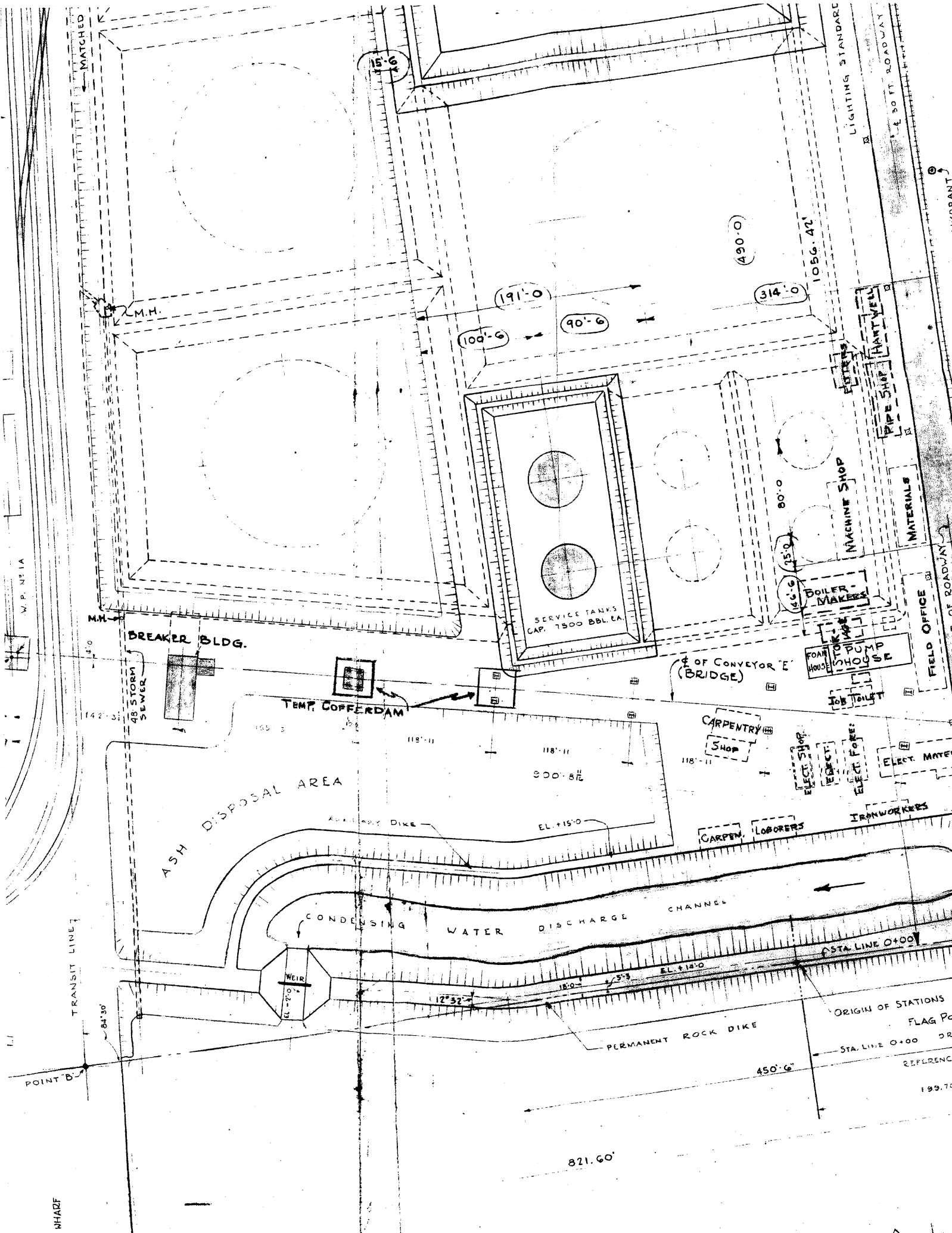
BOILER MAKERS

FOAM HOUSE

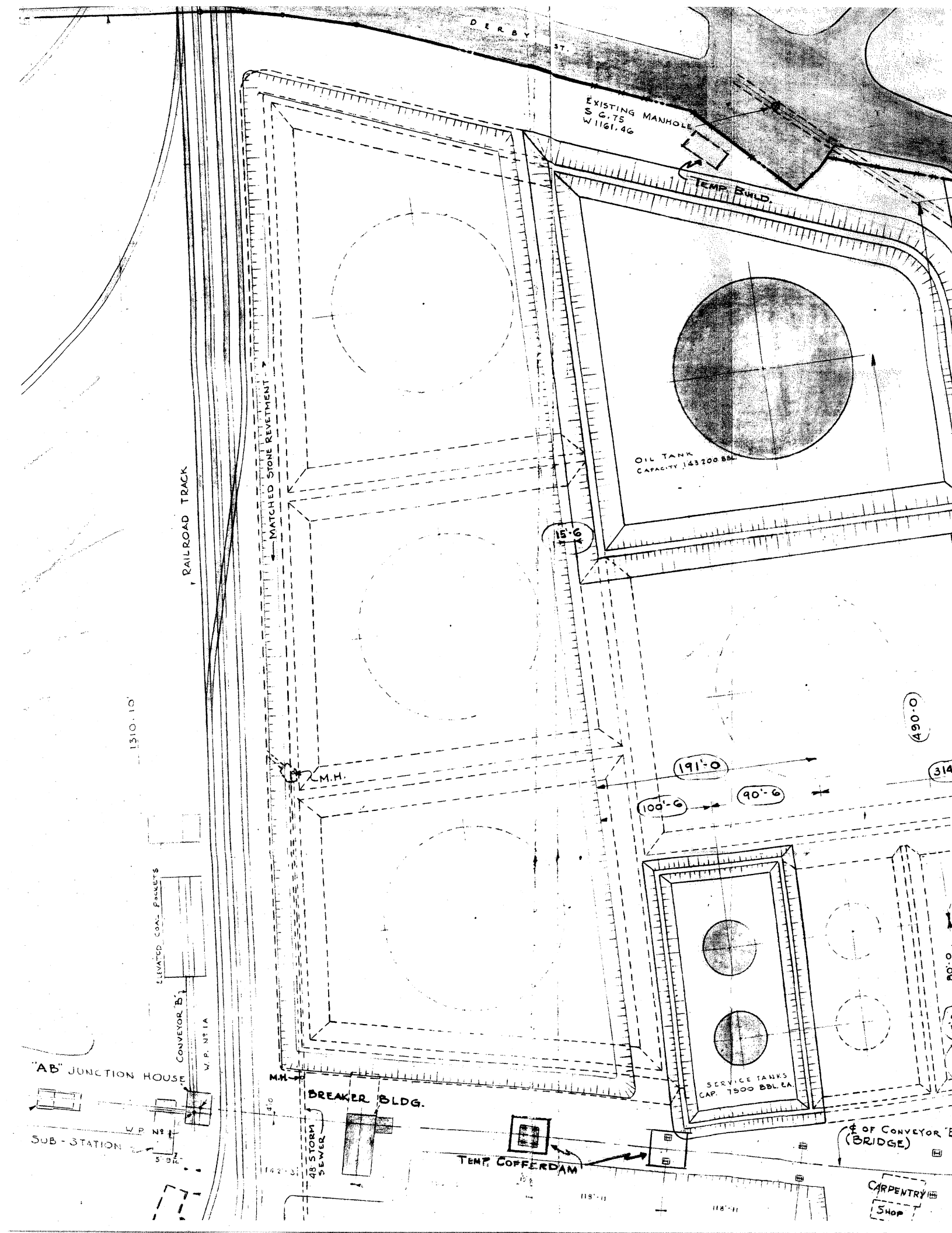
TOILET

MATERIALS

± 30 FT. ROADWAY





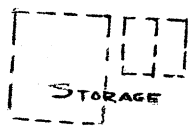


RAILROAD TRACK

S.

AREA

STORAGE



SEA WALL

1310.10'

ELEVATED COAL PASSWAYS

CONVEYOR 'B'

EXISTING COAL CONVEYOR 'A'

"AB" JUNCTION HOUSE

GANTRY RAIL

TRANS. PIT

SUB-STATION

GANTRY

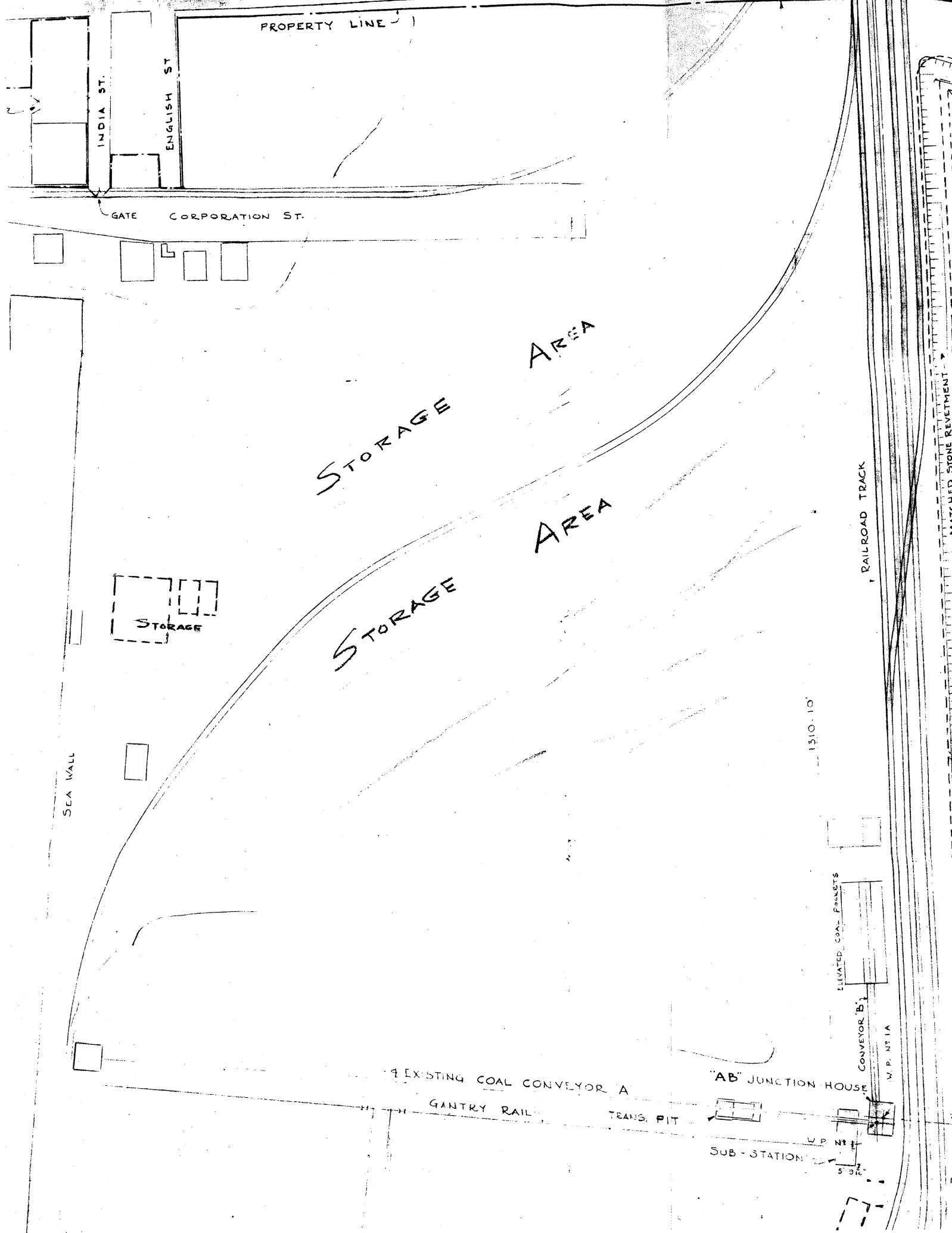
TEMP. BUILD.

RAILROAD TRACK

GANTRY RAIL

CONCRETE SEA WALL

WOOD ROADWAY ON PILING



PROPERTY LINE

INDIA ST.

ENGLISH ST.

GATE CORPORATION ST.

STORAGE AREA

STORAGE AREA

STORAGE

SEA WALL

1510.10'

RAILROAD TRACK

MATCHED STONE REVETMENT

EXISTING COAL CONVEYOR A

GANTRY RAIL

TRANS. PIT

"AB" JUNCTION HOUSE

SUB-STATION

ELEVATED COAL PACKETS

CONVEYOR B

W.P. N° 1A

W.P. N° 1

5.91'

The plant will have a normal yearly output of 1,000,000,000 kilowatt hours and will constitute the primary source of electricity for Salem, Beverly, Gloucester, Rockport, Medford, Melrose, Malden, and Everett. This plant will also be interconnected over transmission lines with the entire New England Electric System which serves over 2,000,000 customers and is composed of a balanced system of 24 hydro-electric stations and 13 steam-generating plants.

The important features of the project include a more detailed explanation of each of the component parts which make up the entire operative unit. A great deal of the information below will be presented directly from the design specifications and the blue prints, since this is the most exact way of obtaining a complete and well organized picture of the features of the plant. The details that are included herein may not be of general interest, but are being presented so as to give a complete basis for comparison and study of what is being done on this job.

An installation of this type involves a vast amount of planning, designing and scheduling by a large number of individuals in the fields of Civil, Structural, Mechanical, Electrical and Chemical Engineering, Metallurgy, and Architecture. The construction phases include the use of nearly all of the trades in the industry.

The specific parts of the installation can be identified from the original plot plan. The entire station

including all auxiliaries is designed for convenience and the most efficient and economical operation possible with the site facilities available and/or within the scope of the expansion.

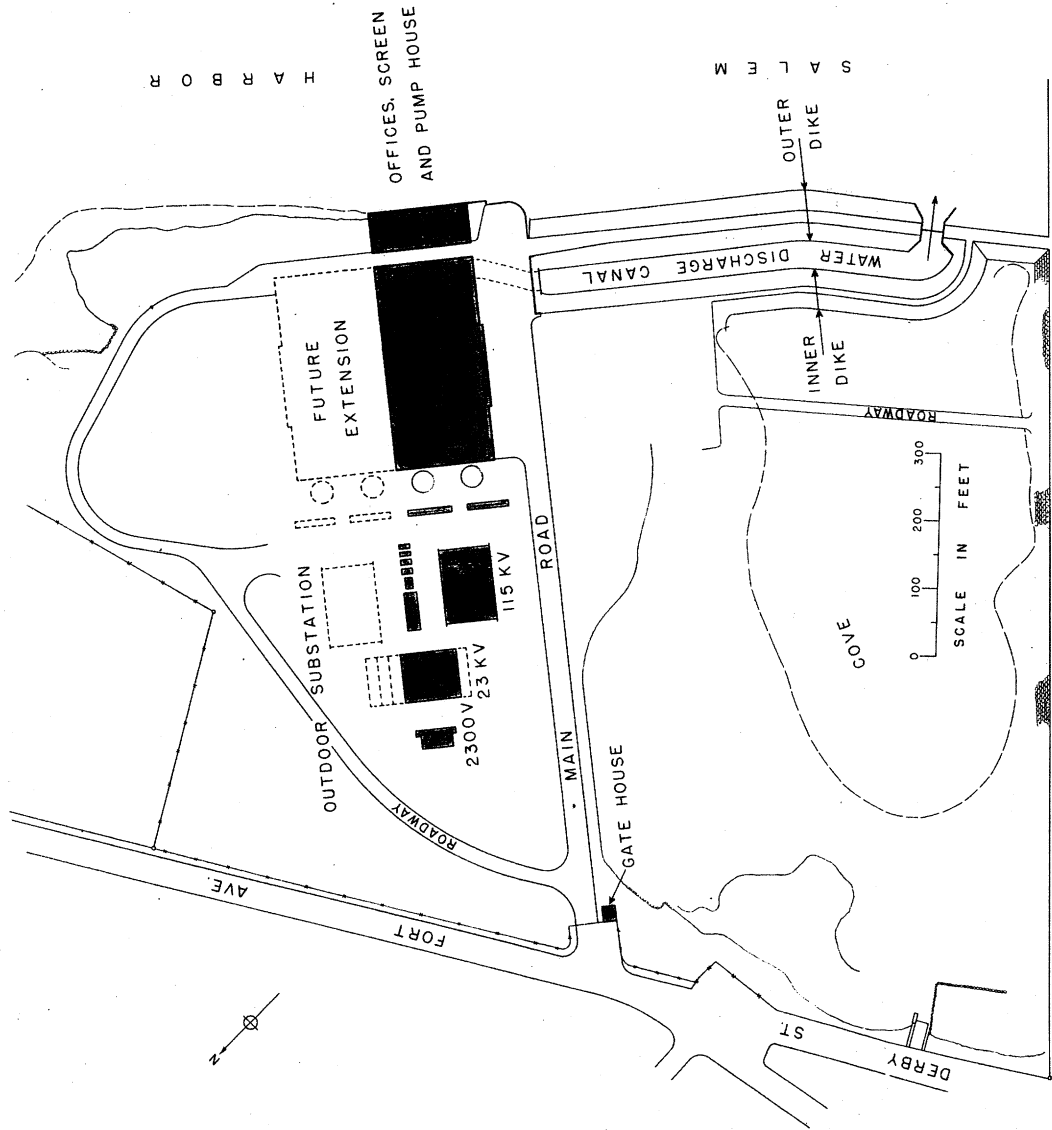
### Important Features

Each portion of the installation will be taken separately, and the details will be presented covering the building, major equipment, yards, storage areas, and terminal system. The building is designed as a complete generating unit consisting of two boilers and generating units and the necessary equipment for their operation. The building is composed of four parts as can be seen in the diagrams shown. See Fig. 2. These are the fan room, the boiler room, the turbine room, and the screen house and office building. It is designed in contemporary style with every effort to make the building as pleasant a land-mark as possible.

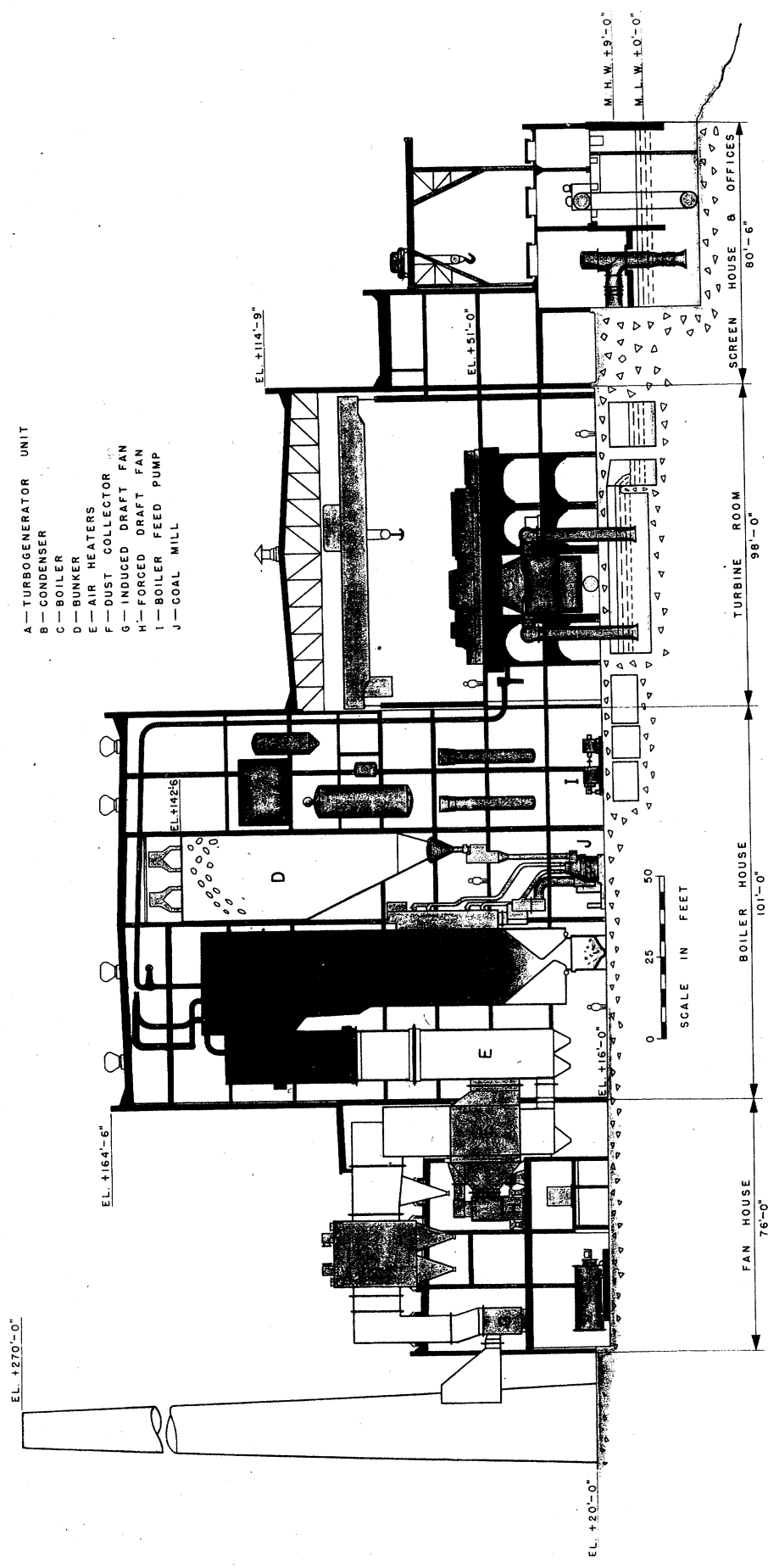
See Fig. 2e.

### Type of Installation

The building is constructed of steel, and reinforced concrete with a light buff face brick exterior. The foundations are set on solid rock and the steel skeleton is the kind encountered with such large and heavy equipment. The superstructure is composed of over 4500 tons of steel, all of riveted construction that has been fabricated at the steel plant and is shipped to site by rail and erected in place according to careful engineering plans. The brick

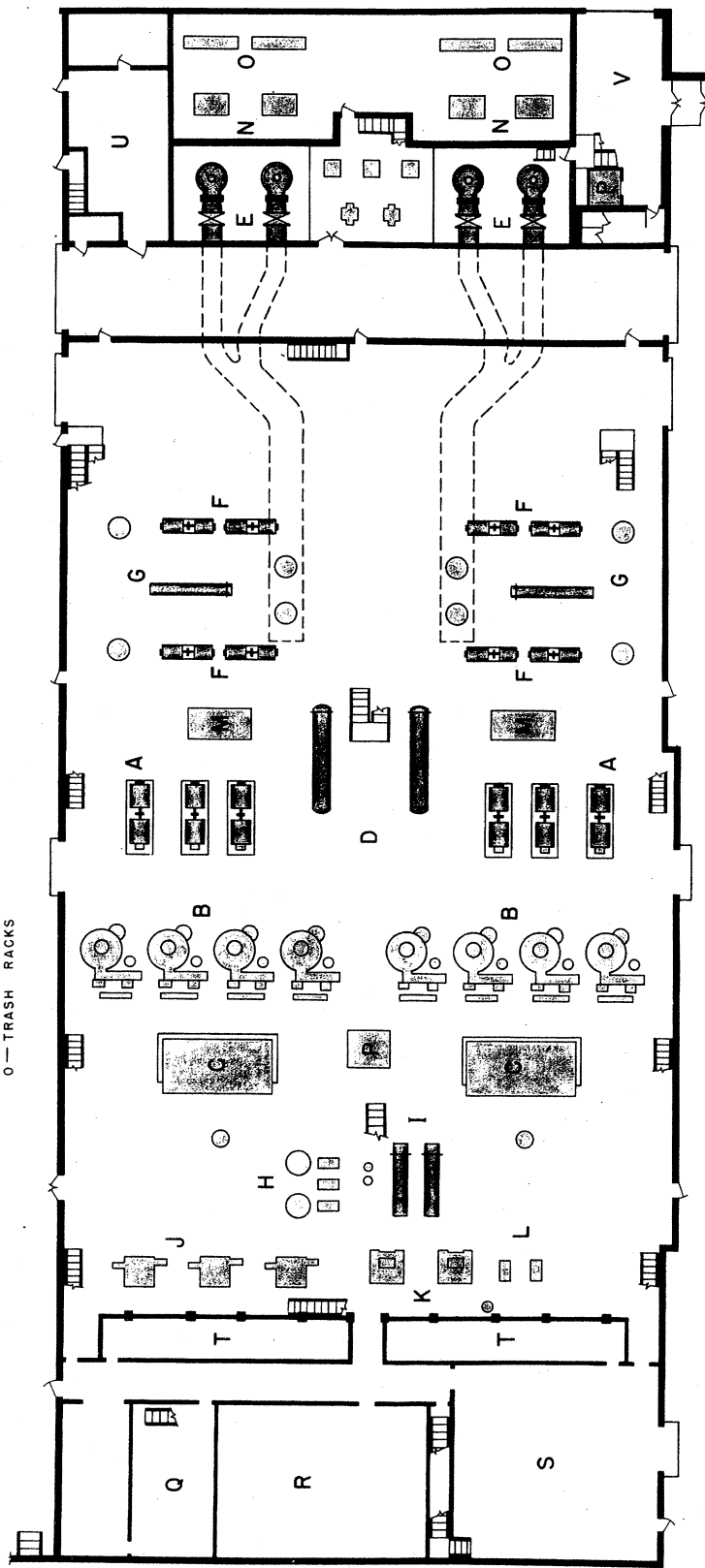


R.R. TRACKS  
 SALEM TERMINAL CORP.  
**PLOT PLAN SALEM HARBOR STATION**  
 NEW ENGLAND POWER COMPANY



CROSS SECTION  
SALEM HARBOR STATION  
NEW ENGLAND POWER COMPANY

- A—BOILER FEED PUMPS  
 B—COAL MILLS  
 C—ASH HOPPERS  
 D—EVAPORATORS  
 E—CIRCULATING WATER PUMPS  
 F—CONDENSATE PUMPS  
 G—CONDENSATE COOLERS  
 H—B.W. TANKS & PUMPS  
 I—BEARING WATER COOLERS  
 J—AIR COMPRESSORS FOR SOOT BLOWING  
 K—AIR COMPRESSORS (STATION)  
 L—AIR COMPRESSORS FOR CONTROL AIR  
 M—OIL TANKS (LUBRICATION)  
 N—REVOLVING SCREENS  
 O—TRASH RACKS  
 P—ELEVATORS  
 Q—OIL HEATER & PUMP ROOM  
 R—LOCKER ROOM  
 S—MACHINE SHOP  
 T—CABLE VAULT  
 U—CHLORINE STORAGE ROOM  
 V—ENTRANCE LOBBY

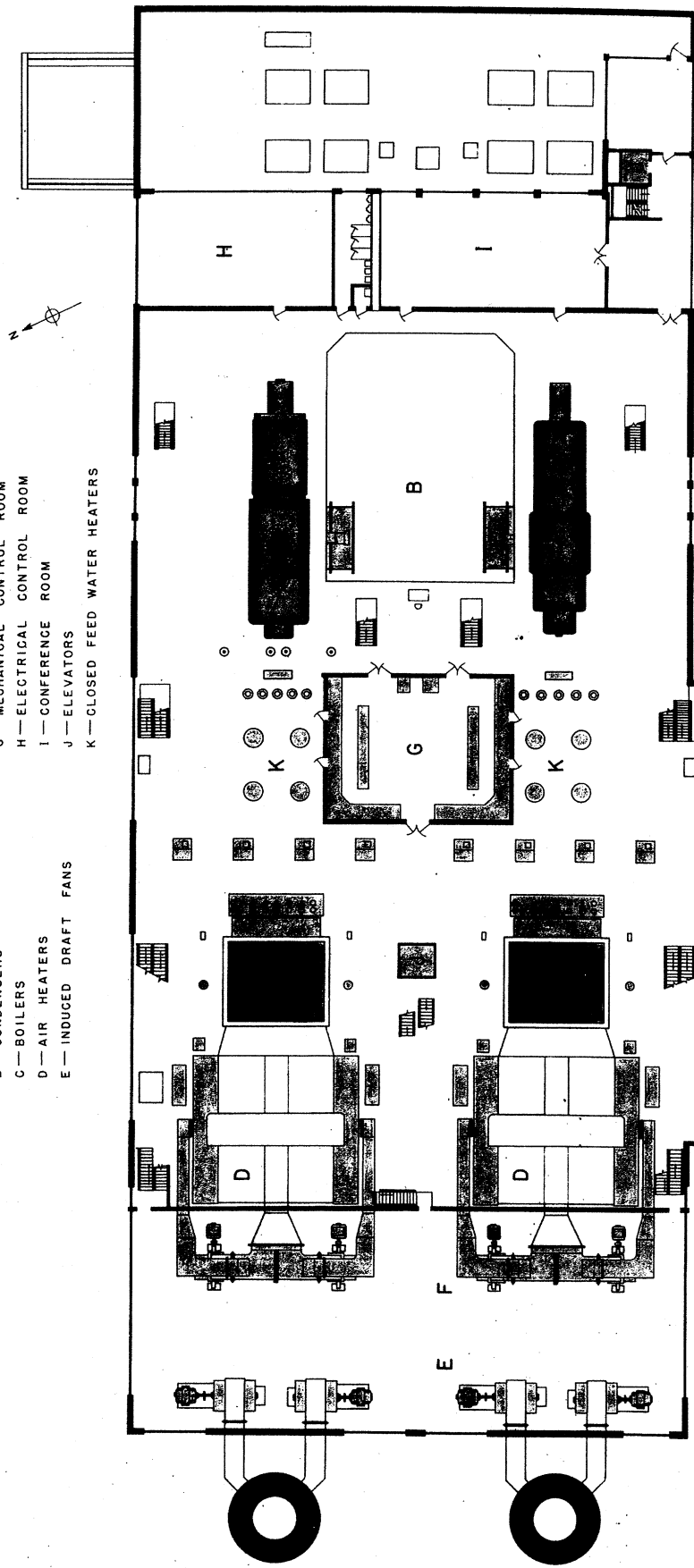


PLAN AT EL. +16'-0"  
 SALEM HARBOR STATION  
 NEW ENGLAND POWER COMPANY



A—TURBOGENERATOR UNITS  
 B—CONDENSERS  
 C—BOILERS  
 D—AIR HEATERS  
 E—INDUCED DRAFT FANS

F—FORCED DRAFT FANS  
 G—MECHANICAL CONTROL ROOM  
 H—ELECTRICAL CONTROL ROOM  
 I—CONFERENCE ROOM  
 J—ELEVATORS  
 K—CLOSED FEED WATER HEATERS



PLAN AT EL. +51'-0"  
 SALEM HARBOR STATION  
 NEW ENGLAND POWER COMPANY

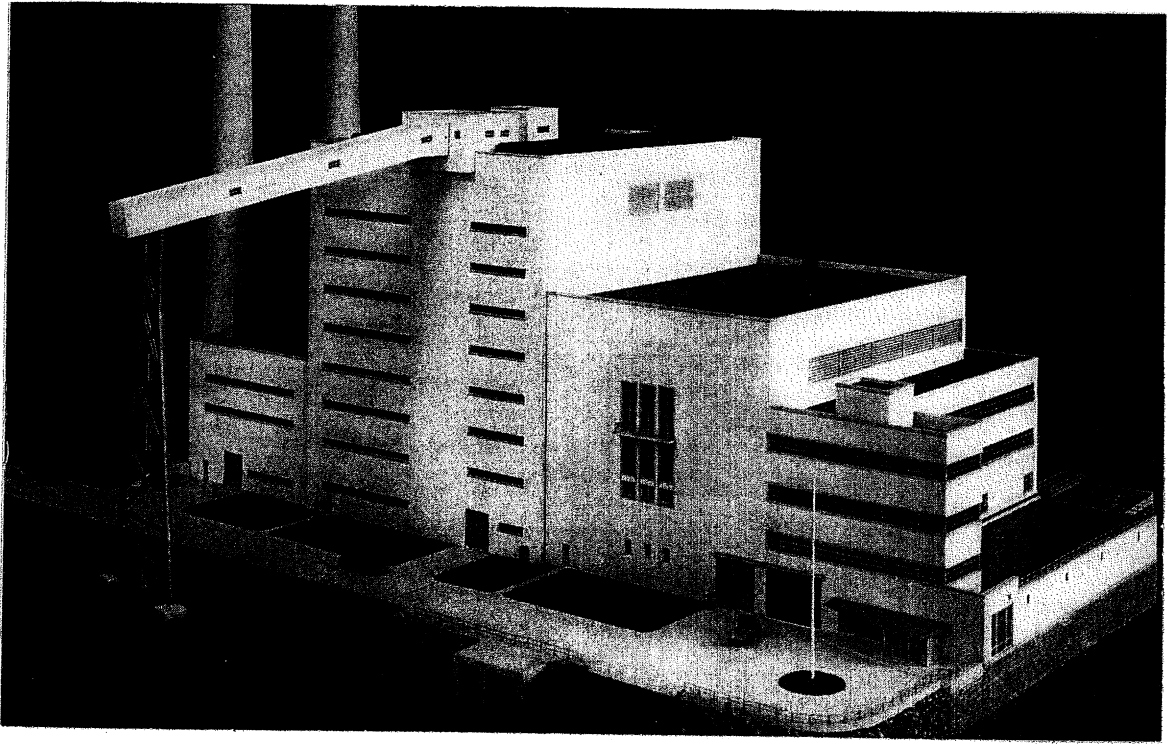


Figure 2e

work amounts to over a million and a half bricks and interior tile units. The face bricks are standard size and are backed up by National Fireproofing Corporation Speed-a-Backer tile and common brick. Trim for the exterior is of Chelmsford gray granite and it provides an exceptional combination of color scheme.

The interior sections are faced with ceramic glazed tile, buff in color, and in the storage areas and some shops clay face bricks are used. The lobby interior is high-lighted by use of Architectural Terra Cotta which is built into the structure by use of Everdur Bronze anchors.

Other details of the construction of the masonry work include the use of asphalt impregnated cotton fabric, reinforced with wire mesh spandel and wall flashing throughout the building. The sequence for wall construction provides for the laying of 5 courses of face brick, parging on the back, and then laying two courses of backing tile. All steel is parged, and hot dipped galvanized steel wall ties are used throughout the masonry work. There are also several large panels of 12" glass block in the building, and slate window sills are used. The following is a table of Mortars used on the job:

Unit	Mix Cement	Lime	Sand	Admix	Joints
Buck hollow tile	1	2	7 - 9	Master Building Unicorn, Mortar-proofing	Flush 1/4"
Interior Facing Tile	1 white	2	7 - 9		do
Glass Block	1	1	4 by dry volume	do	
Terra- Cotta	Non- Staining 1	1	5 white		do
Non- Staining	do	1/5 by volume C.	do		

Bond is full-running headers every sixth course, with concave, with large radius tool joints on the exterior pointing. All wall surfaces are to be cleaned with 5% solution of muriatic acid if necessary and thoroughly washed down. All caulking is to be done with gray compound around all windows, doors, frame openings, and in all joints in the exterior walls between masonry and any other material. Weathercap seal is used and set in the caulking compound where necessary.

On the concrete work, similar details are available concerning construction details. The following table gives most of the data:

Location	Bags cement/yard <sup>3</sup> not less than	Water/bag not more than	Slump not more than	Agg.	Strength psi at 28 days	Mix Cement Sand Aggregate
Pile caps & floor fill	4 1/2	6 gal.	4"	1 1/2	2,000	1 - 3 - 5
Duct lines in layers	5	6 gal.	2"	1/2	"	1 - 3 - 5
Col. footings Outdoor slabs	5	6 gal.	4"	1 1/2	2,500	1 - 2 1/2 - 4 1/2
Foundation Walls & M.H.	5 1/2	5 gal.	4"	1 1/2	2,600	1 - 2 1/2 - 4
Cell walls, conduit envelopes & cases	5 1/2	6 gal.	6"	1/2	"	1 - 2 1/2 - 4
Floor & roof slabs & M.H. roof slabs	6	5 gal.	4"	1	3,000	1 - 2 - 3 1/4

All of the above concrete is Ready-mix transit mixed. Details of placement that are specified include those for cold weather. All concrete must be kept at 50°F for 72 hours when the temperature is below 40°F, and must be placed at a temperature in excess of 70°F but at no time above 100°F. This was accomplished by heating the aggregate prior to adding water. The curing details provided for protection from meshing of all surfaces by means of water and covering for at least 72 hours. Honey-combing, stone pockets, and other defects had to be removed and keyed and filled with good concrete.

All expansion joints in the concrete work had to be made by use of 1/2" mastic material, and waterstops were of 8" wide 12 gauge black steel welded at the corners of all joints.

On the concrete used for casting the precast slabs in the roof construction an accelerator was permitted so that the stripping time could be decreased from the 96 hours to 48 hours on the slabs. The accelerator used was Incor Admix. All aggregate used had to pass a soundness test and be greater than 1/4". Sand had to be less than #4 and 92% on a #100 mesh sieve; pass a soundness test; have a mortar ratio strength of at least 90%; and pass the organic test for good sand. All of the above tests are A. S. T. M. Standards.

The windows were originally to be divided into two classes. Those in the permanent wall construction

were to be bronzed frame, but these could not be obtained so that steel is being used throughout the building on both the permanent and temporary wall construction. All sash are of hot rolled steel members and are the projecting type. These frames are shipped to the site, bonded and painted and equipped with the necessary materials for complete construction and operation. Where it is necessary to have mechanical operation for windows spanning openings or high up in the air, worm and gear type openers are provided.

All roof decks are constructed of precast concrete slabs or of concrete cast in place by the general contractor, who also provides all concrete fills and crickets, roof drains, and sleeves, vents and rain hoods. The roofing, flashing and insulation has been sublet.

There are two main sections of the roof as divided by the different topping surfaces. Red Quarry Tile is to be used over the Screen house and the Fan Room areas, and a built-up tar and gravel on the remaining sections.

The flashing work which is all sheet metal and covers all cap flashings and coping was all shop shaped and shipped to the site as such. Essentially it is all constructed of lead coated copper material which is 16 oz. copper with no less than 7 1/2 # of lead per 100 sq. ft. Construction is to be completed using resin flux and a 40% lead and 70% black tin solder. The flashing on the canopy roof section is all of 16 oz. copper; it is to be

constructed by use of a 50% lead and 50% black tin solder. The flashing details call for all base flashing to be carried up at least 8" on all vertical surfaces, and shall be lapped about 4" by the cap flashing. All end laps are 3" and are soldered.

The sequence of construction provides for a thorough cleaning of all deck surfaces prior to the application of the roofing. The roof is composed of a priming of hot pitch and several layers of hot asphalt which has a melting point of over 190°F. This was saturated with asphalt and 2 plies of 15# roofing felt laid with hot asphalt maintaining 19" laps throughout construction.

The insulation, which is 2" Foamglass under the quarry tile and 1" Vapor seal Celotex, corkboard, or equal, with a K value not over 0.33 over the rest of the building, is laid on hot mopped asphalt and covered with waterproofing. Water cut-offs consisting of 2 plies of felt and 3 moppings of pitch extending at least six inches on the deck and overlapping the insulation at least 4", are being installed about every 25' and at all vertical surfaces. The built-up roofing consists of 4 plies of 15# felt under the slag and gravel topping and 5 plies under the quarry tile. The tile was laid on the clear roofing with a setting mortar 1 part type II Cement. All joints are 1/2" and are pointed. Expansion joints, 3/4" wide extending from surface of the tile through the mortar shall be installed about 20' apart in each direction and at all walls, curbs, and projections.



The main emphasis in power plant construction must be placed on the major mechanical equipment that is used in the installation. For this reason a very thorough analysis will be made of all of the major equipment used and of its operation and reference to all other operating units in the installation.

#### Major Equipment

Two identical Babcock & Wilcox Boilers and all their auxiliary equipment provide the necessary steam for operation of the plant. Each of the units is a water tube, bent tube type boiler with a water-cooled furnace of the dry bottom type. The units are designed for economical use of a two stage superheater, reheater and horizontal economizer, of the continuous loop type, all constructed within the setting of the boiler. Each unit has a working capacity of 575,000# of steam per hour, evaporating 65,000 gallons of water to 625,000 lbs. of steam in one hour at 1450 lbs. per square inch of pressure at the generator, and 1000°F. heat and reheat 1000°F. The burners are direct firing type designed to burn bituminous coal after it has been pulverized to about the consistence of flour in the pulverizers, bunker "C" oil, and possible natural gas in the off seasons. The units will use 1350 tons of coal per day or 252,000 gallons of oil per day.

The water used in the boilers will be composed of the condensate from the deaerating hot well plus about 1%

city water make up which has been properly treated with caustic and sulphate in a hot process softener system followed by an evaporator. Feed water is progressively heated in a six bleed heater system before entering the boiler. The final treatment is accomplished by the addition of phosphate at the boiler drum.

The auxiliary equipment includes two section air heaters and all ducts and duct work between the air heaters and the boilers, and to the coal pulverizers. The air is circulated by forced draft fans and the exhaust gasses are extracted by the induced draft fans. The exhaust gasses would contain any soot leaving the system through ordinary operation or due to the use of the automatic sequential air-puff type soot blowers which are installed for the boiler, super heater, reheater, and economizer. All dirt and soot is removed just before the gasses pass out the stacks by means of mechanical dust collectors and Electrostatic Precipitator which collects the dust particles.

The fuel system can be traced for the use of coal from the pulverizers, of which there are four for each unit. These grind the coal to a fineness of 90% past a #200 sieve so that powder can be blown through a system of coal pipes from the mills to the burners by means of variable speed feeder motors. The pulverizers are driven by squirrel cage induction motors developing 200 horsepower at a high starting torque.

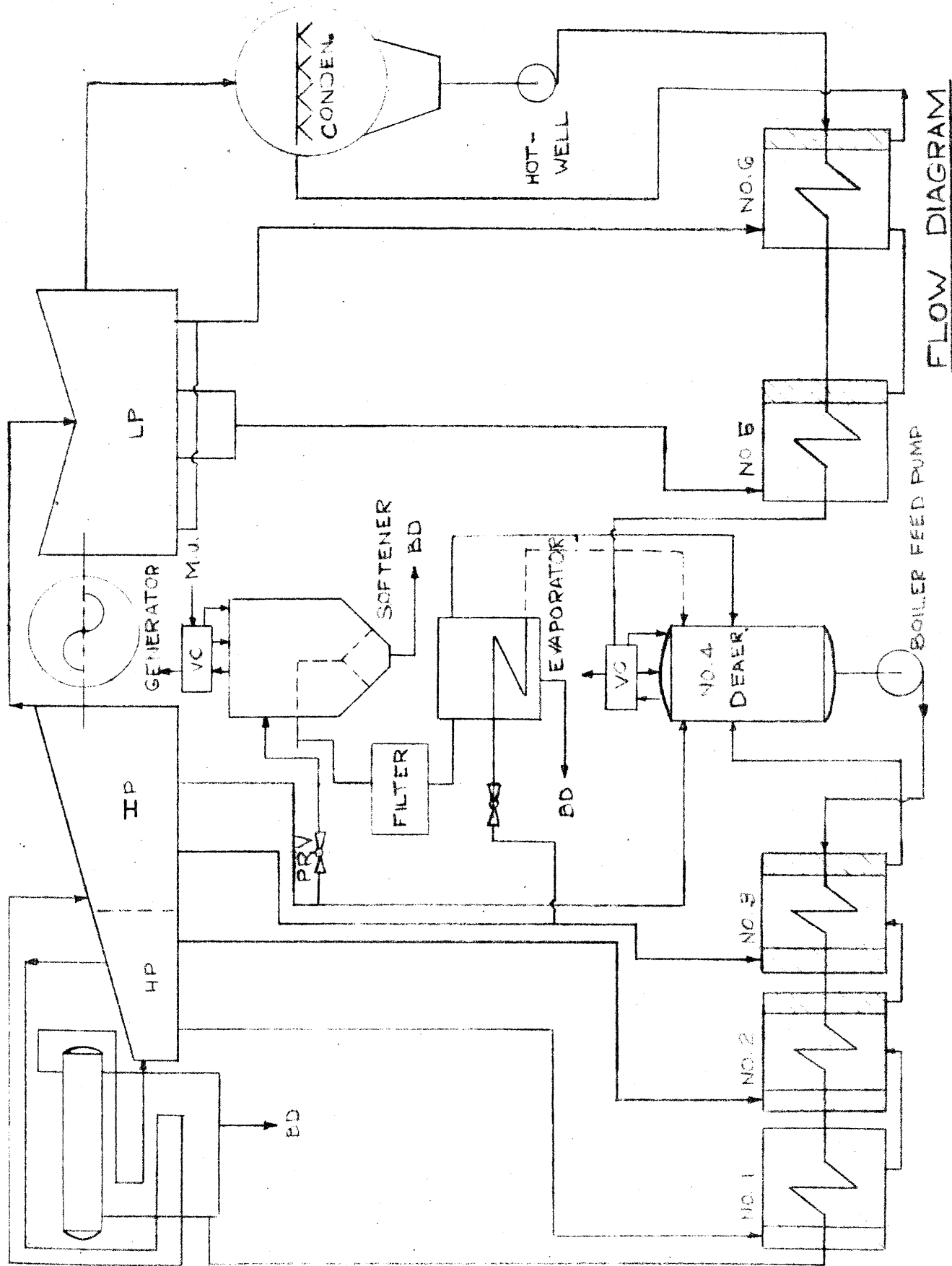
The burners include the wind boxes and manual ignition oil burners of the steam atomizing type for each coal burner. Provisions have also been made to make it possible to install full capacity burning of fuel oil by replacing the plates on the ignition oil guns.

The entire boiler is encased in steel plate over the required insulation of high temperature cement and 85% magnesia blocks with 1" extra 85% magnesia in addition to the usual boiler-makers standards.

The boilers have automatic combustion control systems and temperature controls operated from a central control station. Over-all operational efficiency will be over 89.5% at full load rating. Safety items include water columns at each end of the boiler drum with high-low alarm, working safety valves and Yardway unit type blow-off valves for the boiler and water walls.

The coal handling system will be discussed later in connection with the Terminal System. The Flow Diagram pictured in Fig. 3 will give a schematic picture of the complete system which is being discussed at this time. The boiler unit, the softener and the feed water preparation which have already been discussed can be tied in with this diagram.

The complete feed water preparation system includes the flow system from the condenser hotwell to the boiler. The heat cycle section of this system includes the

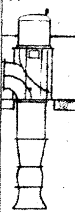


FLOW DIAGRAM

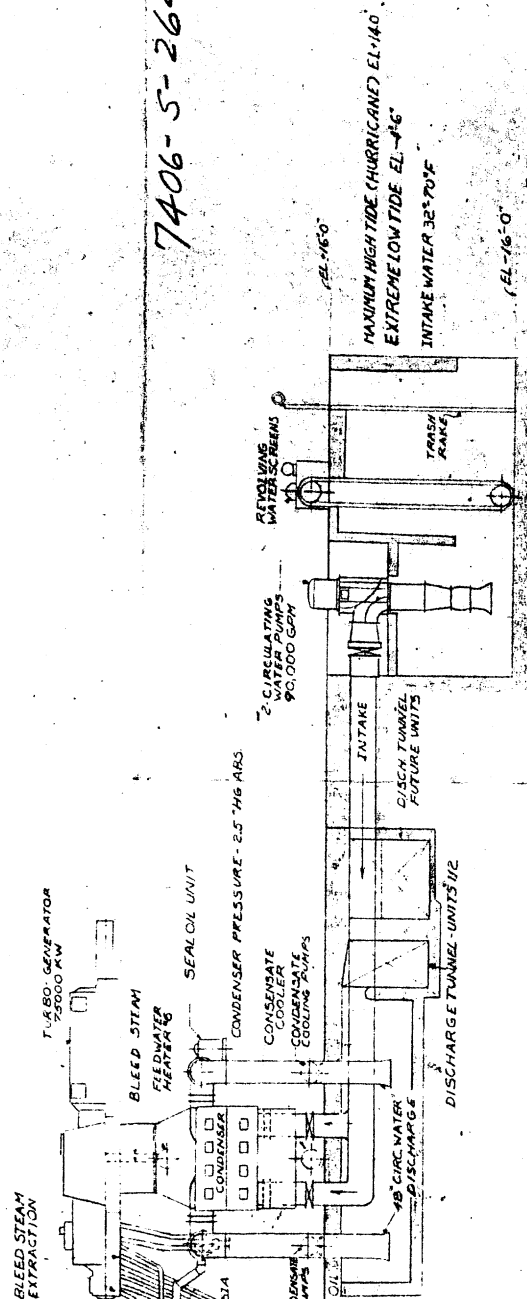
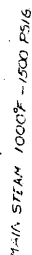
Figure 3b

DATA  
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LING  
FT CO  
RE MA  
TER V  
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ON







7406-5-264

GENERAL CROSS SECTION LOOKING NORTH

SCHEMATIC DIAGRAM UNIT 1

SALEM CAREER STATION  
NEW ENGLAND POWER COMPANY  
UNITED ENGINEERS & DESIGNERS, INC.  
SALEM, MASSACHUSETTS

DRAWN BY GJ/JT  
DATE 2-26-57  
SCALE 3/4" = 1'-0"

FIELD OFFICE SWITCH  
7408-5-264

six stage heater system, the evaporator, and the make-up from the city water. The heater bleeds can be traced from the various take-offs from the high pressure, intermediate, and low pressure sections on the turbine.

The turbine room section of the building houses the Turbo Generators and their auxiliary equipment. Both units, though designed and constructed by two different companies, are designed for the same inlet conditions from the boilers. Each 60,000 to 75,000 Kw unit is designed for inlet steam at the 1450 pounds per square inch provided, and 3600 r.p.m. operation. Non-automatic extraction is used for reheat condensing operation, and the units are designed for continuous operation to meet lighting and power demands when operating along, or in parallel with, other units, and to regulate frequency automatically throughout the system.

The turbine is to be of the reheat two-cylinder, tandem compound, double flow, impulse, condensing type, and designed to insure continuous, safe, reliable and economic operation without undue heating.

The turbine operating conditions include pressure exhaust of one inch of mercury absolute pressure and sufficient steam to supply heat cycle at a temperature of about 455°F. at number one heater, and conditions such that only 1% make-up will be necessary.

The turbine parts in contact with the steam are designed to resist corrosion and electrolytic action of the



steam and of the chemically treated feed water. The steam from the boiler comes through the main steam line, which is a 2" wall, chrome molybdenum alloy steel pipe with controlled carbon content and phosphorus and sulfur. The flow in this line is controlled by the throttle and interset valves which are operated by the overspeed governor trips. The throttle valve also trips the boiler in event of sudden electrical load loss, so as to provide complete coverage.

The generator is the second portion of the turbo-generator units, designed to capacity with 95% power factor. 1.0 short circuit ratio hydrogen cooled at 0.5 psig pressure, at 3 phase, 60 cycle, 14,400 volts output. It consists of a stator and rotor, the latter of which weighs about 150 tons, and is equipped with motor driven turning gear.

The generator is internally cooled as described above and the coolers are built in units of tubes of Admiralty metal with bronze tube sheets to provide the necessary protection of the equipment. The lubricating oil system consists of oil coolers for 95°F. and 125 psig forced feed including storage tanks, centrifugal type main oil pump that is driven off the main shaft; and an auxiliary main shaft pump, emergency oil bearing pump to supply headers and booster pump to suction off main shaft pump.

Excitation is accomplished by means of a self neutralizing excitor that is connected directly to the generator, and is equipped with a self ventilating pilot excitor.

Also as auxiliary equipment should be included the automatic low vacuum trip devices and the blow out diaphragms, the automatic packing steam unloading valve, and the indicating Lochometer. The generator is insulated with plastic type insulation, except where blanket type asbestos is used over flanges. The outer surface of the generator is covered by a sheet metal casing.

The control system with the exception of that portion that will be discussed later under the electrical distribution system includes the valves and controls necessary for complete automatic control. For the turbine the system consists of a main speed governor which is of the hydraulic oil relay type, the pre-emergency overall and the emergency overall speed control valves, the multiple steam control valves with remote manual load limit devices and a Selsyn indicator, and a motor operated speed exchanger.

Three main governors are responsible for the overall control of the unit. These include a speed response governor to prevent hunting at all loads; the emergency and pre-emergency governor which trips the throttle and inlet control valves, and which finally trips completely shutting the intercept valve in case the generator loses its load and prevents tripping of the emergency overspeed governor mentioned above.

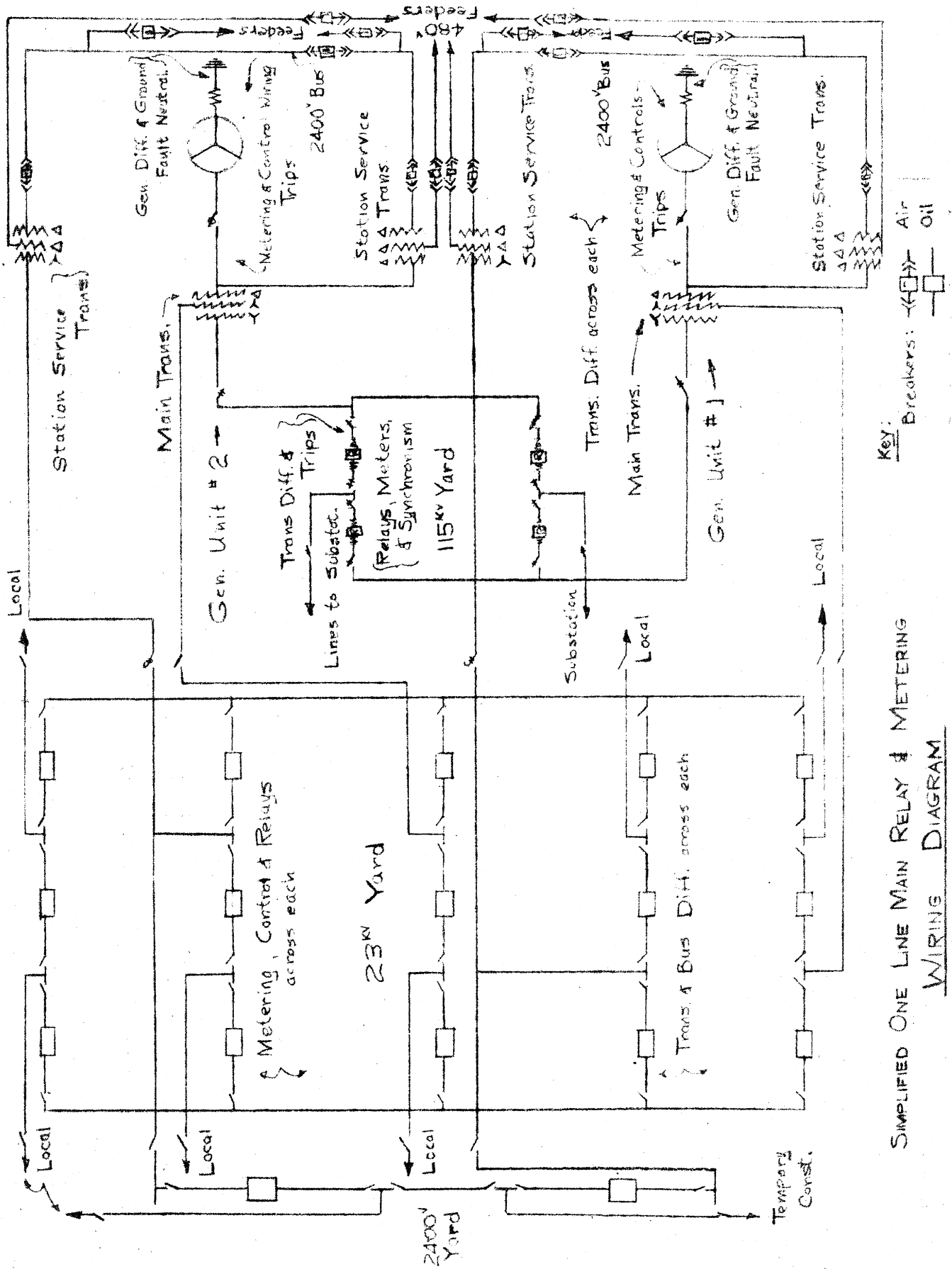
Directly beneath the turbine is the surface condenser which rejects 370,000,000 B.T.U. of heat per hour

from the steam by condensing in a vacuum and by use of 86,000 gallons per minute of cold sea water which is in contact with the 47,500 square feet of aluminum brass tubes. The condensate is then recirculated for re-use in the boiler. The circulation of water is maintained by means of two vertical propeller type pumps which operate against a head of 37'-0" at extremely low tide.

The last remaining equipment that need be mentioned is the overhead 150 ton traveling crane that operates the length and breadth of the turbine room. This unit was designed to handle the generator stator at mid span. The crane is also equipped with an auxiliary hook capable of hoisting an additional load of 20 tons.

The screen house equipment includes the circulation pumps mentioned above and just ahead of these pumps on the ocean side are the rotary screens that are designed to keep out the fish and other marine life. There is an outside crane that will handle the rotary screens after construction, and the maintenance and dismantling that is necessary on the pumps.

The Electrical work and the entire distribution system of the project is a very intricate system which is quite complicated as to details and functioning; for this reason it will only be discussed in general terms. The simplified line diagram shown in Fig. 4 will give a complete picture of the entire distribution system from the generators out to the transmission lines.



SIMPLIFIED ONE LINE MAIN RELAY & METERING  
WIRING DIAGRAM

The first thing to be considered in the electrical line is temporary installations that were necessary before any other work could be done on the job site in the way of construction. Temporary facilities were first established by the local company which installed the first section of the 2400<sup>V</sup> yard. Transformers were installed to step the incoming voltage down from 22,000<sup>V</sup> within the substation. Facilities also included two banks of 450 KVA transformers which stepped down to 440<sup>V</sup> for all general use, two banks of 100 KVA stepping down to 440<sup>V</sup> again but being reserved for stress relieving machinery, and finally two banks of 75 KVA stepping down to 110/220 for lighting and small power requirements.

The initial generation is at 14,400<sup>V</sup> and the lines run directly from the generator to the main transformers. The main electrical work at the generators is the control facilities. Each generator is protected by a system of protective relay differential and ground fault relay and neutralizer. These are important in the protection of the generator against damage that might be caused by difficulties on the line or elsewhere in the system. Protection includes delay timing and complete cut-off if necessary. The differential trips the 23 KV, 115 KV, station service, and excitor breakers and the throttle valves. The generator is designed mechanically to withstand three-phase fault, but high fault currents would damage the generator stator and would

necessitate expensive repairs. Previous to the development of the ground fault neutralizer, very high resistors were used to keep these currents down, but these were much more expensive than the new system of using transformers and reactors.

Other main control items are the generator voltage regulator which controls the Kx, and the voltage differential which effects regulation of the generator field so as to give the desired voltage and Kx. The metering and control trips which are indicated include all the equipment for recording the performance and the output such as ammeter, wattmeter, Kx meter, watthour meter, Synchroscope, and volt meters.

The generators have bushing type transformers with four cables per phase going under ground to the main transformers through the bus structure. Each has a set of three gang motor operated disconnect-switches on the low voltage windings.

There is a direct take-off on each line to the station service transformers, two of which are fed from the generators and two of which are fed from the local 2400<sup>V</sup> lines in the 2400<sup>V</sup> yards. These transformers are all three phase and supply 2400<sup>V</sup> and 480<sup>V</sup> power to the building for its operation. These two voltage systems are broken down into a 2400<sup>V</sup> bus system, a 2400<sup>V</sup> common feeder system, and 480<sup>V</sup> systems including the following: unit bus, control

center, and three feeder busses. The 2400<sup>V</sup> system feeds the pulverizer motors, forced draft fans, induced draft fans, circulating water pumps, condensate pumps, boiler feed-pumps, and one lead to the common feeder system. The common feeder system includes the salt water pumps, ash pumps, spare excitor, soot blower air compressors, feeder to coal handling equipment, and future installations of warm water pump-frazzie ice equipment. The 480<sup>V</sup> unit bus system includes the air compressors, electrical precipitators, bearing cooling water pumps, city water booster pumps, soot blower air compressor exciters, the control air compressors, and the fuel oil pumps. The 480<sup>V</sup> control center system includes the coal vibrators, coal scales, coal feeders, boiler room supply fans, sludge recirculating pumps, backwash pumps, chemical feed softeners pumps, phosphate pumps, sulphite and caustic pumps, condensate cooling pumps, agitator pumps, vapor extractors, oil purifiers, turbine auxiliary oil pumps, make-up water pumps, boiler feed valves, circulating water valves, chlorinator evaporator, revolving screens, salt water chlorine pumps, salt water service pumps, generator main lead duct fan, the hydrogen vacuum pumps, and the M.G. set Buck-Booster exciter. The remainder of the 480<sup>V</sup> bus systems include the following: Motors for doors, turning gears, boiler house and office elevator motors; feeders to the electrical shops, gate house, outdoor switch yard, fan floor hoist, machine shops, heating

boiler, and turbine room crane, transformers for lighting, and chlorinator control; fans for the toilet and locker room supply and exhaust, chemical lab and coal lab main steam valve unit exhaust, mechanical control room air conditioning and compressors, chlorine room vent, conference room exhaust, office supply and the chlorine storage purge; pumps for the heating returns, bearing cooling water, city water booster, emergency bearing and turning gear oil, hydrogen seal oil, sumps in the boiler room, manholes, turbine room, and screen house, and the salt water priming; soot blower air compressor excitor, coal conveyor, turbine room roof vent, hoist for the chlorine tanks, and lastly the gantry crane at the screen house.

This entire system is all laid out through the conduit systems in the plant, and gives some indication of the complexities of such a system. No attempt will be made to explain how such a system would be laid out or wired since it would involve far too many details.

The next piece of equipment in the line system is the main transformers. The primary purpose of these transformers is to step up the initial energy of the generators to 115,000<sup>V</sup> which is to say 115<sup>kv</sup>. These are huge oil-cooled single phase transformers which are mounted on rails so that they can be readily moved from position to position on a rail system, which makes possible interchanges and allows for maintenance and repairs. The oil is provided



through a permanent oil system which includes the oil tanks and storage, pumping house equipped with filter presses which clean the used oil and render it ready for reuse.

The 115<sup>V</sup> lines go underground from the main transformers to the yard. The yard, as can be seen from the wiring diagram, is made up of a yard ring system consisting of oil disconnect switches and the necessary relays, meters, and synchronism equipment. The ring system makes it possible to take any one section of the yard out of service for maintenance and repairs and still leave the rest of the yard intact for operation. This system is used throughout the yards. The leads from the yard to through underground duct lines in oil-filled cables pass through the city to a terminal where they are converted to overhead transmission lines and make their way across the countryside to two other substations of the New England Electric system, as can be seen on the Map layout by referring to Fig. 5. This entire system is controlled according to districts and the power demands within the area.

The second side of the main transformers feeds the 23,000<sup>V</sup> or 23<sup>kv</sup> yard. This yard is composed of a five section three bank ring system similar to that explained above. Each section has the necessary transformer and bus differential wiring and the necessary metering and control and relay wiring. The taps from these sections include that for distribution to the local townships, the return taps to



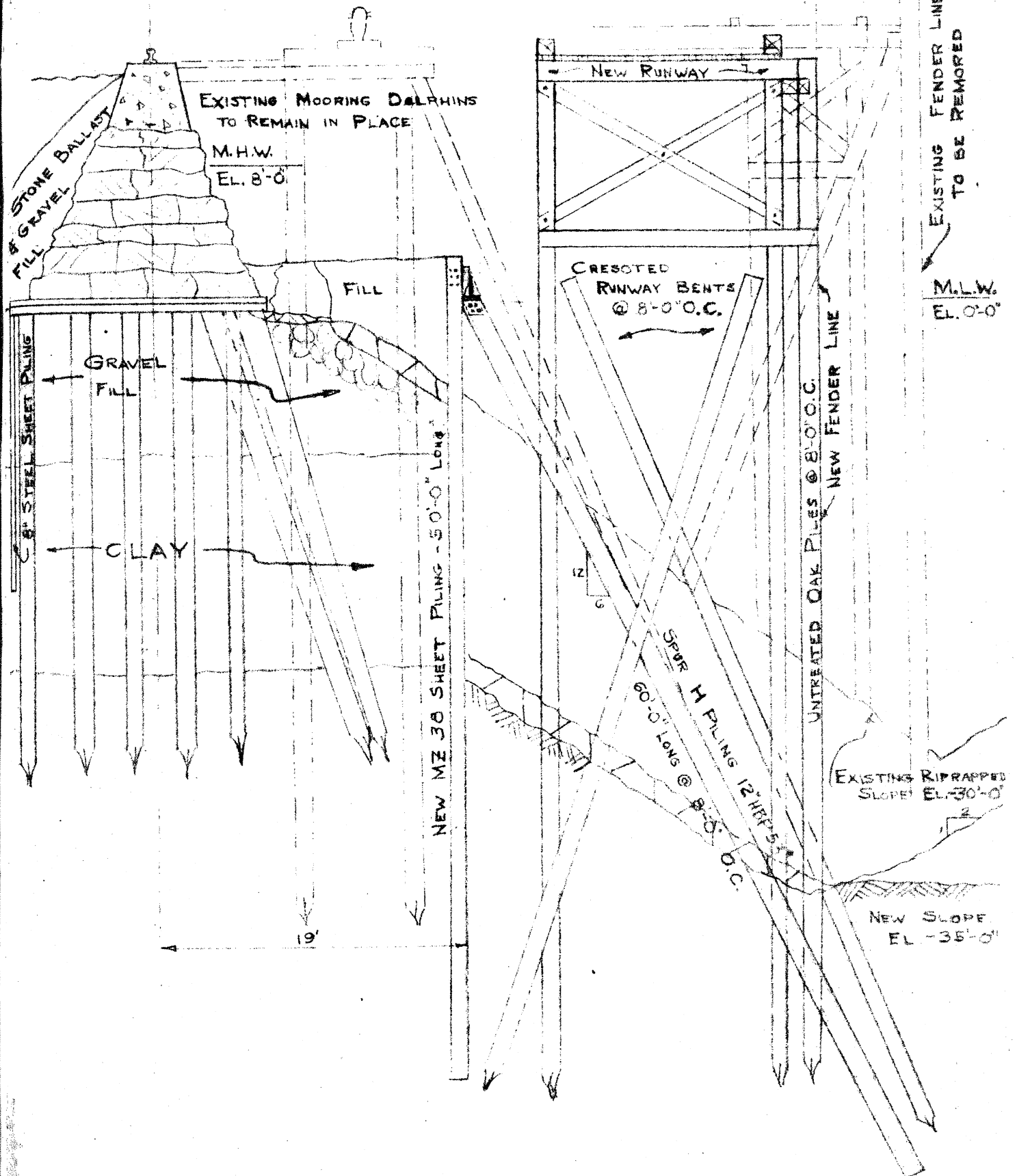
the station service transformers, and the taps to the 2400<sup>V</sup> yard which are connected by means of disconnects and oil switches.

The 2400<sup>V</sup> yard does not follow the ring system. It steps down the voltage so that it can be used directly for the local house distribution in this end of the town, for the nearby power requirements of industry and for the construction power, as has been mentioned previously. This yard is constructed similar to other local company yards that serve the purpose of stepping the power down for use in a specific area.

The terminal facilities will be discussed in three main sections, these being the wharf, the coal storage and local distribution facilities, and the coal handling equipment. The wharf section at the beginning of the construction activities included all of the present facilities. All of the work is remodelling, rebuilding or reconditioning. The actual wharf itself is being remodelled and rebuilt to accommodate larger ships, so that the most modern ships afloat will be able to dock and be unloaded by means of the gantry crane. The relative layout of this entire section can be seen by reference to the site plan in Fig. 1. In order to accomplish the above the existing wharf line had to be moved back, since the gantry crane arm has limited reach. This can be seen in Fig. 6. The existing wall and mooring dolphins indicate present conditions. Since five

46'-0"

40'-0"



CROSS SECTION OF 1951 BERTH  
SALERM TERMINAL

feet more depth was desired, some type of retaining was required; for the intense weight of the coal being stored would cause slippage within the clay layer pictured, and would cause it to subside out into the bay, causing large settlements in the wharf area.

A new retaining wall of steel sheet piling has been designed to maintain present conditions after the dredging is completed. This wall with its H column bracing will make possible the additional excavation and allow the wharf to be moved in towards the gantry. The old fender is to be replaced by a new one, which will allow the ships to get six feet closer to the shore.

The wharf and bulkhead are designed to restrain the clay layer against lateral flow. All sheet piling is designed to a capacity of 35 tons and all batter piles to a capacity of 30 tons, according to the following equation:

$$P = \frac{F h (W + a p)}{(S - 0.1)}$$

In which P = Load in pounds

S = Average penetration in inches under last five blows

W = Weight of double acting hammer and ram

a = Effective area piston in square inches

p = Mean effective pressure in pounds per square inch.

h = fall of hammer or stroke in feet

F = Constant for soil, 3.0 for "medium clays."

All of the driving is being done by McKiernan - Terry Double acting hammers; therefore the above gives a penetration for the last five blows of not over 0.46 inches, on the sheet piling.

The wharf storage area will accommodate 80,000 tons of coal and will provide for the unloading of the oil, for the oil storage area. The storage area is serviced by a large overhead gantry crane which has a span of over 260'-0" and which has a service running length of over 650'-0". However, conveyor arms extending from both ends lengthen the reach both on the ocean and storage sides.

The old use of the terminal as an unloading and redistribution center for the coal companies in this area will be maintained at least for a few more years. The old conveyor system that was used to fill the coal pocket is being replaced by new heavier equipment which will serve both the distribution system and the coal handling equipment for the new plant. This conveyor will run the entire length of the gantry crane run, as can be seen on the plot plan. It will be fed by the arm conveyors on the gantry by means of a large traveling hopper which is designed so as to be able to move along the entire length of the conveyor and act as a transfer box from one conveyor to the other. The ground conveyor will terminate in a transfer pit which will serve to transfer the coal to another conveyor; and this will lift the coal to the junction house. The junction house

will be the separating station where the coal is shifted to the conveyor going to the pocket and to that going to the coal handling equipment for the power plant.

The conveyor to the pocket from the junction house will again raise the coal to the very top of the coal pocket. This pocket is now being rebuilt due to a fire which partially destroyed the entire top section. The pocket is constructed so as to facilitate easy loading of commercial coal trucks which serve this area.

The conveyor to the coal handling equipment will also lift the coal up into the breaker building. This is the first section of the coal handling equipment for the plant, which is entirely separate from the redistribution system. The breaker house contains the equipment necessary for the proper preparation of the coal for transportation across the cove to the plant, for storage in the coal bunkers, and for use in the pulverizers at the boilers.

The conveyor system used is supported by bents at several intervals across the cove and is completely covered throughout the length to the top of the plant. This conveyor-run from the junction house to the plant proper is over 900' long. The bunkers which extend completely across the building will store 4,000 tons of coal; this is enough coal for full capacity operation over a three day weekend without requiring the use of the coal conveying system.

## Fuel Usage

The coal will probably all be Eastern bituminous with a heating value around 13,900 B.T.U. per pound. This will be stored first on the terminal area and then will be conveyed to the breaker house, as explained, where it will be crushed to a size that will allow passage through a 3/4 inch screen before it continues on its journey to the coal bunkers in the plant. The pulverizers will further crush it to the consistency of cement or flour, so that it can be blown into the boilers and will flash and burn instantly.

Oil will be used for lighting off during initial operation and also for full capacity operation later after sufficient storage can be built up. The oil scheduled for use is Bunker "C" which has about the consistency of light tar and a heating value of about 150,000 B.T.U. per gallon. The oil will be stored in the area which was originally the cove separating the terminal from the main plant site. The layout of this area can be seen on the plot plan of Fig. 1. The initial storage will handle about 6,000,000 gallons and final facilities will include five 143,200 barrel oil tanks, one of which is included in the original construction schedule. Three sets of smaller measuring tanks will be used during full capacity oil operation, but only one set is now scheduled for construction. These service tanks each have a capacity of 8500 barrels and are located on the piping route between the storage tanks and the pump house. The



pump house will include all necessary equipment for full capacity operation and will handle the oil as it flows from the heated oil lines and send it on into the station. The oil will be piped at a temperature 160°F., but will be heated to about 250°F., which is just below the flash temperature before it is fired.

Information on the operation of the plant by use of natural gas is quite limited, since at the present time the likelihood of its being used is quite remote. Its use has been considered in the design as a possible off-season fuel. The gas used would have a heating value of about 1040 B.T.U. per cubic foot, and will probably be piped directly to site and into the plant through suitable metering devices.

## ORGANIZATION AND MANAGEMENT

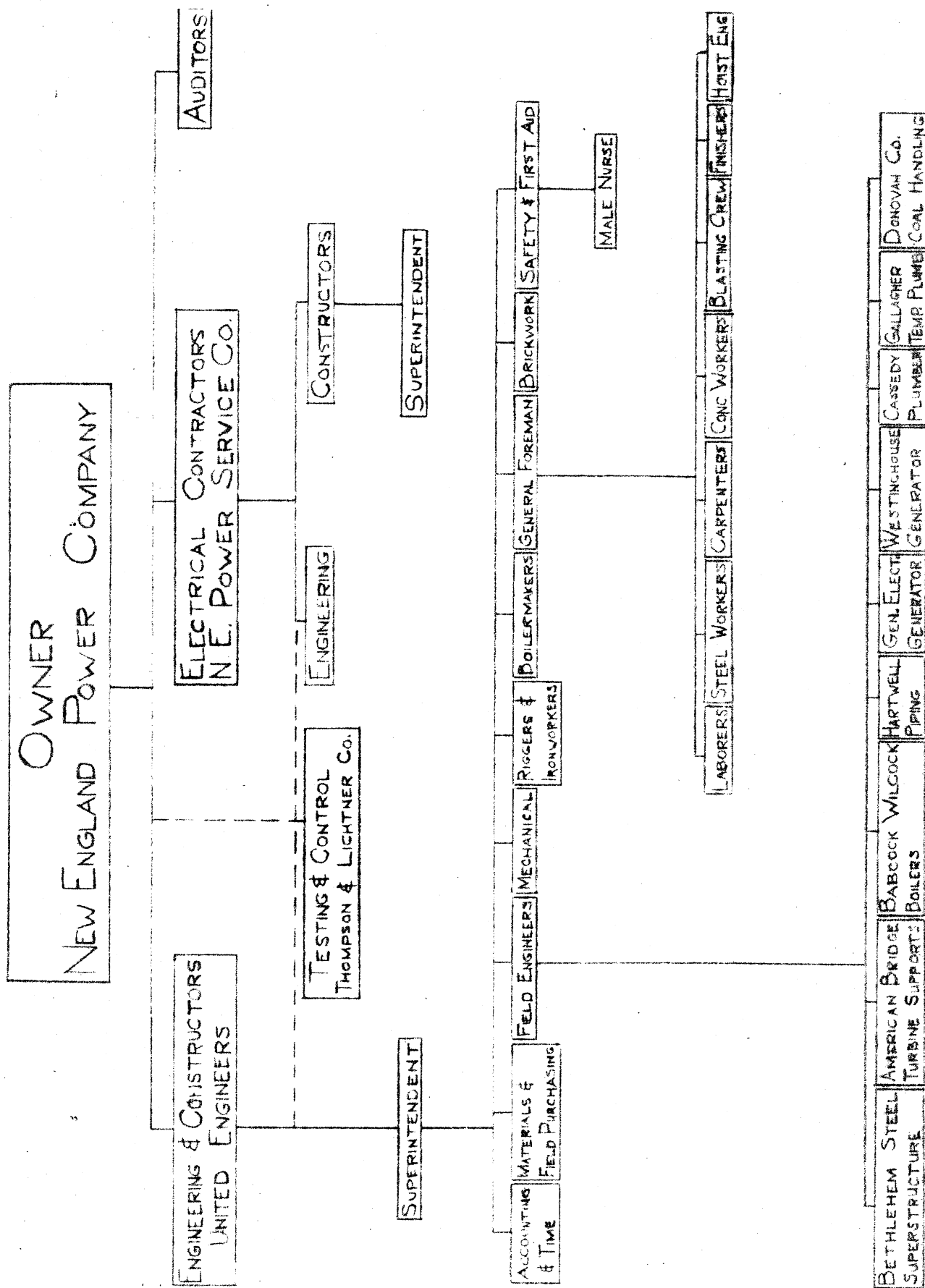
The diagram shown in Fig. 7 gives the complete organizational chart for the construction activities concerned with this project. An attempt will be made to give a complete breakdown of this chart and to give some additional information as to the methods of management and the management procedures used within each of the functioning brackets. The organizational breakdown will include the approximate number of men, as listed according to title, necessary for each group to function as it is presently being managed.

An attempt will be made to explain the function of each individual group within the organization, explaining what they do and how they do it. Each discussion will include an explanation of the relative position of each office or operating group, and how and what they are doing is tied in with the other groups and the entire organization as a whole.

### Owner

The New England Power Company will be the owner of the entire facilities upon completion of the construction, and will take over the direction of the plant at that time.

The long range plan of the Company is to provide a New England Electric System which is a completely balanced system of hydro-electric and steam generating plants in this



area. The accompanying map, shown in Fig. 5, gives a more complete picture of what the system includes.

This particular project is one of the newest additions to the system and is designed to provide the most economical steam generating plant available at this time in the light of the type of installation desired by the Company. The job is designed to be a complete operating unit which can be incorporated in the system as a whole.

An important division between the New England Power Company and the New England Power Service Company should be explained. The Service Company is directly responsible for all contracting and specifications, and then likewise for all purchasing of the major equipment on the construction projects. The Service Company, as the owner's representative, is responsible for "on the job" supervision and residence engineering, and maintains an engineer on the project site for that purpose.

#### Engineering and Construction

The entire station is being designed by both the United Engineers and Constructors and the Power Service Company together, with the division line being a matter of discussion throughout the entire process. Essentially, the scope and jurisdiction of the United Engineers is the design of the plant proper and includes all structural and architectural design and drafting, and placement of mechanical equipment and the design thereof. All of this work is

done in their home office engineering section. There is one exception within the plant itself, namely in the electrical work. This is also being designed jointly as it is being constructed. In general the United Engineers design will stop at the terminals of the equipment; and the Service Company will continue the design from that point and places its work wherever convenient in connection with the general layout or plan which is drawn up by the United Engineers.

Throughout the entire job each of the companies is responsible for the construction part of the installations that they design. As has been explained, the general contractor's work is being constructed under the direction of a resident engineer who is a regular employee of the Service Company; but this is a special case where the owner has requested the engineering firm which is familiar with this type of installation to supervise and check its construction. In this case it has happened to be the Service Company which is also responsible for other duties on the job.

The electrical yards, pump house, relay house, dock work at the terminal and the oil storage and equipment is not included within the scope of the general contractor's work except for the general layout and placement of this equipment on the job site picture. The coal handling equipment and especially the electrical work in connection with it is also divided between the United Engineers and the

Service Company. The United Engineers is responsible for the work inside the building and out to the transfer house on the exterior handling equipment. The rest of the equipment from the transfer house to the storage area and also to the distribution pocket is being done by the Service Company.

The contract between the Power Company and the United Engineers as general contractor is a cost plus fixed-fee contract. This type of contract is almost a must in all power-plant work, because it is usual procedure to have a general contractor who is responsible for design, management, and construction, but it is not usually possible to have definite plans or complete specifications on the job so that it is impossible to bid upon exact conditions and work. The work is designed as it is constructed, and usually the sections are completed one by one during the construction of the previous section. This type of contract is almost a must on any job of this size and price bracket, since materials and labor costs are constantly changing and the length of time needed to construct such a project will allow for considerable price changes. The project contract for the job was let over two and a half years ago. It was based on a preliminary layout of the site and a general picture of the requirements of the installation in terms of the capacity desired and the general terms of estimated costs and time of completion.

In connection with control and supervision, the owner has also stipulated that an outside firm will be employed to be responsible for all actual concrete control with reference to mixing at the ready-mix plant and for placement and testing on the job. The arrangements for this control have been made jointly by the Powere Company and the United Engineers, but the control is actually maintained on the supervisor's level, unless called for in higher offices for checking and reference. The Thompson & Lichtner Company, Inc. has been employed to perform these duties. In connection with the above it maintains an engineer at the mixing plant to control quantities and to make the necessary tests there, and also one on the job to control placement and to make the necessary tests. The control reports are filed in the field office and actual jurisdiction of the control is maintained by the United Engineers. The report procedure, details of how tests are made and how reports are kept is beyond the scope of this thesis, but the author feels that it is important and certain information is being included strictly as reference material. For these reasons, sample forms that are use in the reports and also others that are of interest, will be included in Appendix A.

The line functioning group on the entire job is headed by the General Superintendent and his assistant. The Superintendent is responsible for the construction of

the entire job and is the Contractor's Field Representative on the job, and usually in the entire area, in the case of an out-of-town company. He is responsible for all work being done on the site and for the planning and scheduling. The assistant superintendent, who carries out all of the above and sees to it that everything is completed according to plans and schedules, is actually the leg man of the superintendent, since he usually takes part in most of the on-the-job planning and carries out all the directives from above. It will be taken for granted that the discussion will include the assistant and that, when directives are issued on the job, he will be carrying them out, and the superintendent will look to him for the completion of all work.

The general superintendent directs the work of all of the separate fields and subcontractors on the job, and in the special case he also directs the scheduling activities of the other constructors, even though they are not directly under his control, so that the entire project will run more smoothly, with a minimum of friction and complications. This is accomplished through weekly planning or scheduling meetings which the superintendent holds with all working groups present. The overall job schedule governs what will be discussed and planned for the week to follow, and the actual details are worked out for each phase of the job, so that the necessary materials can be moved in and the work continued with a minimum of confusion on the already



congested construction area. This is especially true in the case of work going on inside the building area proper. All the various foremen or their supervisors attend the meeting and likewise a representative of the subcontractors on the job.

Each of the various trades are told what must be completed during the following week, and they in turn are asked what is necessary to complete that work. Some schedule must be drawn up for the use of the cranes and open storage areas, so that all trades don't try to use the same space and the same equipment at the same time. Thus, all the details are worked out for the week following, so that the job will progress smoothly, and so that no mistake or omissions will be made.

The position of the superintendent is mainly an administrative one, with his assistant carrying out all the line functioning in the field. He receives his directives from the main office, engineering, constructing, and other sections directly concerned with the completion of the job. It is his job to carry those orders to completion on the job and still at the same time run a safe, economical, and well organized job.

There are a number of departments under the direction of the superintendent, each of which is usually independent and functions separately by itself, with the exception of those which are needed or used by all the other functioning groups on the job.

### Accounting and Time Office

The accounting and time office handles all the field office accounting and field time keeping and payrolls or all the United Engineers' field employees. This includes all office personnel who are not already carried on the home office payrolls, all field superintendents and engineers likewise as above, and all tradesmen who work for the general contractor.

The personnel in the section are under the direction of an accountant who is a permanent employee from the home office. He has an assistant accountant, two accounting clerks, and a typist in the accounting section; and a chief timekeeper, an assistant timekeeper, payroll clerk, and one field checker in the payroll section. The cost engineer is also in this section, though he is directly under the control of the general superintendent.

The time keeping section will be discussed first since the payrolls are figured therein and are then checked by the accounting section. General records of the personnel on the job, and the amount of time they work, are kept by means of the brass check system. These are broken down according to trades, as likewise are all payrolls. The checks are picked up by the workers each morning and left again in the evening or at any time during the day, should the employee leave the job or stop work for any reason. After the morning horn the boards are checked and the check

numbers recorded; this becomes the first basis for the days payroll. Each foreman on the job turns in a time sheet which includes the men working, and the distribution, according to the job they are performing. This report comes in at the end of the day and provides a check against the brass board, and also provides the basis for coding the labor costs on each portion of the job according to the code system set up in the original estimate. The field checker also checks the men in the field once every morning and once again every afternoon, which also provides another check on the records.

Hiring cards are used for all field employees, and these provide the first basis for including any employee on the payrolls during any three month period. These are also used for indication of termination since no separate termination slips are used on this job. All payrolls are divided according to crafts and are figured weekly from the ledger sheets. The payrolls include a summary according to sheets, tax deductions, and totals. All tax deduction records are assembled and grouped weekly and sent to the home office which assembles all deductions on all jobs. Thus it is possible to figure returns quarterly on all deductions for all of the United Engineer jobs in the country and to make payments directly to the State and Federal Governments with a minimum of office work, especially in the field.

The accounting section takes care of all bills and with the aid of the cost engineer codes all expenditures. The office receives a copy of all purchase orders from the main office or from the field office purchasing departments. Copies of all invoices are also received from the suppliers, and these are attached to the original purchase orders, along with the materials receipt which is forwarded from the receiving department, and are checked and coded according to use. The payment checks and vouchers are made out directly from these three sheets. All of the above are then turned over to the auditors for checking.

A disbursement summary is made up at the end of each month which includes every expenditure during the month and lists all bills paid, and all payrolls during the month. This is extended to give a total figure for the entire month and also a total for the job to date according to work order.

A cost ledger is maintained for each individual account or code and this is checked and balanced against the distribution book. Another regular function of the department is to maintain an accurate record of all finances, and to give a daily bank statement of the advances received, the expenditures, and the total balance of the United Engineers account as agents for the Power Company, to the auditors, so that a transfer system can be maintained to insure that the Power Company has forwarded

enough money to the United Engineers to enable them to pay all bills.

A time record is also kept on all equipment that is used on the job, whether it be owned or rented equipment, according to the use of that equipment as determined by the field personnel. This report is kept on each separate item and all time is figured to costs and coded directly according to use. A separate record is also maintained for all gasoline used on the job in all types of equipment, since it is possible to get a State Tax rebate on gasoline used for construction purposes.

The last remaining function of the department is to tabulate all the information that comes in from the field engineers and to add to this the data on personnel for the day, the man hours and cost figures, and to type up the daily reports. These reports are checked by the resident engineer and are kept on permanent file as a record of the job.

The cost engineer is responsible for all costs and coding on the job. He also maintains copies of the estimates and thus has all the information that the superintendent might desire with reference to costs and expenditures.

The estimate itself was developed from a preliminary estimate which was drawn up when the contract was first let, and since has been extended to include all final

prices and estimated labor costs. The estimate will not be discussed in detail, but the general divisions should be gone through, so that a picture may be obtained of how it is developed and used. The general breakdown of the estimate is as follows: Substructure, including foundations below finish grade borings, excavation work, and pumping; superstructure including the exterior and interior walls and partitions according to the four sections of the building; service equipment including all heating and ventilating, lighting, elevators, fire protection, and electrical facilities; outside improvement including ground improvements of all types; boiler plant equipment which is broken down by tracing through the flow system; turbo-generator and all accessories; electrical control work; and finally miscellaneous equipment which is a final section which usually includes everything not included as above. All equipment and installations are divided as above because of possible changes in the course of the job or even in the future. This breakdown according to location, equipment, and use makes it easy to separate any one item from the rest of the estimate.

The cost engineer is responsible for the checking and coding of all quantities. The values as used or erected in the field are turned in by the field engineers, and records are kept on total quantities according to work order and code number on all excavation, forms, reinforcing,

concrete, steel and/or iron work, and masonry. A summary report on materials is taken off from this breakdown. The item of concrete is very important because it is contracted for by a blanket bill according to quantity at a certain unit price. All deviations from specifications as to slump, water content or otherwise, cause a difference in that unit price.

Other records kept include a complete record of man hours by work order and account number and a percentage record of all work completed according to man hours. These records are compiled from the information of the foreman's distribution sheet and provide a permanent job record for costs and progress. A labor survey is also taken from each of the respective superintendents, which provides a check on the man hours and the payrolls.

Monthly reports include a complete revised estimate and cost report in which the cost engineer checks his quantities and unit prices against what have become actual costs to date. In the light of these figures and the man hours and percent completion figures he recalculates the remaining portion of the estimate and derives new estimated costs for the rest of the construction work. This revised estimate becomes the basis for additional payments by the owner and also is used as reference by the home office estimating force on other jobs which are related in scope and conditions. This is one of the most important functions of the cost engineers.

## Safety and First Aid

The safety and first aid section is maintained for the use of all the other groups and trade divisions on the job. The section is maintained by the United Engineers as the general contractor, but facilities are designed to administer emergency first-aid assistance to any one injured or hurt on the job at any time. A fully equipped first-aid station is kept up in the field office; a registered male nurse is on the job during all construction activities, and arrangements have been made so that a doctor is on call at all times.

The safety section is under the direction of the resident safety engineer. He is a home office representative and is specially trained in safety methods and procedures. His responsibilities include overall direction of the entire job site safety program; and his decisions and directives are final in all cases and must be followed by all personnel on the job. The general superintendent is obligated to carry out and complete all necessary safety precautions and safeguards as directed by the safety engineer. The latter's decisions remain the final word in all cases or discussions; and he is responsible for checking, locating and removing all hazards, for location and maintenance of all fire protection and fighting equipment, for all fire patrols, and for safety instruction throughout the job.



Safety coordination is accomplished by means of a weekly safety meeting and by organized safety instruction. The safety meetings are held among all working superintendents and/or foremen, and are designed to convey instruction and to discuss safety problems and the correction and prevention of accidents. Most of the safety instruction is carried on by the working superintendents and/or foremen in the field according to trades. They obtain their instruction subjects from the safety engineer and each are provided with a "Manual on Safety Talks for Construction & Maintenance Foremen," which is published by the National Safety Council, Chicago, Illinois. This publication provides all information that any of the foremen need in order to prepare and give intelligent safety talks and instructions to their men.

This general instruction covers the following: Accident prevention; protection to the public; first-aid; personal protection equipment; fire hazards; nail and hammer hazards; how to lift and handle materials, creosote, cement, etc.; moving heavy equipment such as shovels, cranes, draglines, etc.; hoisting signals, rigging gin poles, and derricks; handling fiber and wire rope; prevention of ladder accidents; using ladders, scaffolds, planks, scabs, and up-rights; knots and hitches; falls and how to fall; electrical work and protection thereof; use of portable hand and electric tools and how to ground them; Power saw operation; storage and use of welding equipment and cutting; and

transportation of men by trucks. It also includes operational instructions on the following: demolition by hand wrecking, and the removal of demolished materials; clearing brush and burning; tree falling and stump removal; excavation, ramps, runways, loading trucks, dumping, trench work and the use of wheelbarrows in excavation work; form building and erection for concrete work; mixing and placing concrete; form stripping; placement of reinforcing steel and structural steel erection methods; blasing operations; and pile driving operations.

Thus the instruction which is given on the job is quite complete and serves to give all personnel a feeling that job safety is as much his responsibility as it is the safety engineer's. This training and instruction has been of considerable assistance in keeping the job safe and in keeping job accidents down.

The safety engineer has required that all persons on the job wear hard hats and that all injuries regardless of how slight be reported to the first aid office. He must report all progress and details on safety to the safety section of the home office construction organization.

Materials and Field Purchasing.

The materials-receiving and field purchasing section forms a separate organization whose main job is that of checking, storing, distributing, and replenishing all job materials. The section is under the direction of the

general superintendent; all employees work for United Engineers and thus are concerned only with the materials for the portion of the job which United Engineers is general contracting. This means that the department will officially receive only materials for the steam plant proper, and any other materials are routed to the electrical or subcontractors where they belong, with the exception of some courtesy-receiving that might be done for any organization having work on the job, but which has not arrived on the site to start operations, or which has not at that time set up its own receiving department.

The department staff includes a chief storekeeper who is responsible for the operation on the section, his assistant, two material receiving clerks and checkers, and three storeroom and tool men. All material is checked upon receipt, when a Material Receipt Slip is filled out, which remains as a permanent record on the job. The department receives a copy of all main office purchase orders, whether originated in Boston or Philadelphia, which are recorded in a Log of Purchase Orders by number and wherein each vendor is listed. These are then filed in an A - Z file according to vendor, so that they can be easily located when the material is received. One copy of the material-received slips is posted to these orders; and the remaining two copies go directly to the accounting department to enable them to keep their records up to date. Completed purchase

orders are removed for the above file and are refiled as such, since they are of little use to the department for other than back checking.

The department also has the authority to issue field requisitions on large items which have been overlooked or which are needed on the job for construction purposes. These requisitions must first be approved by the general superintendent, but then are sent directly to the Service Company main office where all large orders are placed. Purchase orders would then be returned and would be handled as above. Local purchases can be made directly from the field office by use of Local Purchase Orders to cover items such as tools, some lumber, lubricating oils, etc., on small items, controlled by a limited maximum per order. These are mainly used in rush or emergency cases and also require the approval of the general superintendent. Actual purchasing is completed in this office, as is all pricing, but checking and orders are prepared, coded, and sent out by the field accounting office. These field orders go through the same process as any other purchase order on the job.

A running record is kept on all freight shipments to the job site except parcel post. This also provides a recheck on receiving records. Active records are also kept on all construction equipment on the job whether company-owned or rented. Numbers are assigned to each item, and all records according to use are kept according to these

numbers. All purchased equipment must be ordered by Service Company Purchase Orders or must be brought directly from another Power Company job or one that United Engineers is constructing for the Power Company. All rented equipment is obtained by local requisition to be ordered on a main office Purchase Order. Complete records on equipment in use are sent to the accounting department; and termination of use is indicated by use of a Material Return Slip which also goes to that office and authorizes complete payment for use.

#### Field Engineers

The field engineering department is one of the most important of all the sections since its work includes the field engineering and civil engineering layout work for the entire job site rather than for just the station proper, under the direction of United Engineers. The Power Company has specified that all field engineering, lines, and grades shall be completely under the direction and control of the United Engineers, so that there would not be any chance of differences on the job, and so that all information would be consolidated in one location and would be in the same form for easy reference.

The department is under the direction of the Job Engineer who is a permanent home office employee. The organization is divided into two sections as would be expected with reference to the work to be done.

The office section is under the direction of the Field Office Engineer who is also a permanent home office employee, and who has the full time assistance of several junior engineers. This section handles the receiving and filing of all drawings, specifications, recprds of construction, daily reports, field sketches, quantities of materials and compiles all field information and records. In connection with drawings, all prints are received and distributed from this office, and all revisions are checked and noted for attention of the construction superintendents. Specifications are also handled in the same way, and any conflicts on either drawings or specifications are interpreted herein and checked throughout the entire supervision system. All questions as to interpretation of drawings and specification are also decided in the engineering section, and they are responsible for the checking on all subcontractors to make sure that they are following the same. Inspection to date has been mainly on steel and brick masonry. All field sketches are made up in this office for distribution to the main office engineering section, main office and field purchasing departments, and to the construction forces in the field.

The outside engineering and layout work is under the direction of the Field Engineer who is also a permanent home office employee, and who is assisted by two engineering party chiefs and their parties each consisting of one

instrument man and from two to three rod men. The engineers are responsible for all quantity take-offs, and for all quantities as constructed in the field, and distribute this information to the cost engineer and also for use in making up the construction schedules and progress charts. The subcontractors also turn in progress and completion charts, so that the construction schedules can be revised, and the monthly reports can be drawn up for all the work on the job. The section also handles all permits through the Service Company for construction on the job and keeps these permits for reference and inspection.

The field parties are responsible for all layout and grades on the entire job site. The owner provided the original property lines and grades were run in connection with the city engineers. The work in later stages of the job was divided between the crews as inside and outside work, with the inside gang handling all machinery and equipment installation. These crews were also responsible for all field engineering records and for records on plumbing inspection for the city engineers and for records on pile and sheet pile driving as to penetration depths and capacity. The surveying books provide an accurate record of all site layout information and elevations. The surveying crews are also responsible in most cases for the information necessary to make up the daily construction reports and progress.

The rest of the organization breakdown concerns individuals rather than departments, although these individuals would ordinarily be in charge of working groups, if the general contractor constructed the entire job himself.

#### General Foreman

The General Foreman's duties include supervision and coordination planning over all the working trades on the job. These include the laborers, reinforcing men, carpenters, concrete placing men, blasting crews, cement finishers, and hoisting engineers. Each of these union groups has their own union foreman who usually directs their work and gives out the orders, but the general foreman is responsible for scheduling the work and seeing that it is accomplished. He receives his directives from the general superintendent and plans all necessary work so that the trades can work in a minimum of confusion and in the most economical fashion. Each of these trades has a superintendent in charge to see that the work is done properly and to provide the necessary information for construction, but the general foreman handles the scheduling and coordination planning.

#### Mechanical Superintendent

The first of these superintendents mentioned above is the mechanical engineer who is the general superintendent's special assistant in his field. He is directly responsible for supervision of the construction activities and the work



of the millwrights on placing, upkeep, and repair of all equipment, and for the hoisting engineers. Supervision over all subcontractors on all mechanical work on the entire job is included in the above also.

#### Riggers and Ironworkers Superintendent

The riggers and ironworkers superintendent is directly responsible for the direction and supervision of all steel and light iron work on the job including placing and construction. Rigging work includes unloading and re-locating of materials and equipment in the stock area and on the site, and handling of all heavy installations.

#### Piping Superintendent

The piping superintendent is in charge of coordination and inspection of all the piping work which is a subcontract on this job. Thus he is not directly over the men who work for another company but is responsible for seeing that everything is constructed according to plans and specifications. As superintendent for United Engineers, he works directly with the Hartwell Construction superintendent on planning the construction activities and on carrying out the piping specifications. He also handles all the details of extra work and checks progress to relate it to that of the rest of the job.

#### Boilermakers Superintendent

The boilermakers superintendent is directly in charge of the boilermakers who work for the United Engineers

in this case. He is responsible for the actual construction of the boiler and its equipment and controls all construction activities through the union foreman.

#### Brickwork Control Superintendent

The brickwork superintendent is responsible for all masonry construction activities on the station. All brick layers, except on the stacks, work directly for the United Engineers, so that their work is directed through the union foreman on the job. Brick work is planned in the regular weekly scheduling meeting, and quantities are kept by the field engineers so that materials, mixing, and erection are the primary problems of the brickwork superintendent. The stacks are under subcontract, so that in this case the work of the superintendent is in the line of coordination planning, inspection and control.

#### Subcontractors

The discussion on subcontractors will include as much information as possible concerning the contract, organization, and operation of each of the subcontracting companies. The same methods of discussion will be followed except that all discussions will be considerably more limited and will contain only such information as was available on the job prior to 1 May 1951.

The Bethlehem Steel Company constructed the superstructure of the main building and later returned to construct the oil storage tanks. The field force included the

superintendent and his regular followers who made up the majority of the organization in the form of a time keeper and five foremen or pushers who worked the gangs on the job. The superintendent works directly with the general superintendent on the job through the riggers and iron workers superintendent.

During steel construction the problem of scheduling is not as difficult since there are fewer trades working on the job at the same time. The main problem is quick, efficient and safe construction operation, with a minimum of errors of routing and placing, and with great stress on safety, since it is the most dangerous part of the construction activities.

The superintendent is responsible for all company relations on the job, and his only administrative assistant is the clerk or time keeper. The clerk handles all office work, time keeping, payrolls, field purchasing, expediting, receiving and also all safety instruction. The company offers incentive bonuses for perfect safety records to both the superintendent and the clerk, since the insurance rate will be lowered according to the total number of safe hours of construction, and this is a major item in the cost of construction.

The contract provided for furnishing, fabricating, delivering, and erecting all structural steel in the main superstructure of the station proper. The contract was bid

essentially on a unit cost basis in per unit weight of steel as above with continuous erection insured by the general contractor, or if not possible, delay time must be paid in return by the general contractor per unit time.

A completely different field force was assigned for the construction of the oil storage tanks because of the specialized work required. The force was made up of a field superintendent in charge of construction and a time keeper, and construction force under two engineers and boilermaker and welder pushers. A resident engineer was on the job during the entire construction, who worked directly with the superintendent, though employed by the Pittsburgh Testing Laboratory which is responsible for the testing and control of the construction activities. All of the tradesmen were boilermakers with the large majority being qualified as welders also.

The American Bridge Company constructed the turbo-generator foundations which were held separate from the structural steel superstructure. The entire foundation is essentially separate from the steel. The organization was probably similar to that of the steel contractor.

The Babcock and Wilcox Company carried the contract on the boilers within the station. The contract provided for designing, furnishing, fabricating, delivering, unloading, hauling, erecting and placing in operation the complete boiler with all its operating equipment. The general

contractor provided all field labor, crane service and blocking and rigging, for hauling and erecting all materials except for the boiler setting and the insulation work. All special tools, however, had to be provided by Babcock and Wilcox.

The contract also provided that the boiler maker company would provide an experienced field superintendent who would erect all work through the direction of the boiler-makers superintendent and would also control the number and quality of men. The Babcock and Wilcox superintendent is also responsible for the proper assembly and sequence of erecting of the entire unit.

All piping on the job is within the contract of the Hartwell Company which is a subsidiary of the Grinnel Company. In this case the design work on the piping was done by the general contractor and the contract provides for fabrication, furnishing, delivering, unloading, and erecting including testing on the job. The original contract was bid on a portion of the work that was designed at that time and was let on a lump sum basis. Since that time, however, extras on piping have almost doubled the work; these are figured on a cost plus percentage basis and are all considered additional to the original work. The piping work now under the direction of Hartwell comprises over 90% of all the piping on the job site and includes the piping from the boiler to the turbine, condenser to the boiler

auxiliary equipment and piping, the bleed steam, and the condensate piping.

The Grinnel Company's home office engineering section does all of the fabrication design and sketch work for all piping over 2 1/2", and these are checked and approved by the general contractor before they are adopted. Blue prints are then made up including all fabrication and hanger information for use in the field by the construction gangs.

The field superintendent is responsible for erection. He works directly with the United Engineers piping superintendent on all scheduling and control. The erection superintendent is a permanent employee, and carries with him a student engineer, who is being trained on field operations and who is responsible for all engineering work. The office force includes time keeper and tool man, and the field work supervision is carried by three main steam fitter foremen.

All piping work is done according to standard specifications and according to boiler code requirements. Grinnel has standard specifications for fabricating and erecting all piping according to type, size and use. The following table covers the main ideas behind each specification:

Location	Pipe	Bending Fabrication	Weld & Rings	Preheat	Stress Relieving	Inspection
Main steam 1500 psi 1000°F.	Chromium Molybdenum alloy steel 2" wall	Sand filled, preheat to 2000°F., stress relieved to 1425°F for 1/2 hr. 1/4 wall not less than 2 hrs. Cool at 200°F. to 600°F.	D.C. arc Cr-M Electrodes shielded Cr-M backing rings	500°F.	As bending continuous	Radio- gramic x-ray
Reheat steam 400 psi 1000°F.	Cr-M alloy	ditto	ditto	ditto	ditto	ditto
Turbine Exhaust to reheater	Seam- less	Sand filled preheat to 1950°F. slow cooled	Backing	500°F. electrical in- duction over 4"	1225°F. 1 hour/ inch wall but over 2 hours cool 200°F./hr. to 800°F.	
Carbon moly.	given		Shielded arc Lincoln #85 backing when over 2 1/2"	ditto	1325°F. 1 1/2 hr./ 1/4" but over 2 hours	Hydro- static to 150% service
1200 psi & higher	Carbon steel		Shielded arc	ditto	1225°F. 1/4 hr./ 1/4" wall but over 1 hour	ditto
600 psi & below	ditto		ditto	none un- less over 1/2" then as 1200 psi	as preheated	ditto
Evapo- rator Drainer Discharge	Stain- less		D.C. arc Electrodes "Stain- less" Weld D2	60°F.	none	ditto

This chart may seem complicated but it must be kept in mind that the welding and preparation of the piping is one of the most important aspects of the job. All welders must be qualified according to standard tests under the Boiler code, and welding is closely inspected by the United Engineer Piping superintendent. Temporary records are kept on all stress relieving operations.

An unusual procedure was also followed in the case of the plumbing subcontract on the job. The work was divided between F. Gallagher Company and J. S. Cassedy Company; the former doing all the temporary work on the construction installations, and all the plumbing work in the way of drains and piping below the ground floor elevation in the station, and the latter handling all plumbing work above ground elevation. Actual details on these companies was not available but may be assumed to be similar to that of other subcontracts.

The General Electric Company and the Westinghouse Electric Company are each subcontracting one of the turbo-generators in the station. Each contractor is working under exactly the same specifications for design and with the same arrangements for construction. Each contract provides for furnishing, delivering, unloading, and erecting the complete unit with all piping between throttle valve and turbine, between intercept valve and the turbine, all piping for lubricating, governing, cooling, and all control



accessories under the direction of a company superintendent, with the labor provided by the general contractor on the job. The superintendent will be in charge of all control and construction procedures and will also be able to require labor to be supplied in order that he may keep up with the schedule. Specifications on the turbo-generator also require that the complete assembly be shop tested prior to shipment to the construction site and that all auxiliary equipment also be pretested.

Other organizational details are not available since the construction activities had not been started prior to this report.

The W. I. Donovan Company was given the subcontract on the coal handling equipment on the site and which includes the conveyor system from the terminal to the station. Although this work had been started at the time of this report, detailed information on the contract and construction activities was difficult to obtain due to the stress that the contractor was operating under in an attempt to get the work under way and completed before the scheduled starting date, since the Power Company plans on starting operation on coal.

#### Electrical Contractors

The New England Power Service Company is both a subcontractor and an independent general contractor on this job site. In the power station proper, all electrical work

has been reserved for the Service Company essentially as a subcontractor to the general contractor, except that the organizational and functional arrangements are slightly different, especially with reference to supervision in the field.

The work in the yards on the other hand is the direct opposite since in this case the Service Company is directly responsible for the design and construction and acts as a general contractor over all work with the United Engineers during some of the laboring work essentially in the form of a subcontract. This arrangement is used throughout the entire yard and substation work.

All of the main office engineering and design work on the above mentioned work was handled similarly to that discussed with reference to United Engineers engineering, design, and purchasing. This is not intended to be the subject of this thesis, and it should suffice to mention that this work is being completed by the Service Company and not by the Power Company as the Owner.

All necessary field engineering work is being completed on the job in the electrical contractor's office under the direction of the field superintendent who is in charge of both engineering and construction activities. The staff or office group handles all necessary engineering, sketching and revision work, and all blue prints, time keeping and store room work. The field engineer and draftsman

handle the former parts of this work, and there is a time keeper and materials and store-room man to handle the latter. All payrolls and accounting are handled in the main office of the Service Company; thus it is not necessary to have a large force to do this work on the job.

The field construction work is carried on through the direction of a general electrical foreman who is responsible directly to the superintendent. The scope of this work has already been explained and is divided into the inside station work and the outside work, each division of which is under the direction of a separate foreman. Each of these foremen has several pushers to keep the working gangs divided into small working groups of practical size and also to enable the most efficient use of more experienced men on some of the work.

#### Auditors

The auditing section is the only completely New England Power Company section on the job and thus is completely separate from the construction and operational aspects of the job. The office is manned by a field treasurer or accountant and a clerk who does all necessary form preparation work and typing.

The auditors receive all the funding operational figures from the earliest beginning of the planning phase of the construction project, which is usually the authorization for expansion from the board of directors. This

original authorization includes a lump sum figure for the entire improvement and/or expansion program. This is later subdivided into work orders; these are then further broken down according to standard code systems, as provided by the owners central auditing sections.

The field office has over-all accounting control of the entire construction project, and maintains all records and final approved accounting forms for authorization for payment. All checking on bills and all field payments either originate or are authorized through this office. Requisitions for material and/or equipment purchased for the entire project, whether from the main office of the Power Company or from the field office, are checked, approved, redistributed and a copy kept also by this section. All invoices are also checked, numbered, entered on the Invoice Register, and redistributed to the United Engineers, if they are to process and pay them or retained, if to be checked and paid within the accounting office. These invoices are all processed first in the main office of the Power Company where each is approved by the designated designing engineer after the purchasing department places the orders. Vouchers are prepared in the field office upon proper distribution and approvals of invoices as above, and these are made up so as to include as many invoices from one vendor as practicable and are grouped with the receipt of materials. All vouchers are recorded in the Voucher Register, and are posted to the accounts according to codes. The above mentioned Receipts

of Materials are kept on all material, supplies, equipment, machinery, or otherwise by the materials department and are forwarded to this office directly from them. This Voucher Register is also checked bi-monthly and all entries are also recorded in either the General Register or the Cash Book.

The General Ledger comprises all accounts for the entire job, and is to act as a line of control for all funds advanced for the United Engineers and the Service Company. This ledger is charged with all funds advanced and credited with all disbursements as evidenced by the Record of Disbursements at the end of each month along with the vouchers, original invoices, and cancelled checks. A special account is also maintained for the use of the field office of the Power Company for costs other than those of the United Engineers; and which are posted in the Cash Book. A separate account is also maintained for unfinished construction and improvements as recorded in the Detail Cost Ledger. This account is charged or credited with all costs of the project. A record is also kept of the unadjusted credits and construction advances from the Power Company main office to the United Engineers and to the field office. The final account is the accounts payable and audited voucher account which is credited for all vouchers in favor of the individual vendors, except if covered as above in any of the special accounts. Charges are made from the Cash Book and the Voucher Register.

The Cash Book is used for recording all cash deposits in and for drawing all checks out. All cash receipts from the main office are also recorded, and check disbursements are listed according to the voucher, date, check number, vendor, and folio number used. This book is closed monthly and the cash balance is brought forward as a receipt.

The unfinished construction and detailed Cost Ledger is made up of separate accounts according to work orders, and postings are made direct from the vouchers according to code number, quantity, and with a brief description.

All these records are balanced each month and the bill is sent to the main office in the form of a record of disbursements, listing all costs by work order. This comprises the main report of the field office.

It should be remembered that the Service Company is the owner's resident representative and is responsible for the general supervision of the project, the installation of all work not covered under the contract with the United Engineers. All costs of services, labor, and expenses incurred are paid by the Power Company upon the presentation of a monthly. All purchasing is done by the Service Company in the name of the Power Company and is paid for by the Power Company upon receipt of the invoices.

The main function of the Power Company, regardless of the operational functioning which has been made necessary by the complicated organization for construction

on the site, and by the unusual role played by the Service Company, is to audit all accounting and financial records of the United Engineers. For this purpose all detailed cost records of all the original vouchers and cancelled checks supported by the vendors invoices, record of disbursements, statement of accounts and a reconciliation of bank statement, must be turned over to the auditors each month. All of the invoices, and other advances for the United Engineers' accounts must go through this auditing office first, and then are forwarded to the accounting department. All purchase orders and pertinent accounting dates must be sent to this office to be maintained as permanent records for future auditing as explained above. All checks must be approved by first having all vouchers with invoices, receipts of material, payroll, etc., and checks audited and approved. No payments can be made without first receiving full approval; thus complete financial control is maintained.

## CONSTRUCTION PROCEDURE

### Introduction

The object of this section of the thesis is to give a word and picture presentation of the actual construction procedures used on the job, and to provide a background of information on general construction procedures for future reference. As many pictures as possible will be used, since it is far easier to explain actual procedure by a photograph than by trying to give a word description alone. Most of the photographs included have been taken by the author on the job site throughout the visits made during the months of October to May. Some attempt will be made to give at least some information concerning the construction procedures used prior to these field visits, but this will be limited in scope.

The main object is to tell "the how and what" of each particular phase of the project in question. Equipment will be pictured and explained where important and where not discussed previously.

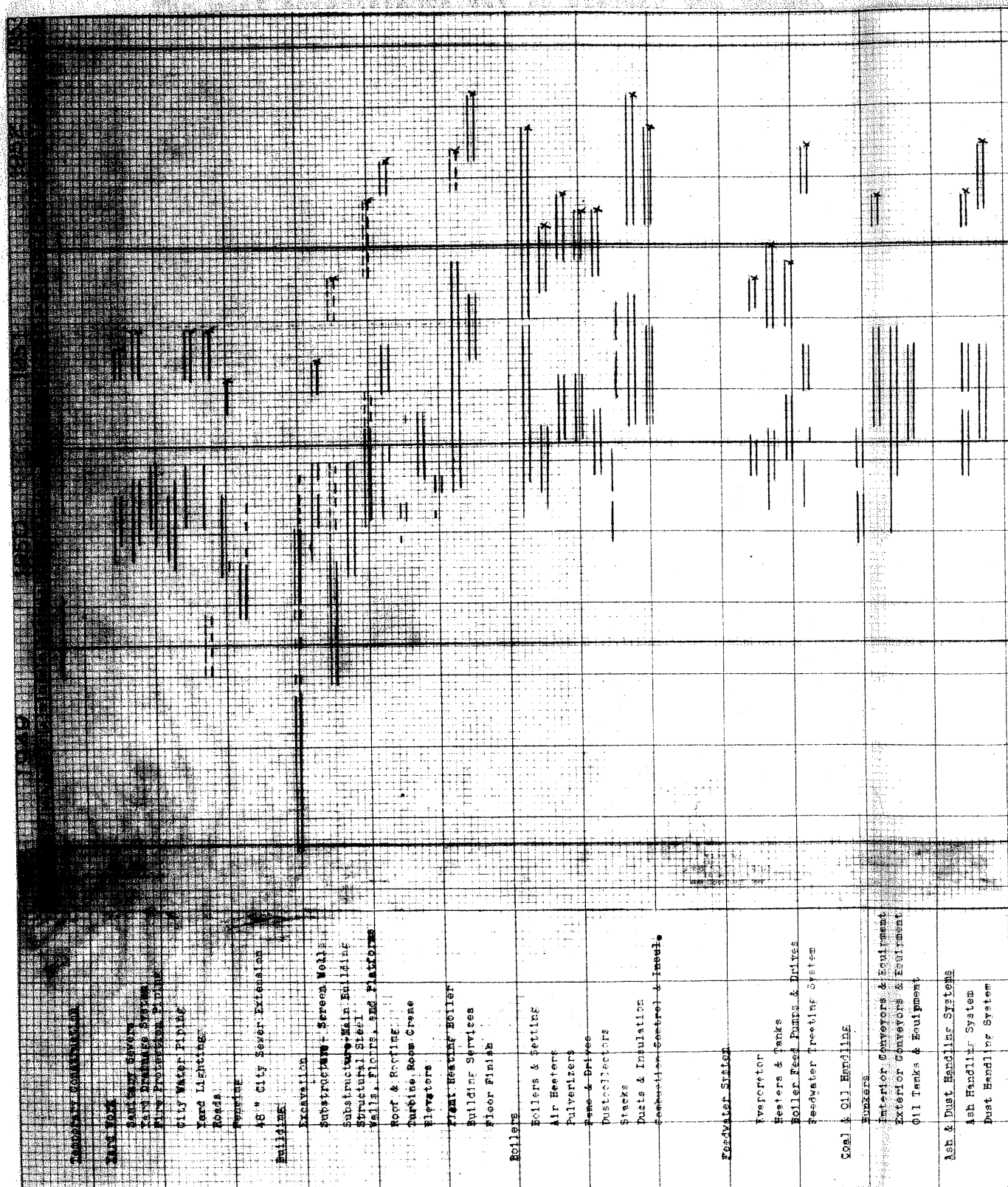
The main problem in the construction project is one of timing, and it will continually be coming up in this discussion also, since it is practically impossible to explain any details as to procedures without first integrating the specific part under discussion with the project as a whole and relating it to some other portion of the job.



### Construction Schedule

Proper construction requires that a very detailed and explicit scheduling chart be made up so that all operations will be built in such a way as to be integrated towards a final complete end result. A copy of the Schedule and Progress chart for this project is shown in Fig. 8. This chart is usually prepared in advance by the general contractor in an attempt to work out on paper a well organized and well planned job. Proper scheduling will eliminate errors and omissions during the construction, and will provide an accurate check list on work to be completed.

It may not be possible to follow the construction schedule right to the letter throughout the entire job, due to difficulties that might arise with reference to materials and/or labor stopages on the job. For this reason periodic reviews must be made of the work completed and the work still to be done; and a revision of the schedule made if necessary. The top horizontal line of each subtopic on the schedule indicates the original planned timing of the operation; and the lower line, usually drawn in red, indicates the actual scheduling and/or the revised estimated schedule timing with reference to the rate at which the work is being completed at the time of the report. This allows for any change to be indicated as soon as it is apparent that it must be made.





The most advantageous way to discuss the actual procedures would be to cover each item as it was started in the field and thus follow the actual construction schedule throughout the discussion. This would be all right during the early months of the job, but would be very complicated during the peak of the construction activities, when there may be several hundred small projects going on at exactly the same time. It would be very difficult to carry on a discussion on this many items at one time, so that it becomes necessary to deviate from this strict schedule method almost immediately after the main portion on the construction activities get under way. For this reason the schedule will be followed only to the point that a new section of the construction activities is introduced, and from then on that particular phase of the activities will be discussed until the procedures are brought completely up to date. In this way each phase of the activities will be traced completely through construction and the methods and procedures will be explained completely without adding confusion by bringing in any other items that are not directly related to the portion under discussion.

#### Preparation of the site

The first activities were in the way of site clearing and temporary construction in preparation for the foundation and substructure work in the area of the station proper. The earliest of this work was started in October

1948, but the actual stripping and ground work was not completely under way until the beginning of December of that year.

The site was stripped over the entire area of the station, yards~~m~~ parking lots, storage areas, and temporary building areas on the station side of the cove. This included all areas where future expansion is planned.

The entire area of the station was originally an outcrop ledge of rock so that it was necessary to blast and excavate even to level this area. This simplified the foundation details in many ways but gave rise to some intricate problems with reference to the screen house area and the tunnels for the cooling water. All loose earth and rock was first removed by means of a 1 1/2 cubic yard shovel, bulldozer, and carryall. All excavated materials were immediately place<sup>d</sup> in the permanent dike construction which can be seen on the plot plan of Fig. 1. The area within the yards was leveled also so that no further operations would be required when construction of the electrical work was scheduled to begin.

All blasting operations were prepared by means of drilling by use of wagon drills on the knob of ledge. The major portion of the earth and rock excavation when in full swing was handled by means of a 2 1/2 cubic yard shovel and clam shell buckets. Figure 9. Excavated materials were also used to construct the auxiliary dikes and to fill on the

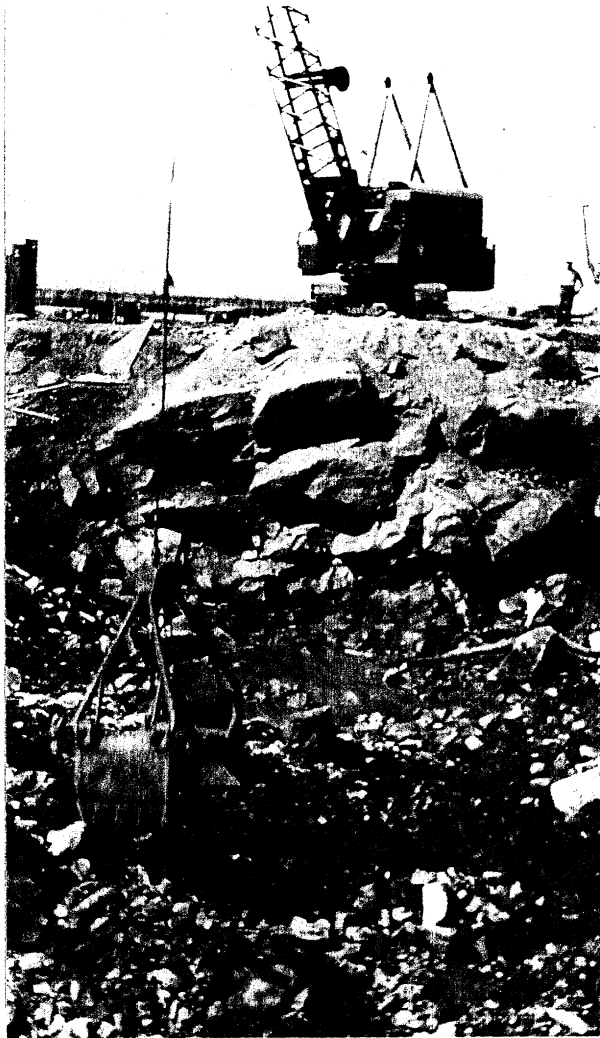


Figure 9

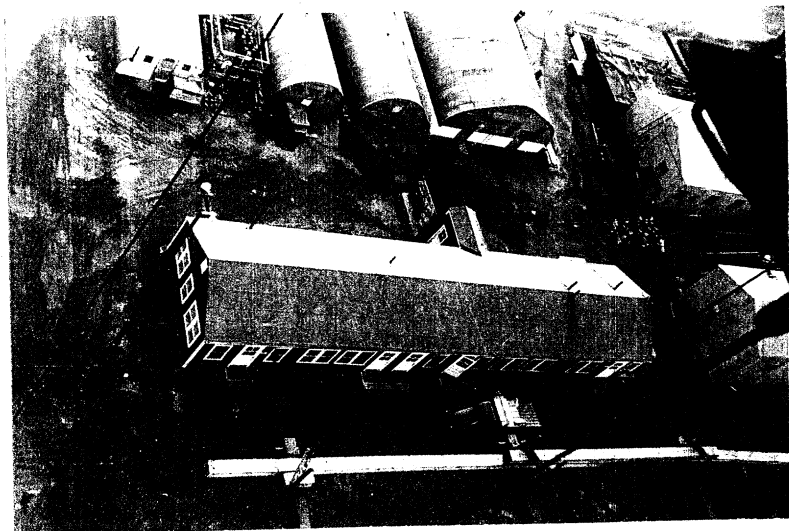


Figure 10

terminal side of the cove. The major portion of the entire dike system was constructed in this way.

### Temporary Construction

Temporary construction buildings were started as soon as the areas were cleared. The location of these can also be noted from Fig. 1. Not all buildings were constructed in the early stages of the temporary construction but in most cases were added as additional room was needed for office space, personnel, and storage.

The main features of the office buildings include separate facilities for each of the field offices and superintendents' trade groups. The main field office houses the United Engineers' field supervision forces, engineers, and office personnel; the Service Company's resident engineer and supervision forces; and the Power Company's auditing section. This building is pictured in Fig. 10.

The other larger buildings house the foremen's offices, and the material storage facilities as indicated. The smaller quonset huts are used as field shops and workmen's locker rooms and toilets. The largest of the shops is the carpenters' shop which is designed with exterior working platforms and storage racks for materials. This and several other buildings are pictured in Figures 11-14.

The construction storage areas are divided between the station site and the terminal site. All materials that arrive on the job by rail are first received on the



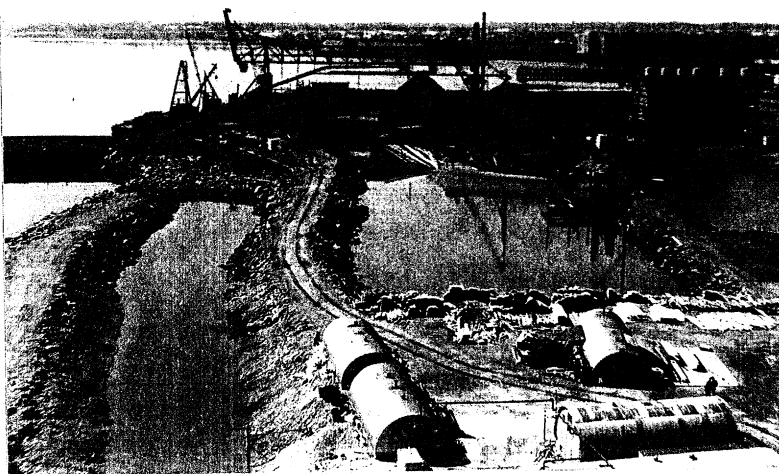


Figure 11

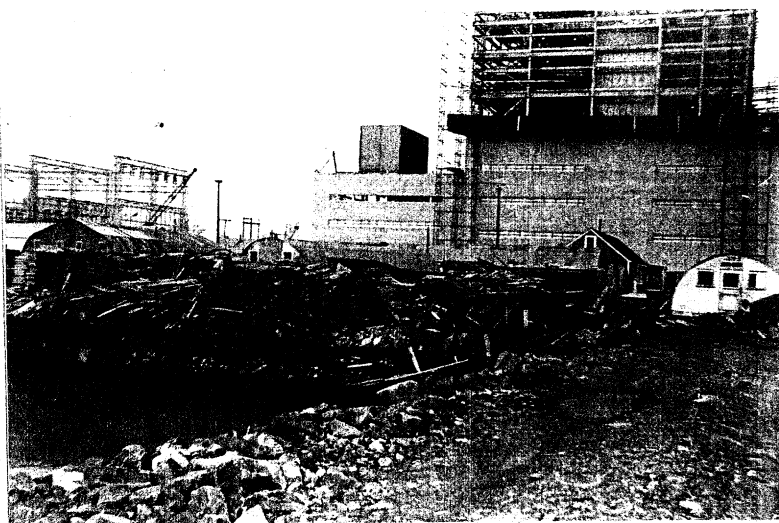


Figure 12

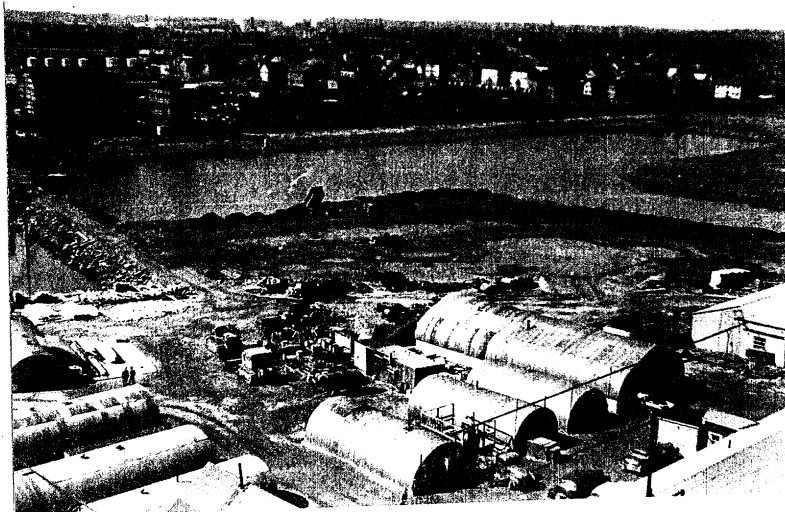


Figure 13



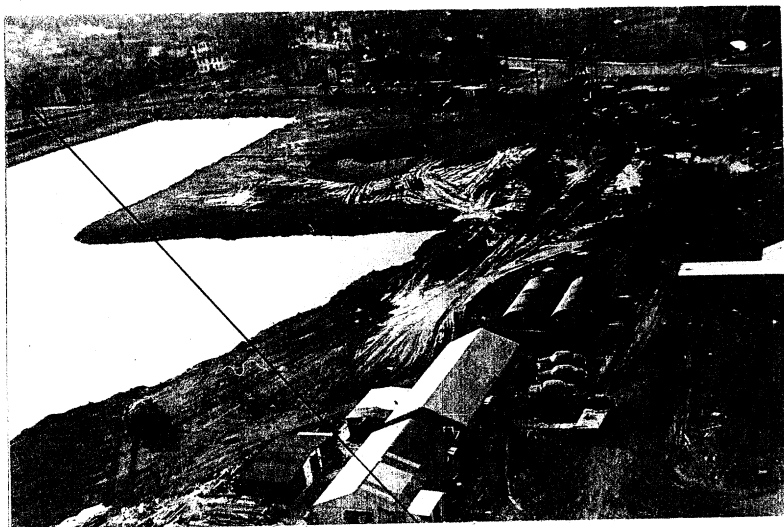


Figure 14



Figure 15



Figure 16

terminal site where they are stored until needed. Figures 15-19. The buildings are used for storage of materials that must be protected from the weather at all times. Figures 20 & 21.

The second area to be used is that around the building itself. This area is used for materials that are in the process of being constructed at that time and these are brought over from the terminal areas as needed. The section around the other side of the knoll is also being used as shown in Figures 22-25.

#### Building Excavation & Foundations

Within the station area most of the excavation work involved blasting and a large amount of loose rock removal. This ledge outcrop ran out into the bay area and made it necessary to do a considerable amount of rock removal in order to open the area for the intake tunnel. Since this excavation work required going from 14 to 16 feet below the water level it was necessary to construct a cofferdam to keep the water out.

This cofferdam was designed to handle a maximum high water level of plus 14'-0", and is constructed of M type steel sheet piling. The piling was all driven to the rock level under the water and was sealed off by means of exterior rock and earth fill which also acted as additional support. Figure 26.

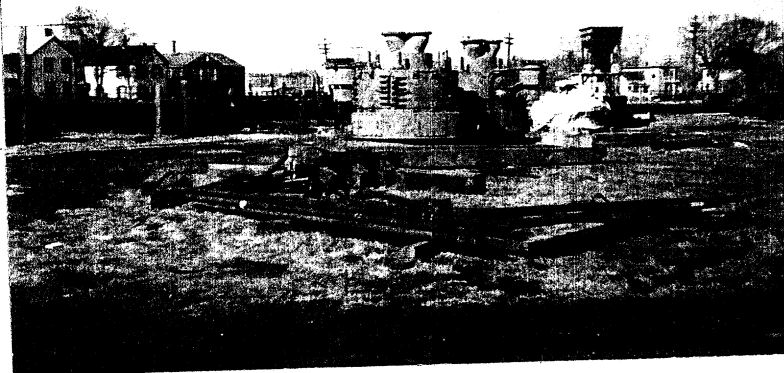


Figure 17



Figure 18



Figure 19



Figure 20



Figure 21

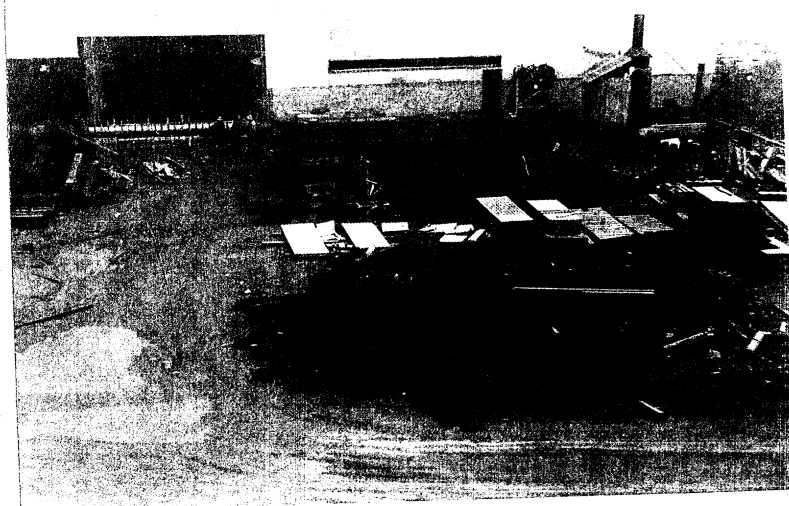


Figure 22

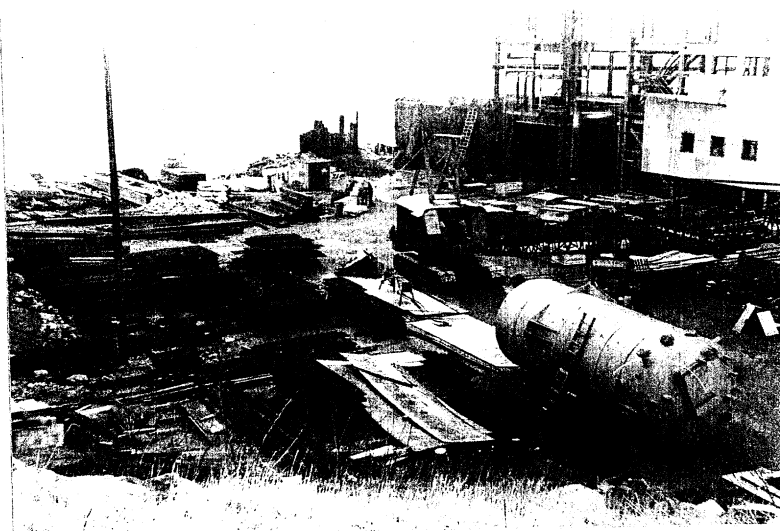


Figure 23



Figure 24



Figure 25

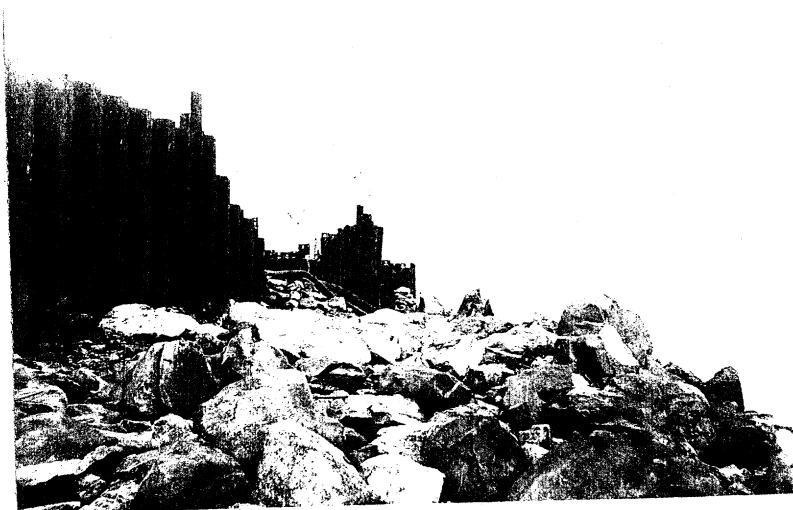


Figure 26

Several difficulties were encountered in the driving and blasting within the cofferdam. An underground stream was located during the driving on the west side of the dam and gave rise to an additional source of leakage. This stream kept the level of water about a foot deep during the entire screen house blasting operations and also was the primary source of leakage during the later excavation work.

The screen house blasting and excavation work required going down to an elevation of minus 17'-0" within the cofferdam for the bottom sections of the intake tunnels. After this work was completed, the cofferdam was braced to the building facing before further work was started.

The facing on the ocean side was designed of granite since this natural rock provides the best resistance to the constant beating of the sea. The granite blocks were set first and were used as the exterior form for the concrete back up. All of the concrete in the screen house area was placed in sections according to the structure of the tunnels and foundation walls. Most of it was placed by use of long shutes which were made up from sections of sheet piling with pivoted ends so that they could be easily moved around within the area. Figure 27.

After the completion of the screen house area and the construction of the stop logs which serve to keep the water out of the tunnels when it is necessary to work

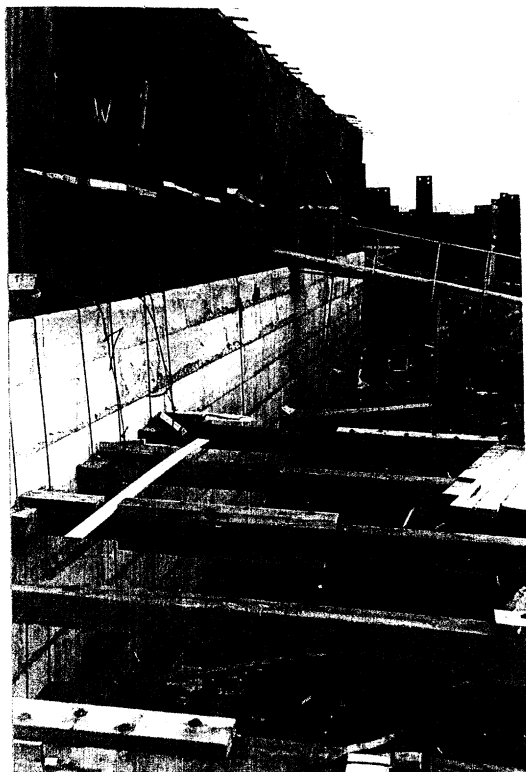


Figure 27

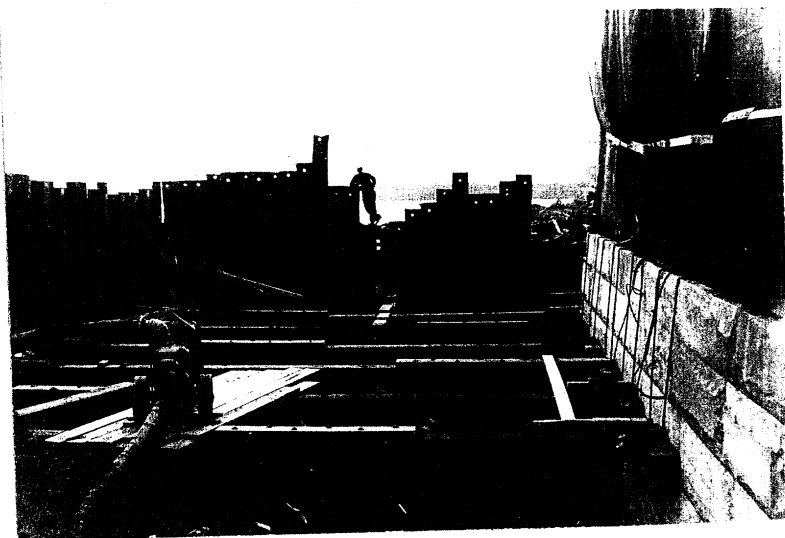


Figure 28



in them, the work of clearing the cofferdam was started. Figure 28. The entire structure was braced from the exterior was so that there would not be danger of the sheet piling failing during the excavation work.

The first layer of bracing was constructed prior to any excavation in the area. The design of these braces and their construction can be seen in Figures 29-34. The loose dirt was excavated first and the bracing was continued on down as soon as spacing permitted. All excavation was done by hand or by clam shell where spacing permitted its use, and where there was no danger of injury to the cofferdam or the finished walls. Figure 35.

The major portion of the excavation required drilling to break up the rocks and to get them to manageable sizes. Figure 36. Most of this work was accomplished without blasting, although some light charges were used in the lower sections. The rocks had to be loaded by hand for the most part since the limited space made it very difficult to maneuver the bucket around for independent loading. These operations are shown in Figures 37-40.

Two splits were located in the cofferdam piling as the excavation continued along the interior section of the piling. One leak developed due to a split in the sheet piling at a seam in about the middle of the south side. The split was probably caused by the twist or spread caused by the rock at the base. The gap had to be repaired by

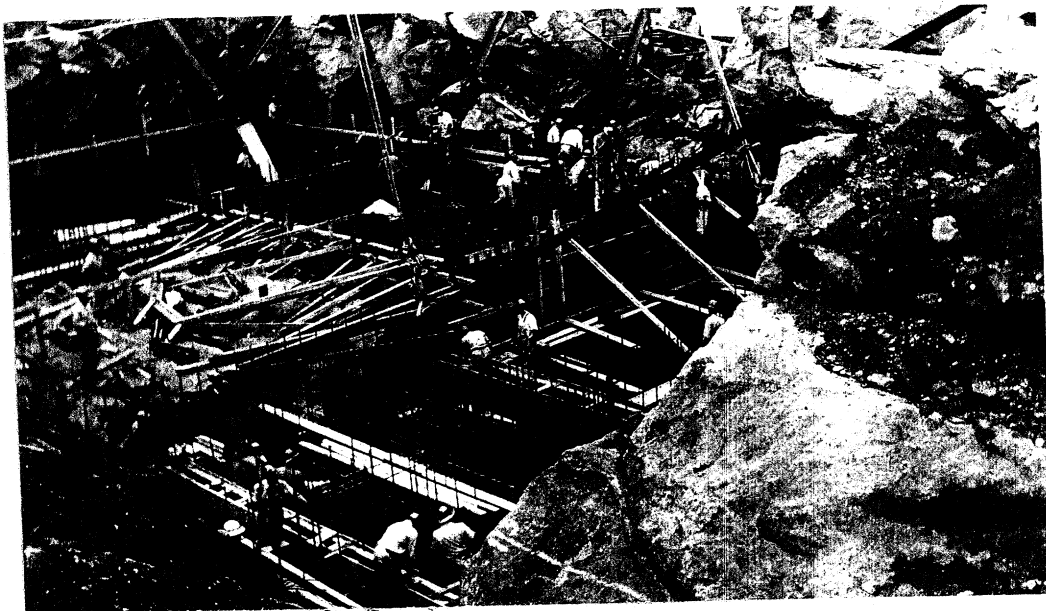


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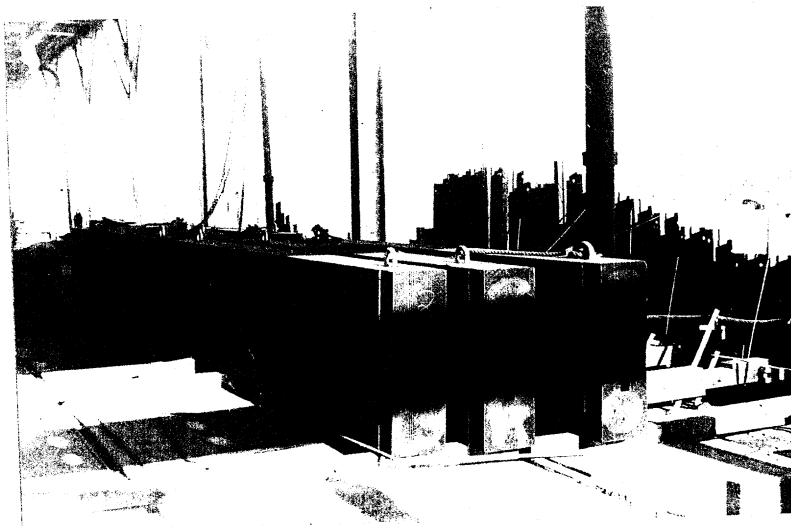


Figure 30



Figure 31



Figure 32

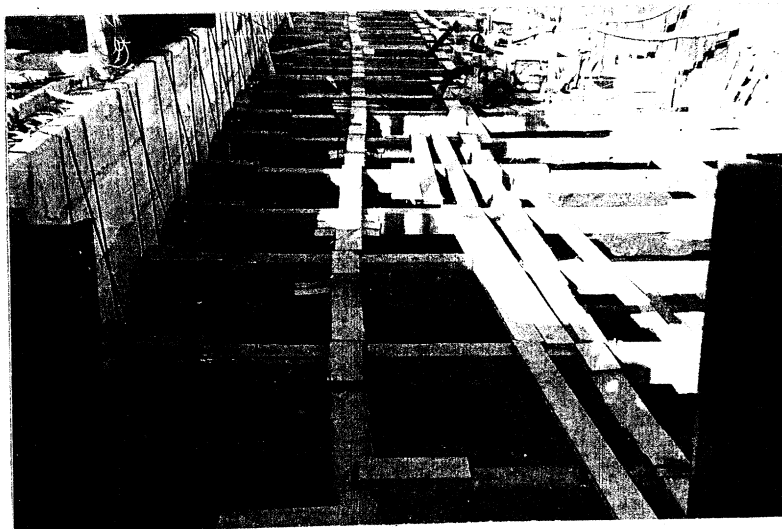


Figure 33

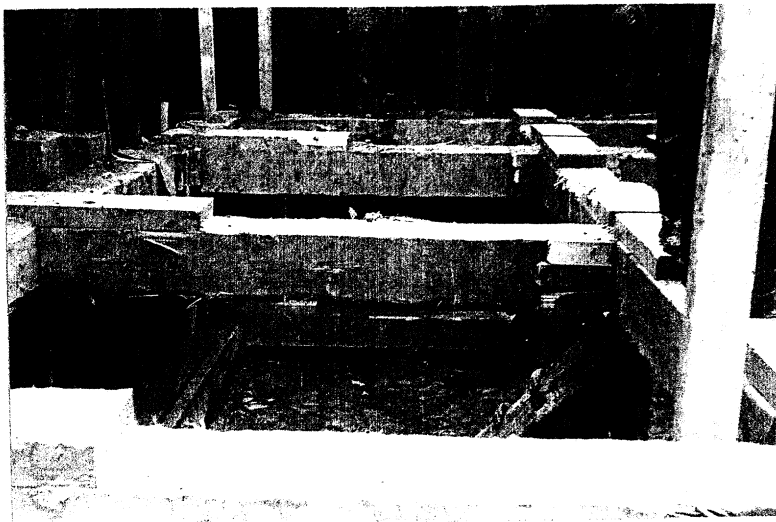


Figure 34



Figure 35



Figure 36

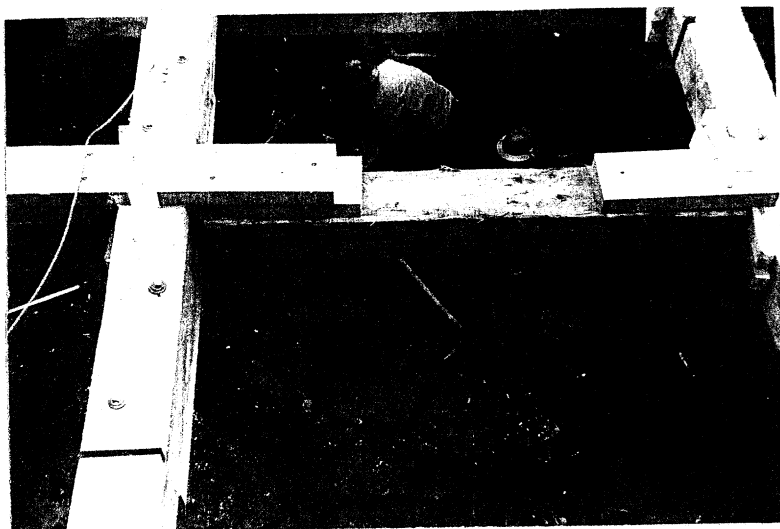


Figure 37



Figure 38



Figure 39

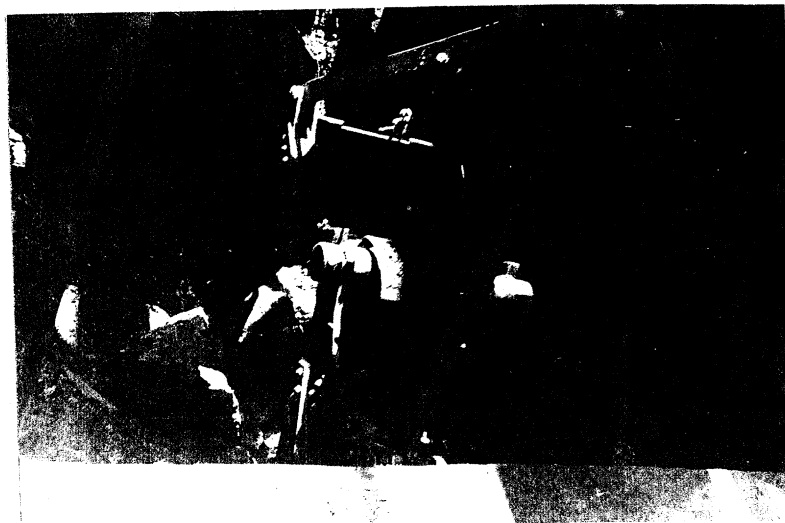


Figure 40



Figure 41

welding a plate into the split to close the leak. Figure 41. The other split occurred near the building on the west side. It was also caused by compaction at the rock, but in this case the gap was closed again by driving and did not require further repair upon being uncovered.

Figure 42.

Most of the foundation work had been completed and covered so that pictures could not be obtained, but the standard methods were used in this section of the construction. The process of forming, placing the reinforcing, and then the concrete was followed on the tunnels, pedestals, generator foundations, and grade beam construction, in that order. The concrete work was built up to the ground rough slab level throughout the entire building area, and the column bases continued above this elevation where necessary. Figure 43.

#### Structural Steel

The structural steel erection was started in May 1950 by Bethlehem Steel, and was constructed without interruption through November. Most of the work was done by use of 40 and 50 ton cranes each with a boom of 140 ft. Two guide derricks each with a capacity of 25 tons were raised and used as soon as possible. Five gangs were used throughout the construction; each under the direction of a gang pusher.



Figure 42

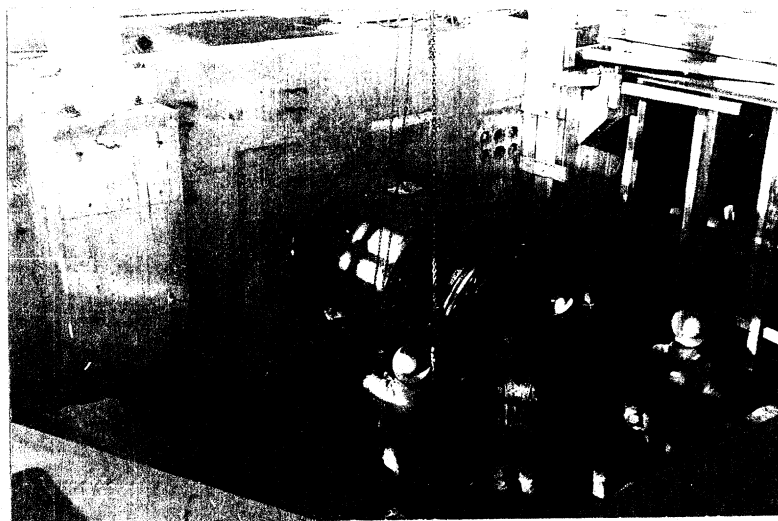


Figure 43

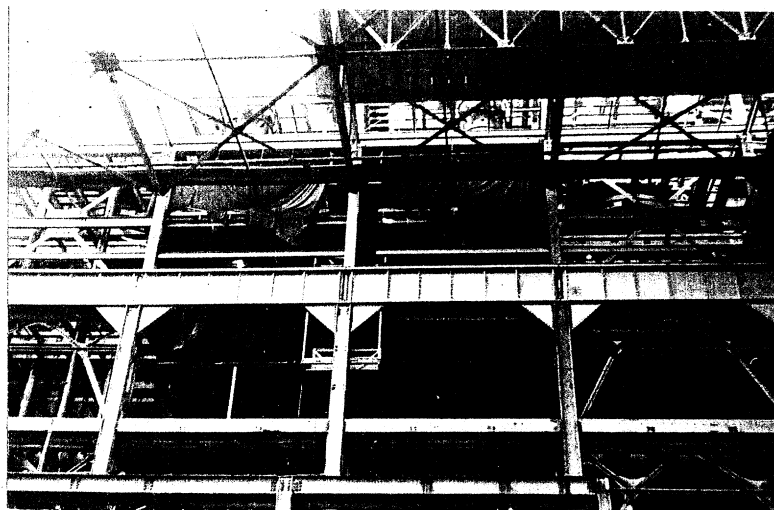


Figure 44



All the structural members were shipped to the site via rail and then transferred by truck to the building site according to the erection drawings. Accurate planning as to placement of the steel members was most important because errors would be costly and would cause delays in the erection. There are several views of the completed steel shown in Figures 44-49, and various other views will be seen later in connection with other aspects of the job. Figure 50 also shows how steel stairs were projected during construction.

The turbine room crane and the turbo-generator foundations were also erected in connection with the structural members as soon as the supportin<sup>g</sup> members were completed. Each of the box girders of the crane was raised individually and the moving unit as raised last completing the assembly. Figures 51-53.

After the completiong of the structural steel and before the derricks were removed a large rotating guyed derrick was raised on the roof for use during the construction of the remainder of the plant. The roof derrick was erected in about the center of the boiler room area with a boom of sufficient length to reach over three sides of the building so as to be able to raise loads from the ground and place them almost anywhere within the building. The foundation and details in the rigging are shown in Figures 54-56.

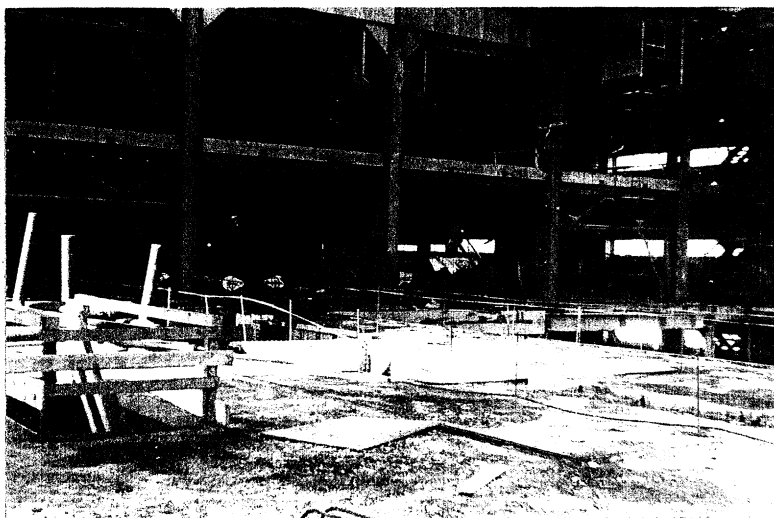


Figure 45

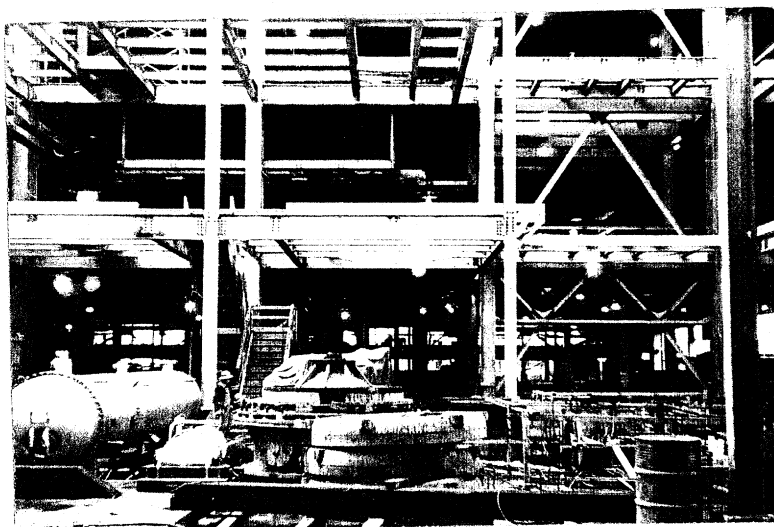


Figure 46

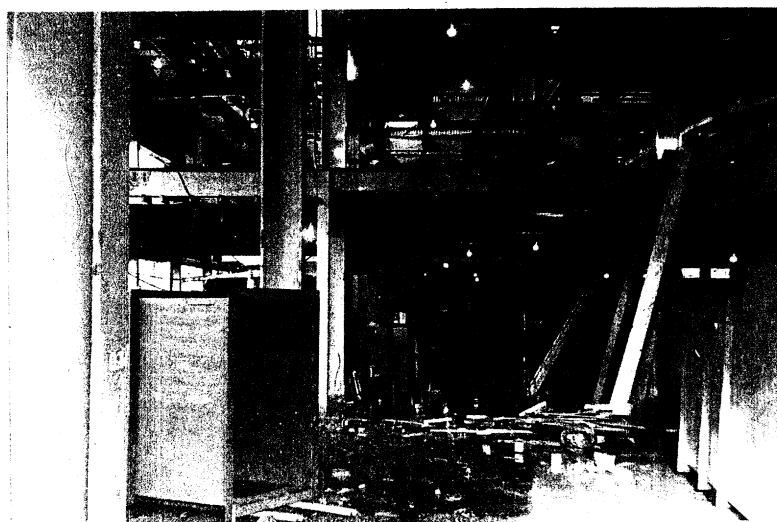


Figure 47

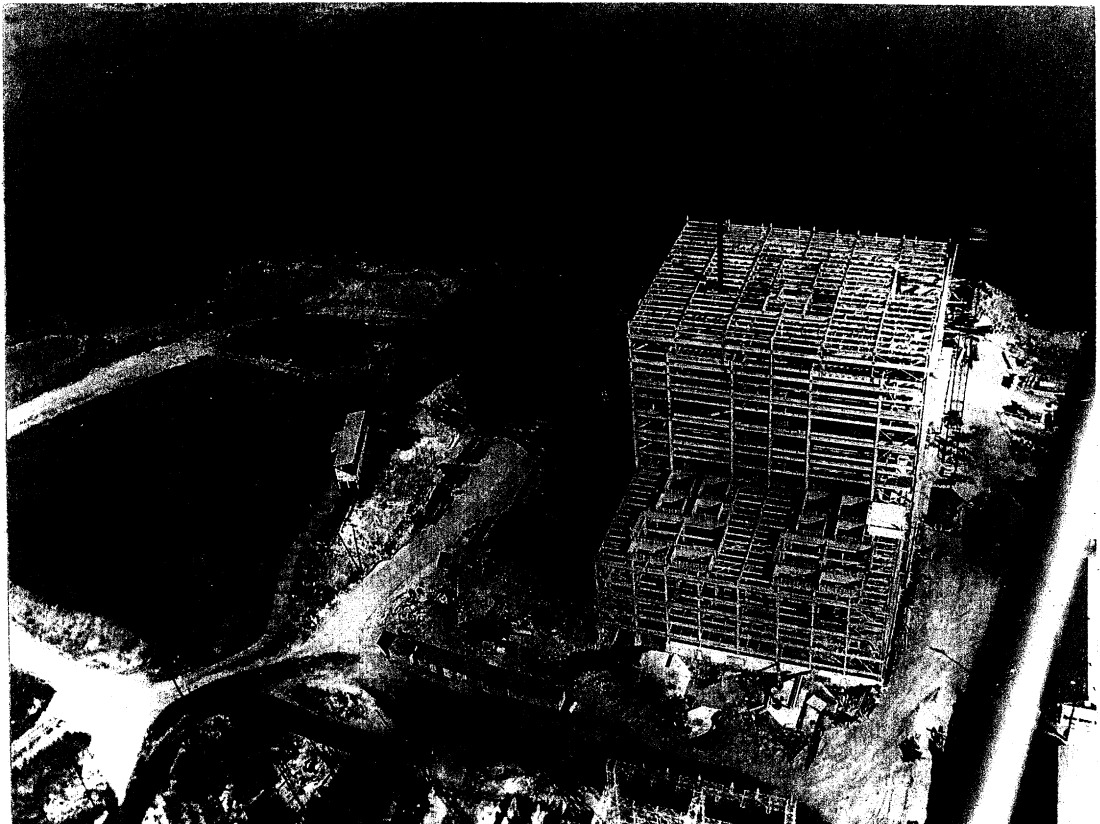


Figure 48



Figure 49

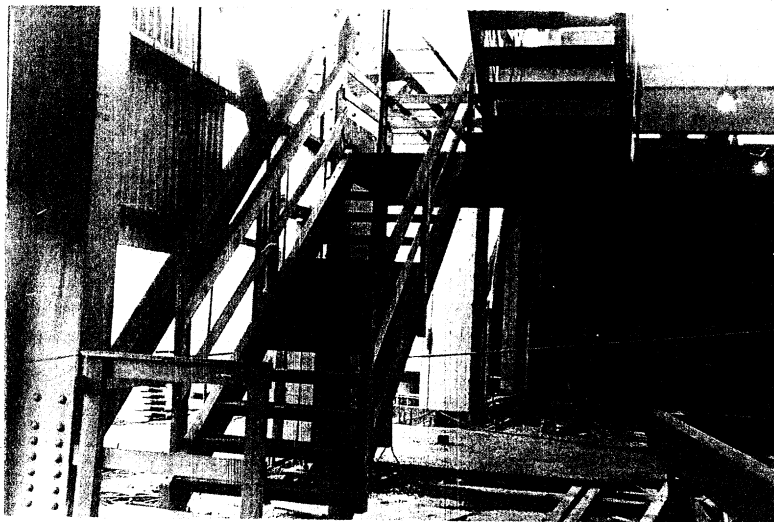


Figure 50

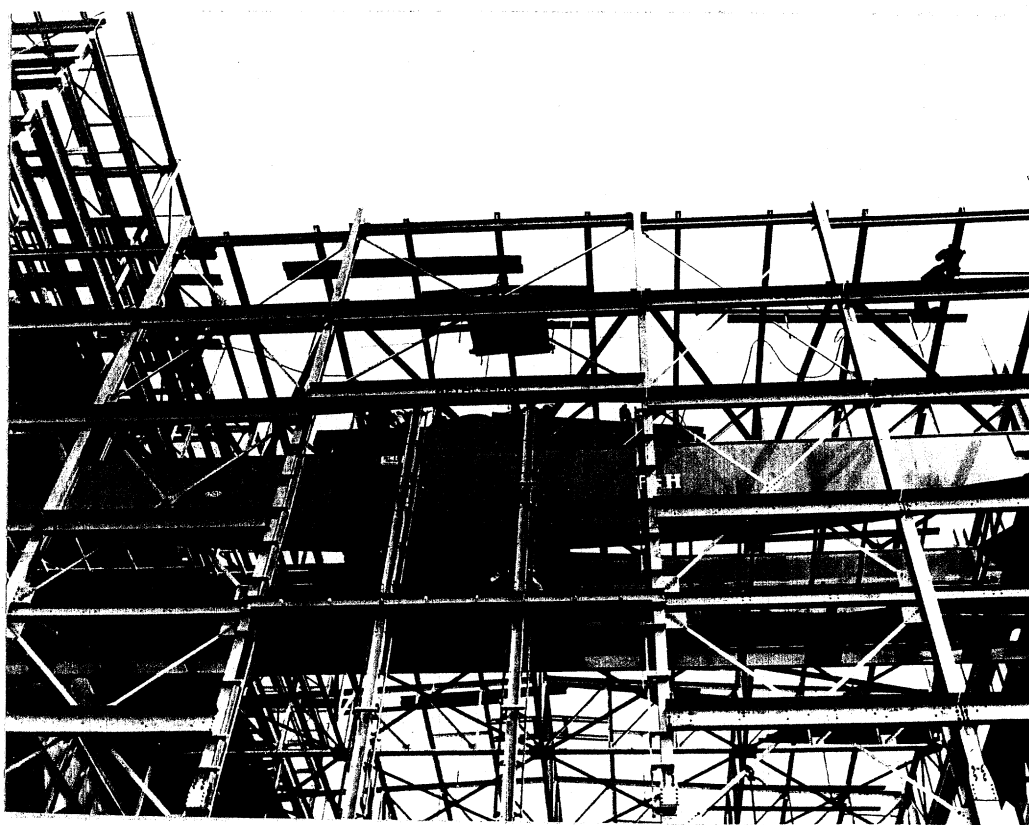


Figure 51

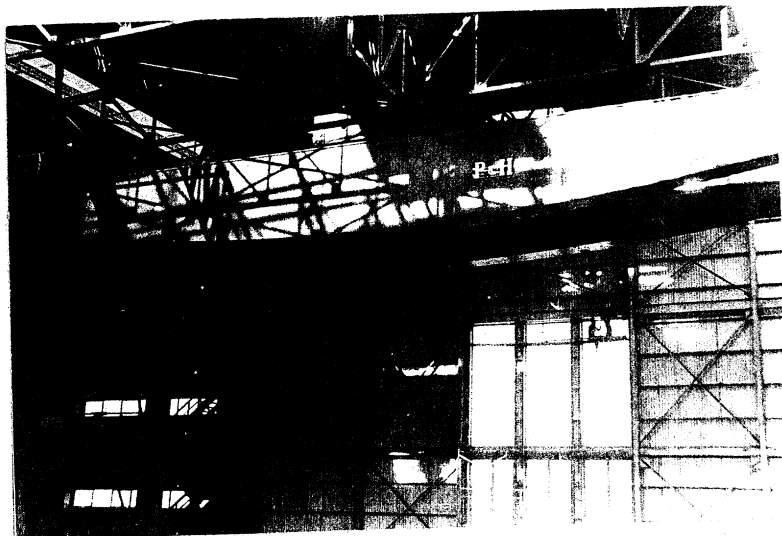


Figure 52

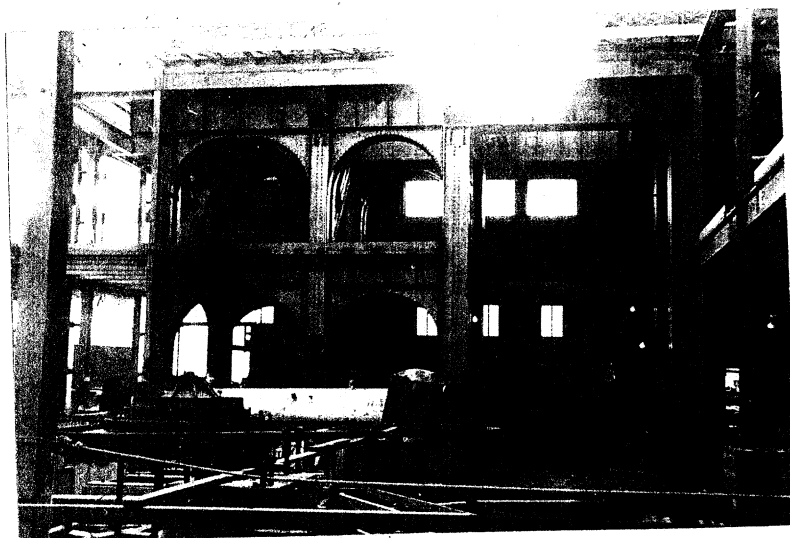


Figure 53

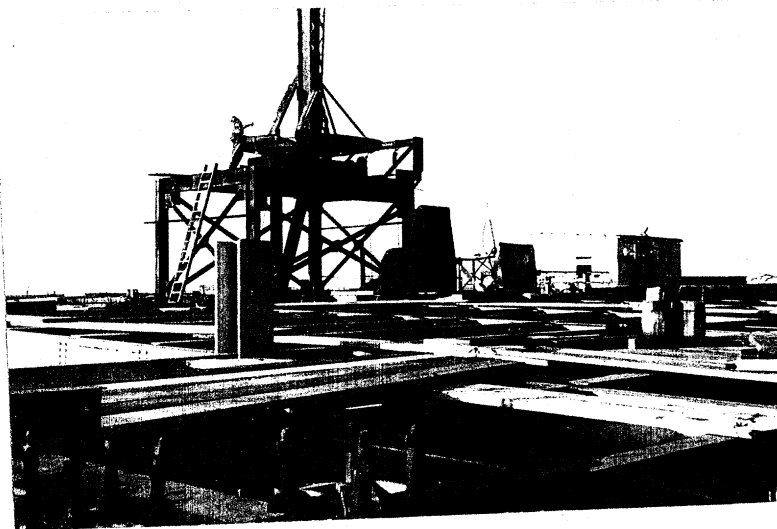


Figure 54

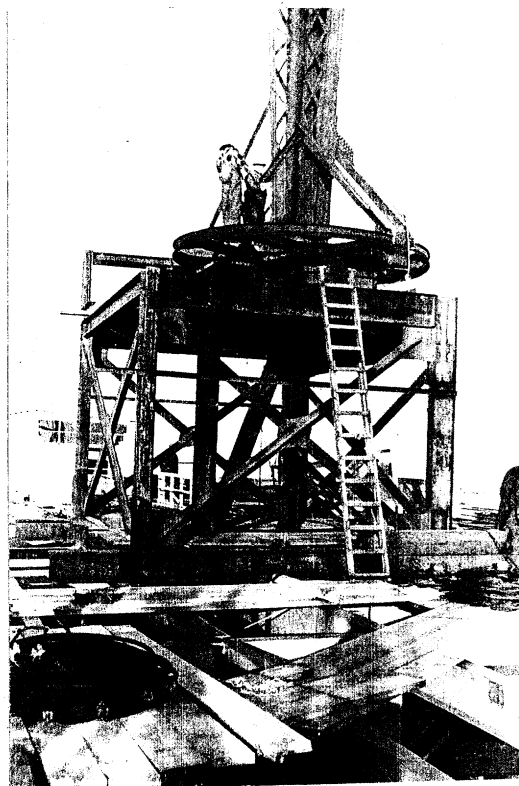


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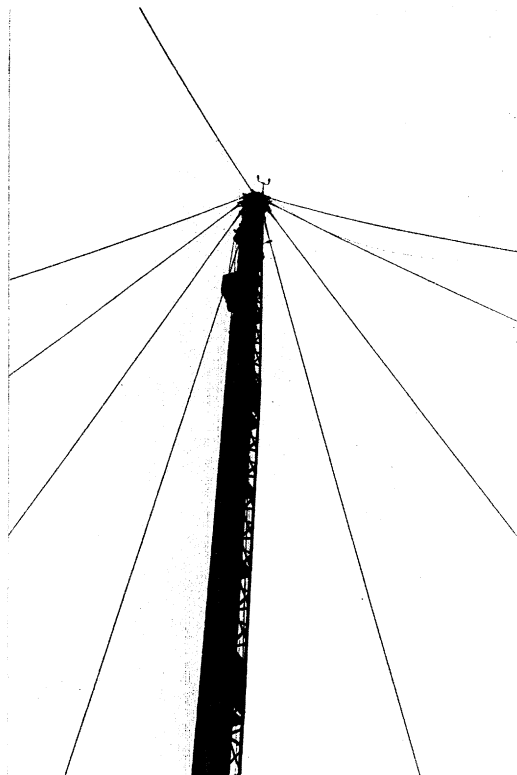


Figure 56

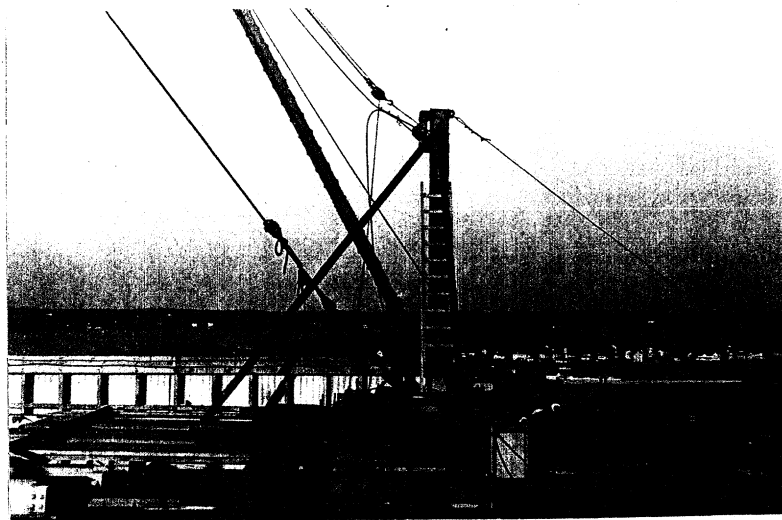


Figure 57

A Chicago Boom crane was also erected on one corner of the boiler room area so as to be able to lift from the storage area on the east side of the building up to the turbine room roof. Figure 57.

Figures 58 & 59 are two later views of the steel work from a distance showing the roof crane and the hoists on the south side of the building.

#### Walls, Floors, and Platforms

The masonry wall sections will be discussed first showing the equipment used during construction and the actual masonry structure. All masonry materials were shipped on to the site by rail and thus were stored on the terminal section prior to their required use. The cement products were brought directly to the station site and stored in quonset huts reserved for that purpose. Most of the other materials were stored in canvas preframed storage areas near the materials hoists. Figures 60-61.

The sand was brought to the job as needed and unloaded in position for use in the mortar mixing unit. This unit was built adjacent to one of the hoists and included the mixer, heating pipes for the sand and storage space for the lime and cement being used. The unit is shown with one side open giving a view of the sand pile and piping, and the mixer. Figure 62.

The standard patented type staging was used throughout the masonry work. Figures 63-66 show its structure prior



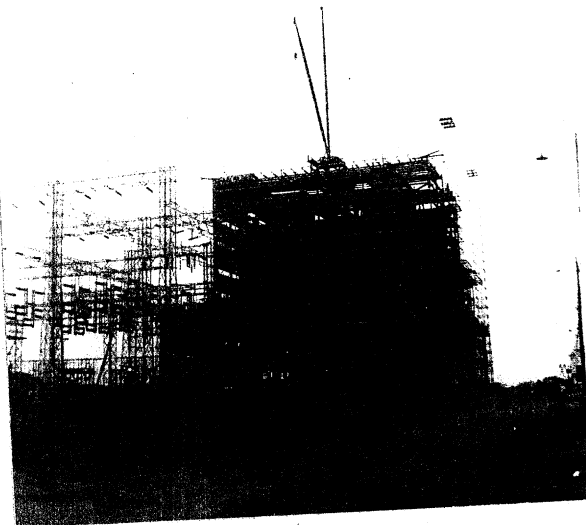


Figure 58

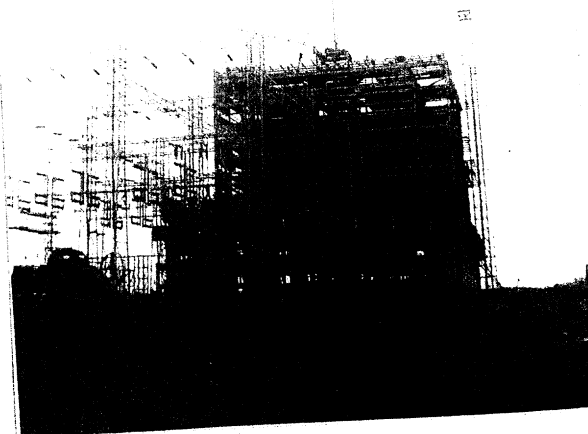


Figure 59

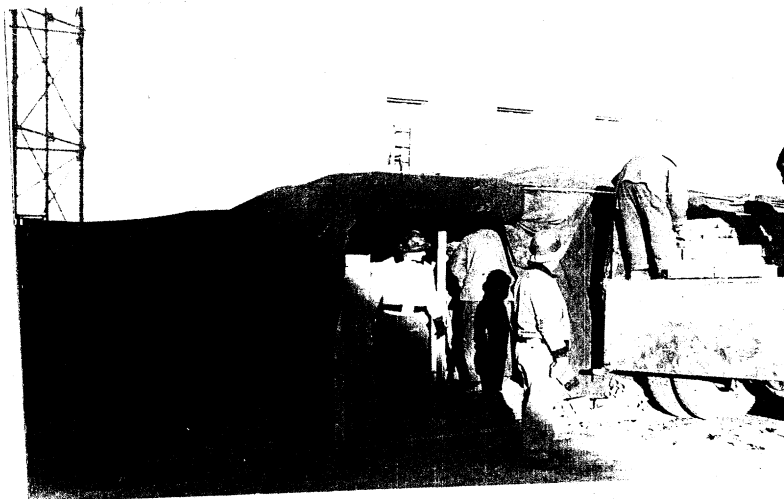


Figure 60

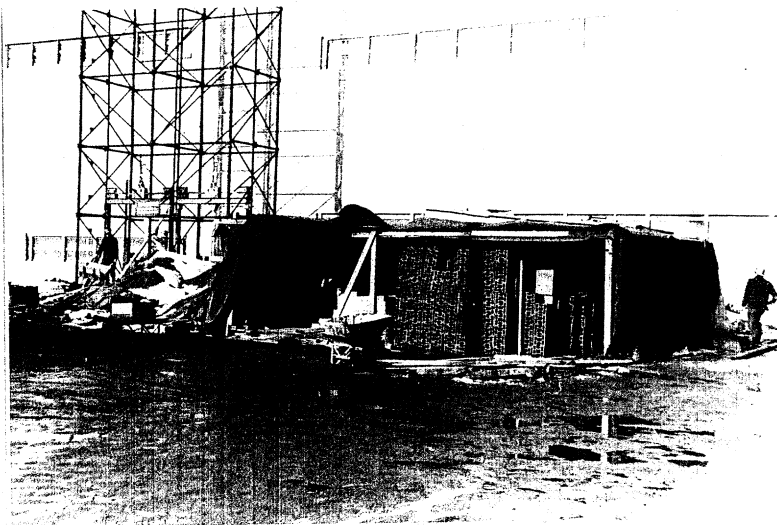


Figure 61

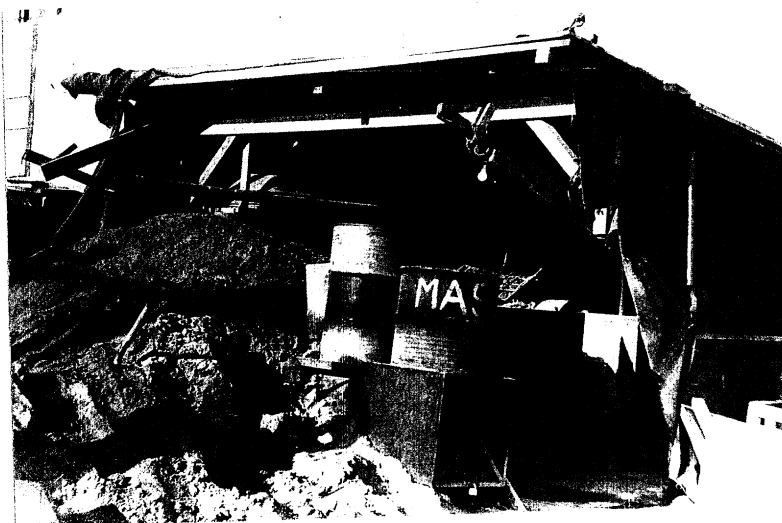


Figure 62

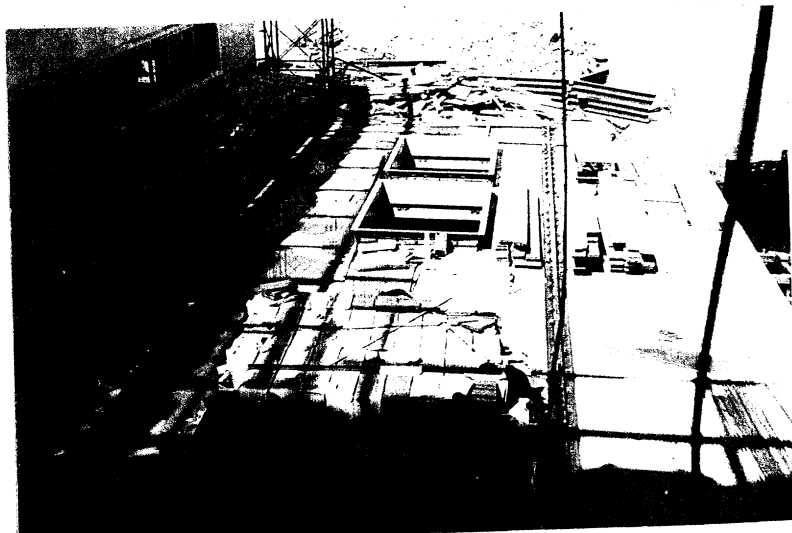


Figure 63

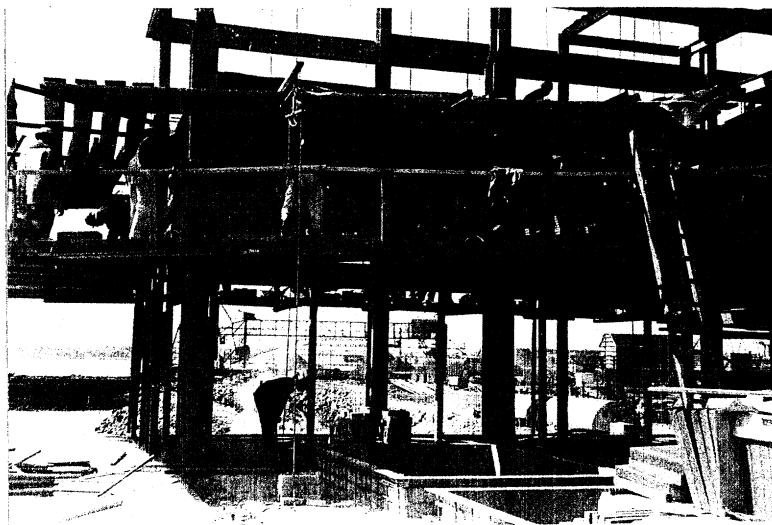


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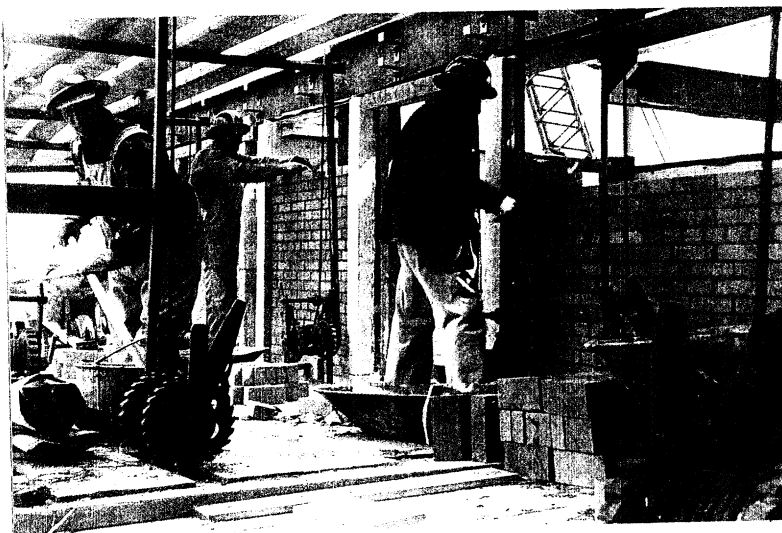


Figure 65

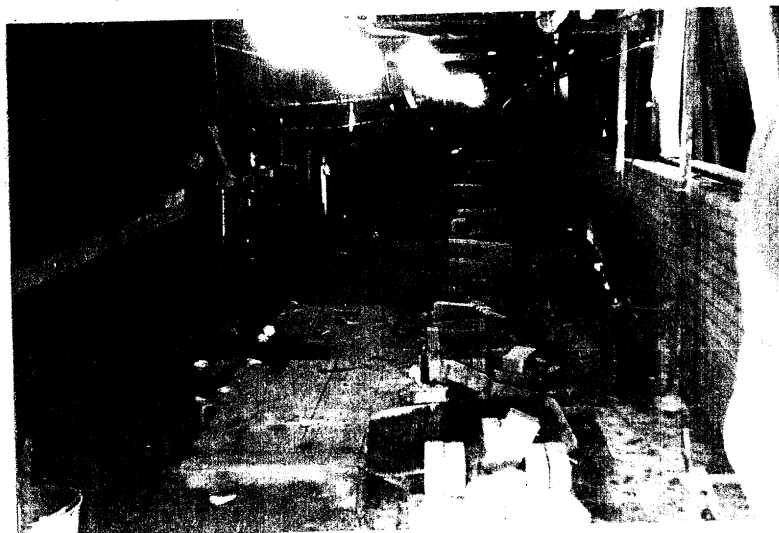


Figure 66

to connection to the roof supports, and the way it is used in both warm and cold weather. The open view shows how the safety rails are constructed and also how the materials being used on a particular section of the wall are kept within easy reach of the workmen. This view is of the construction of the wall structure on the screen house. Figure 66 shows how the staging is heated and lighted, and how the materials are stored on the staging for ease in construction of a wall section made up of face brick and back-up tile.

The structural details of the backed-up wall construction of face brick and tile are shown in Figure 67. The headers every sixth course fit into the sections of the back-up tile if they are laid as shown. The spandrel details including the flashing and common back-up are also shown in Figure 68.

The corner sections are built up first to insure proper coursing and joint width; the rest of the wall is then brought up to level and the corners again raised so that lines can be used for the coursing. All steel must be parged before the brickwork is laid. Figure 69.

The entire building was bricked-in on the permanent sides with the exception of the screen house area which was completed later. The staging encompassed the south and west sides for the entire height and was raised simultaneously as the work was completed. The views below are of the

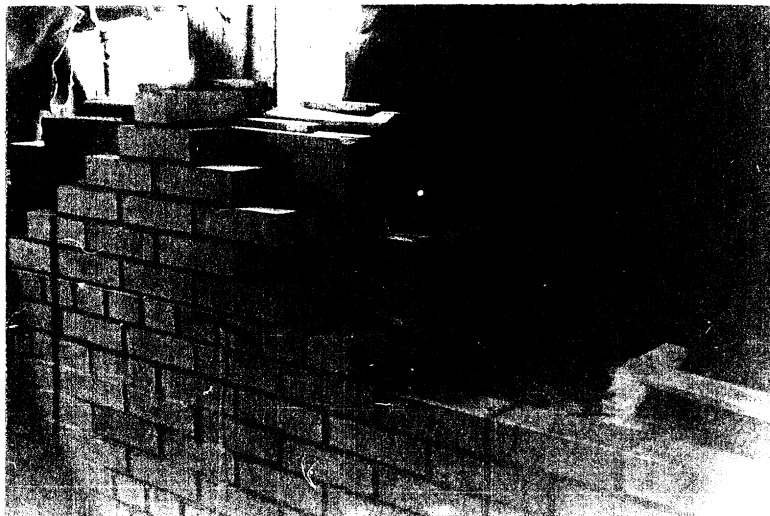


Figure 67



Figure 68

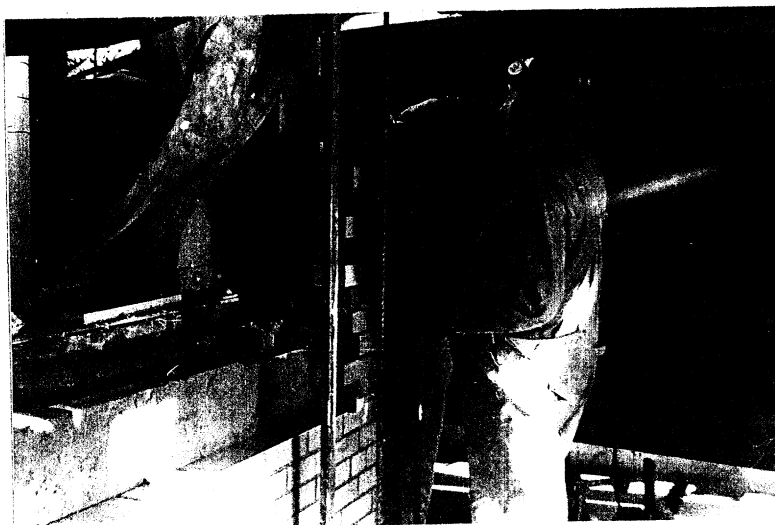


Figure 69

brick work completed at various elevations. Figures 70-72.

At the completion of all the brick work on these two sides of the building the stagings were removed, and the hoisting towers were used for hoisting to the roof only. The towers were removed by use of the guyed derrick on the roof. Each tower was supported as shown and dismantled from the ground. Figures 73.

The additional views in Figures 74 & 75 show the building after completion of all the brickwork and the removal of the hoists and the roof derrick crane. Note that a lighter and smaller boom has been installed to replace the derrick crane.

The temporary side of the structure is enclosed by vertical corrugated asbestos siding. This is attached directly to the structural steel by lock nut bolts which provide ample anchorage but also allow easy removal. This siding as shown will be removed when the future addition to the station is constructed. Figures 76-78.

The floor systems include both reinforced concrete and steel grating. The former are usually constructed as rough floor slabs, fill, and finish floors. This division makes it possible to construct the floor slabs and thus enclose the steel and provide working landings without subjecting the finishes to the wear and tear of construction activities.

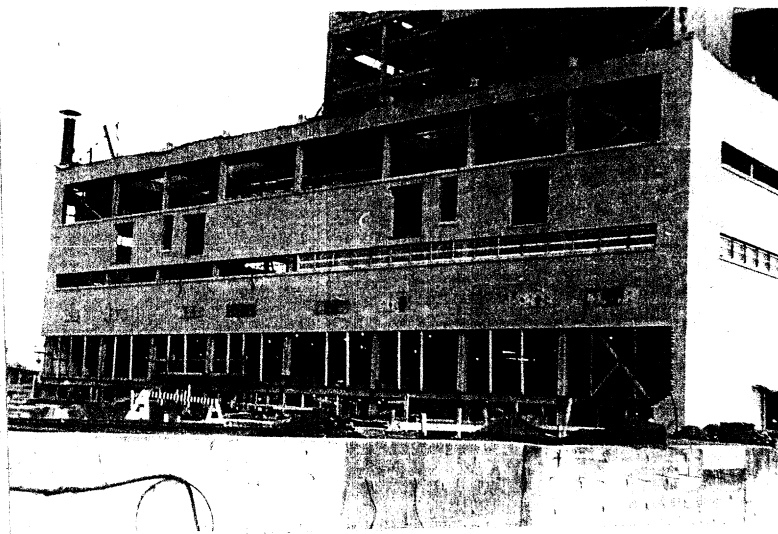


Figure 70

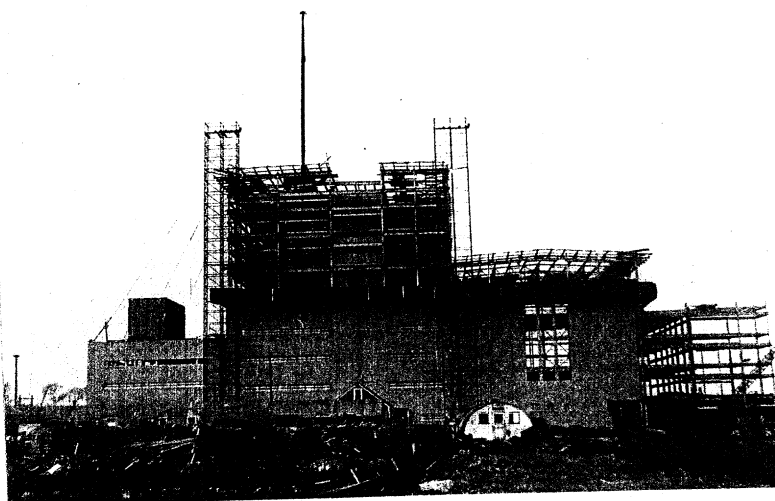


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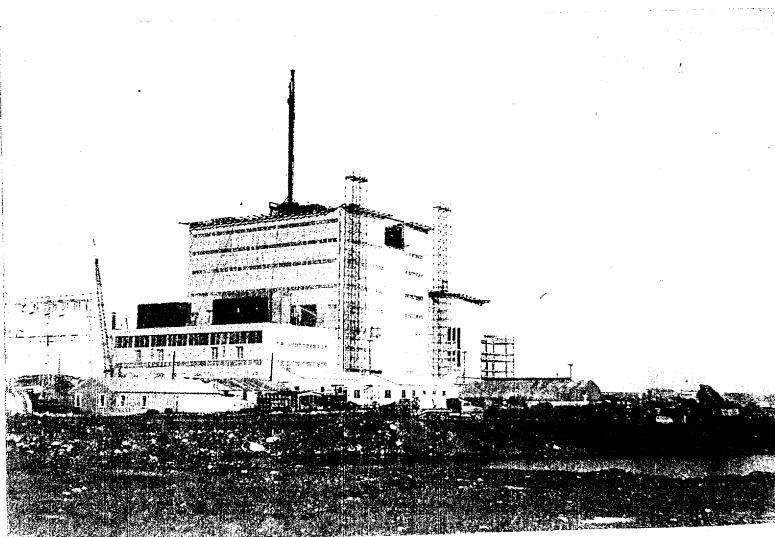


Figure 72



Figure 73

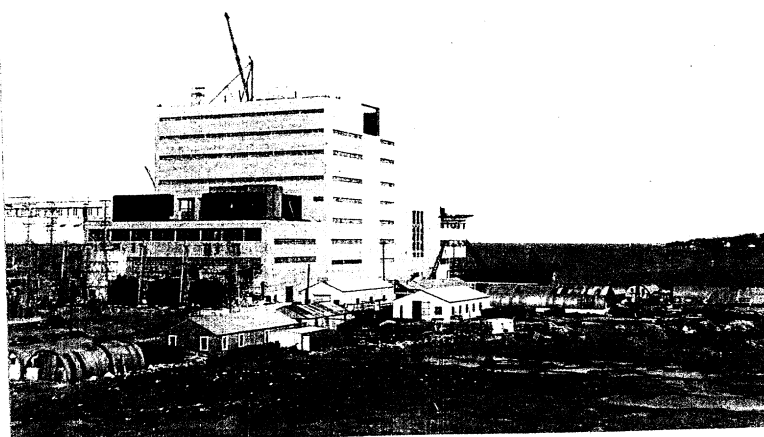


Figure 74



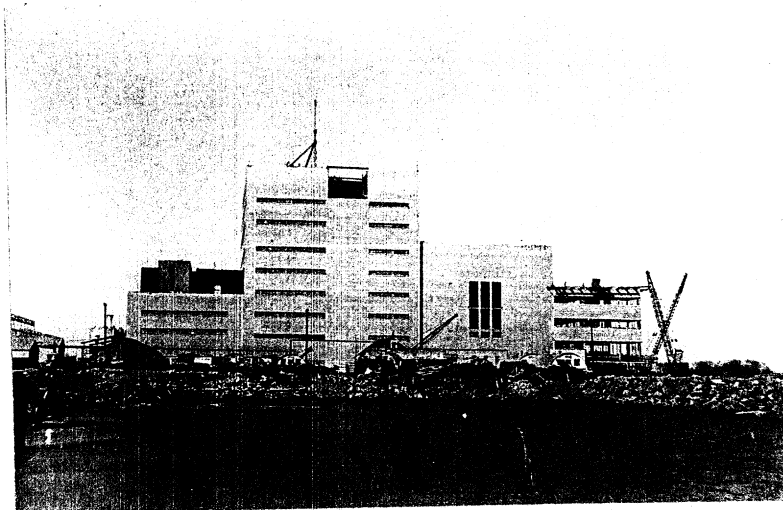


Figure 75

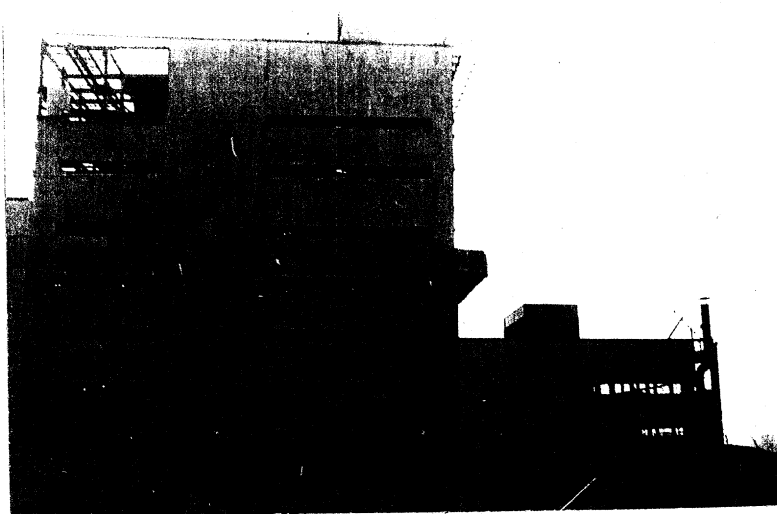


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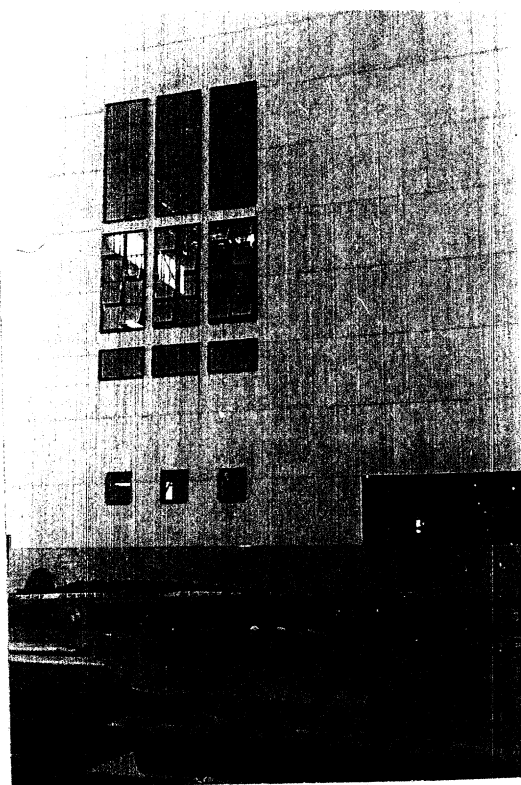


Figure 77

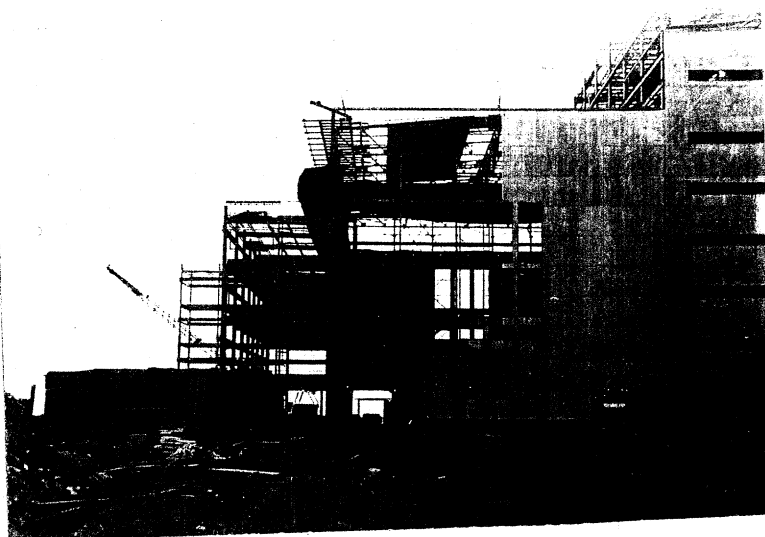


Figure 78

The forms for the most part are constructed of plywood even around the beams and girders. Figure 79 shows the typical form construction as seen from the floor below. The details of construction at the intersections of beams, girders and columns can be also seen in this view.

A top view of the same type of form, Figure 80, shows the placing of the reinforcing in the slab construction. The details of the supporting chairs and of the tying can also be seen in these views.

The ground floor slabs that are poured on the foundations and/or on fill present a different problem as to reinforcing details. In this case the rods are usually supported on precast concrete blocks that are set directly on the supporting structure or fill. Form sections that are inserted to make indentations or holes are also supported in this way. Figure 81.

All inserts and conduit must be place in the slabs prior to the time of placing the reinforcing and the concrete. The conduit is usually run in groups. This system speeds up the placing of conduit and also simplifies the forming details. Figures 82-83/are of conduit runs and also show the typical type of floor passage spaces and supporting structures used in conduit work. X

A considerable amount of the concrete was placed on the job during cold weather which made it necessary to protect it from freezing and to keep it at sufficiently low

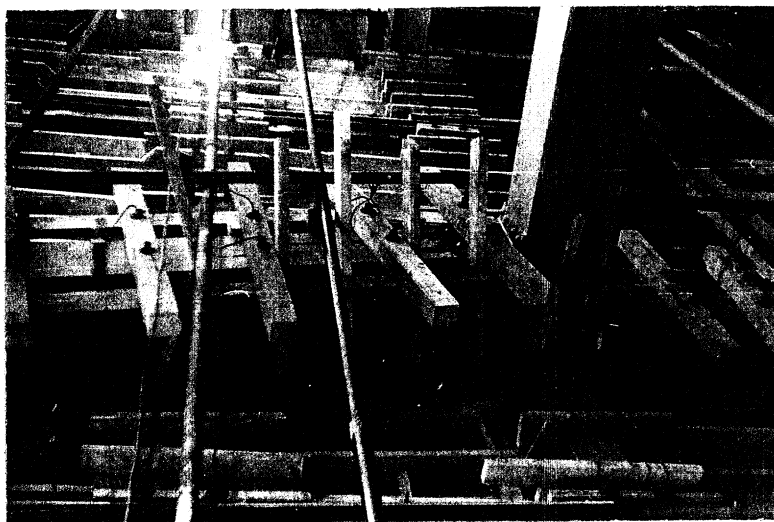


Figure 79

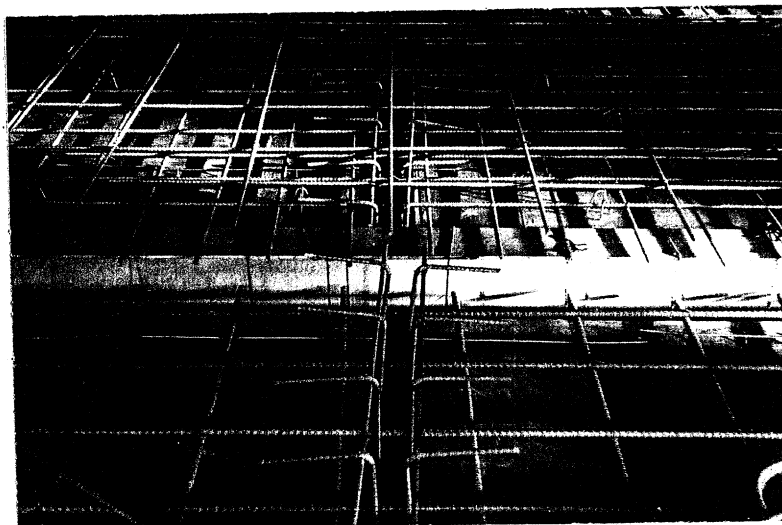


Figure 80

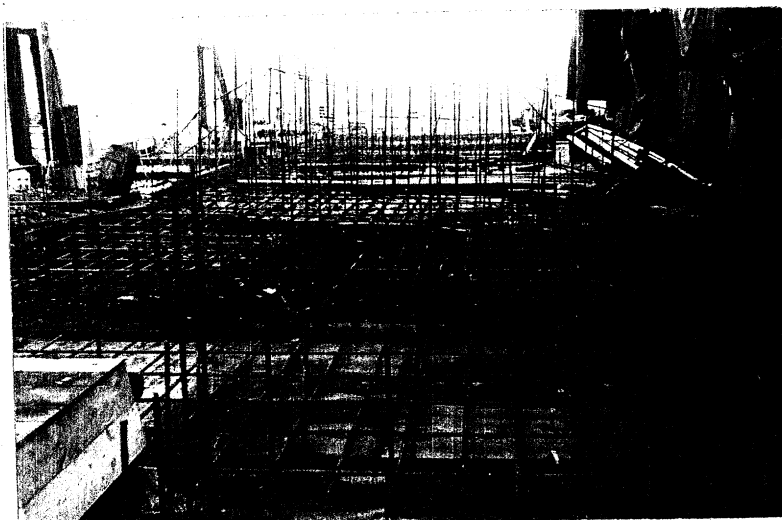


Figure 81

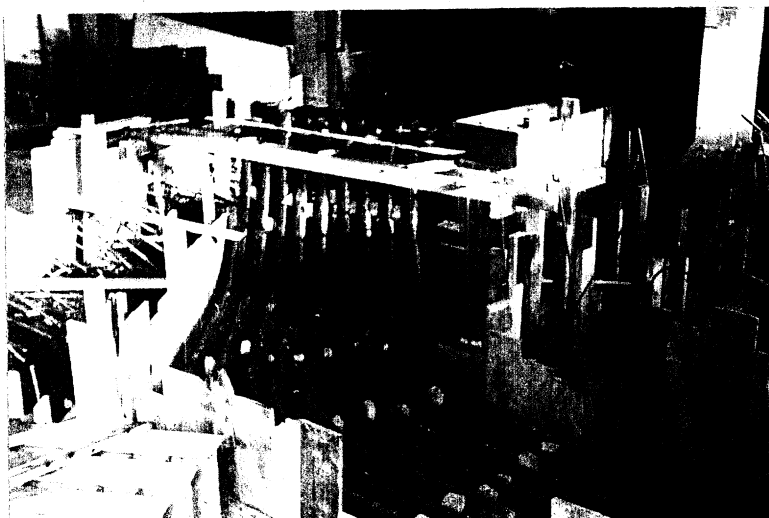


Figure 82

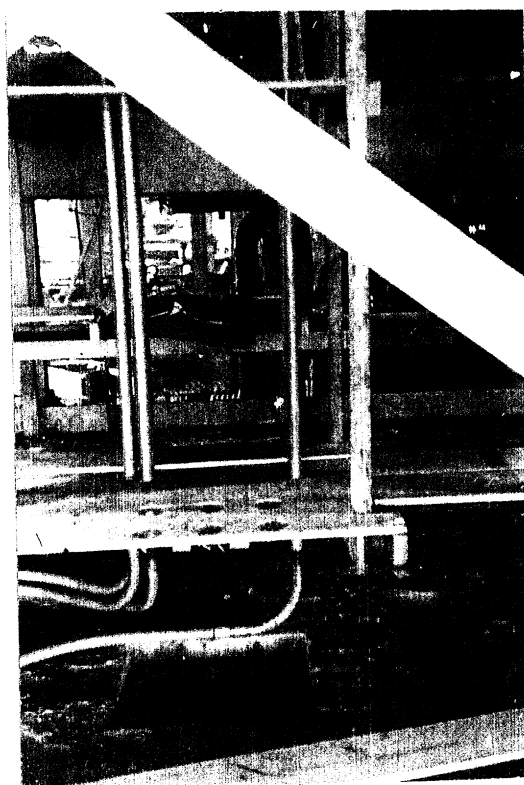


Figure 83

temperatures to allow time for proper curing. Live steam pipes were used to accomplish this end throughout the job. These were usually placed below the floor slabs and/or sufficiently close to the concrete to keep it at the required temperature. On exposed concrete work the entire area being poured was protected from the cold by use of heavy tarpaulins enclosing the steam pipes and forms. These tarpaulins were usually supported by planks which in turn were supported on a frame of light reinforcing rods forming a monkey cage network over and around the area being protected. An example of this type of protection can be seen in the picture of the placing of the turbine room floors, Figure 84. The concrete is being placed by use of a concrete bucket supported by the turbine room crane, and the picture shows the workmen placing the planks on the framework and the canvas in turn on the planks.

Special finishes or foundation preparations are required on some of the floor slabs which support equipment. This often requires that special forms be supported within the slabs and that certain areas of the floors be finished rather than being left rough. An example of this can be seen in the picture of the foundations of the water storage tanks on elevation 101'-0", Figure 85. This smooth finish was required since the bottom plates of the tank lay directly on this surface.



Figure 84

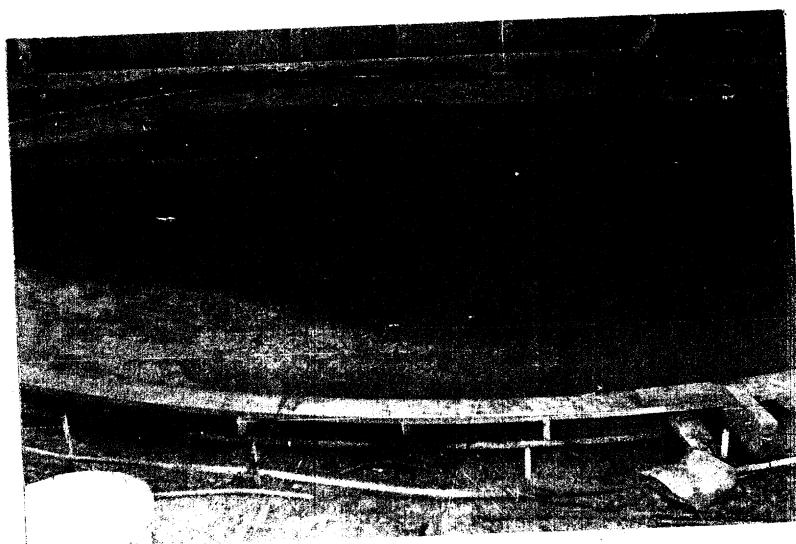


Figure 85

The majority of the interior wall sections are floor-to-ceiling partitions which are constructed of tile and/or red face brick. This brick and tile work is laid in the same way as the exterior masonry work with the exception of differences in wall ties and scaffolding. On the interior sections the scaffolding is made up of patented aluminum tubular members that come in sections and require only a minimum of erection and can quite often be moved without dismantling. A great amount of the work can be done from the ground and in this case storage of materials and supply of mortar is simple. Figure 86 shows an example of the partition structure and the bricklayers at work.

The roof slab is constructed precast slab sections which are laid directly on the purlins and are fastened with small metal clips. This structure can be seen in Figure 87. of the slabs in position on a section of the turbine room roof.

The completed roof slab looks like a poured slab since all the joints are reinforced and sealed and the crickets are built-up of cement mortar. Figure 88 shows the roof ready for application of the insulation and the built-up roofing materials.

The construction of the stacks should also be considered along with the rest of the masonry, even though they are a special type of construction and in this case



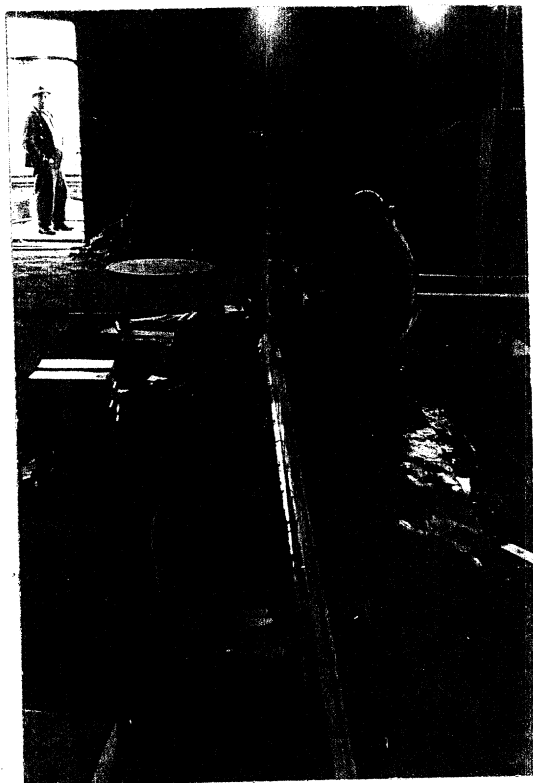


Figure 86

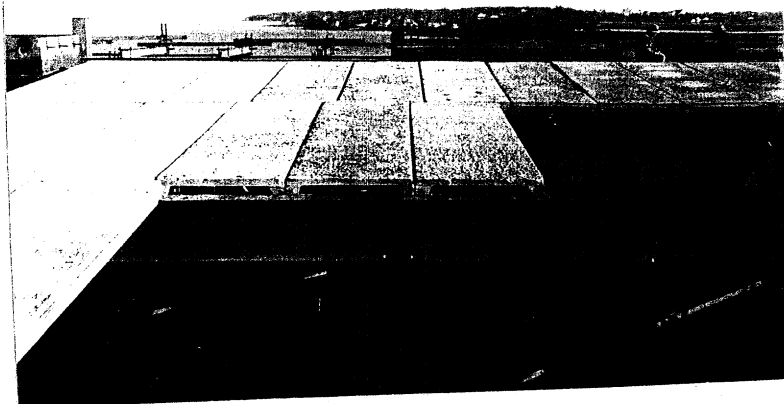


Figure 87

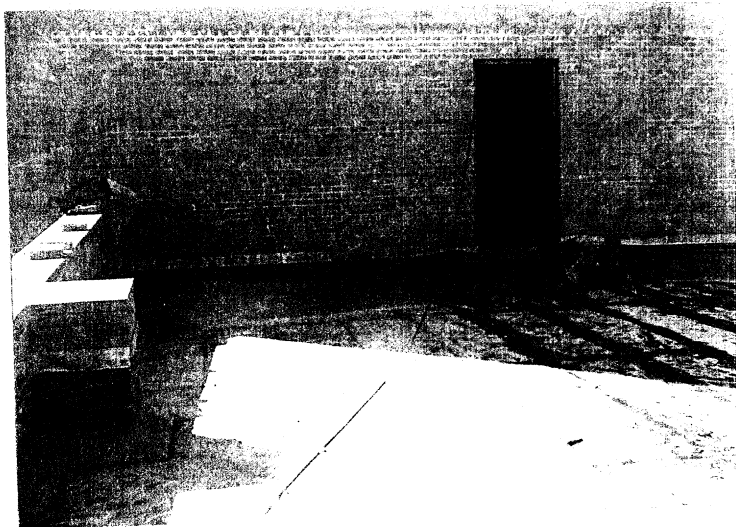


Figure 88

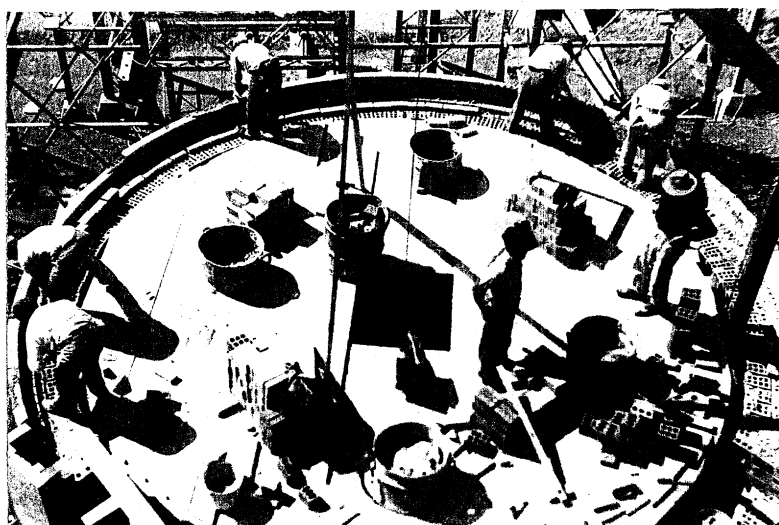


Figure 89



Figure 90

were even sublet to a separate contractor. The stacks were not started until warm weather was expected to continue for the duration of their construction. The Russel Engineering Company has the contract for the construction of both stacks which they are building simultaneously.

Construction is carried on from built-up platforms which are raised at convenient intervals as scaffolding from the inside of the constructed portion of the stack. Materials are raised to this platform by means of hoisting line through the center of the scaffold. The materials are stored within the constructed portion of the stack directly below the working platforms and thus are protected from the weather. Figures 89 & 90.

Figure 91 shows the construction of the platforms, and the rigging and bracing for the hoisting line. The masonry is covered during the off-work periods so that a minimum of water, and other foreign matter will get into the open tile structure.

### Boilers

The major portion of the boilers and equipment has been constructed during the period of this report and the procedures used in the construction will be discussed according to the starting time of each section. Work on the air heaters was started first since the tube sheets were laid with the steel and the construction activities on this section could be carried on from the exterior side

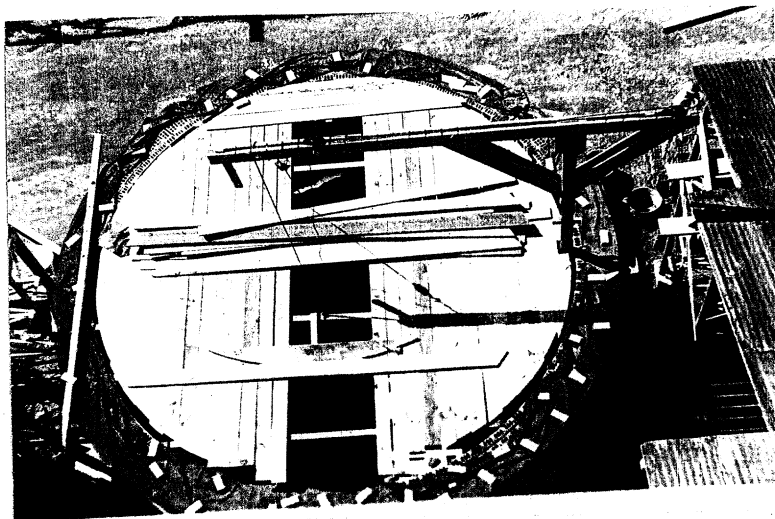


Figure 91

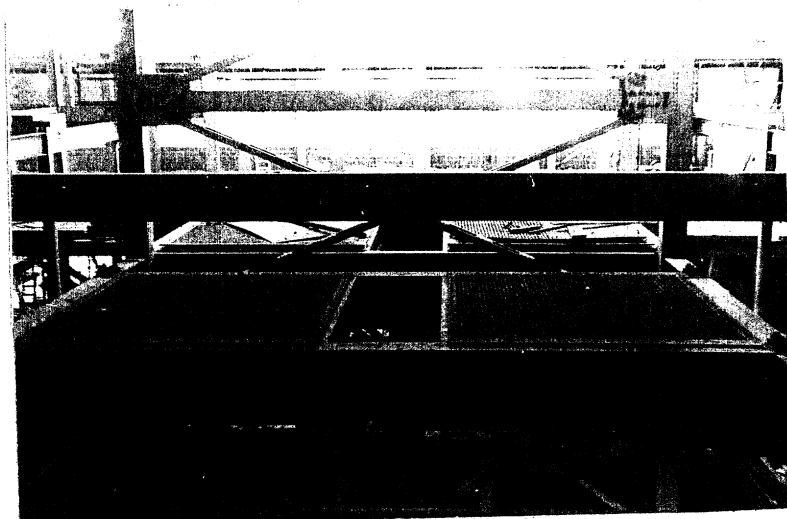


Figure 92



Figure 93

of the boiler room section, with the roof of the fan house providing a working platform for receiving and unloading materials. There are four sections to each heater, as can be seen in Figure 92, of the tube sheets in their final positions.

The tubes were lowered from the fan house roof by placing them in position in the tube sheets and sliding them down the complete length of the heaters. These were placed according to a pattern which allowed room for the workmen to get at the tubes at the joints in order to complete each layer as the sheets were filled. The tubes were handled by two men above and two below to ensure proper sliding through the sheets and contact with the tubes below. This system is shown in Figures 93 & 94.

The section above the air heaters is constructed of horizontal tubes which receive the heat from the hot gases as they are turned in the top of the boiler proper. These sections were raised to the fan house roof by the boiler room roof crane as pictured in Figures 95 & 96 and there were placed on rollers on platforms which made it possible to roll them directly into the area of air heaters where they could be raised into position. This last lift was accomplished by means of an air hoist set in the boiler section, and rigged through the top of the boiler section on the supporting steel.

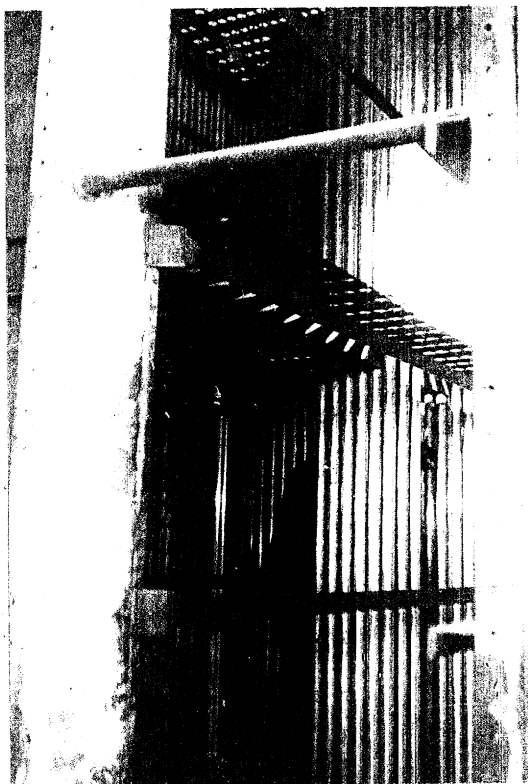


Figure 94

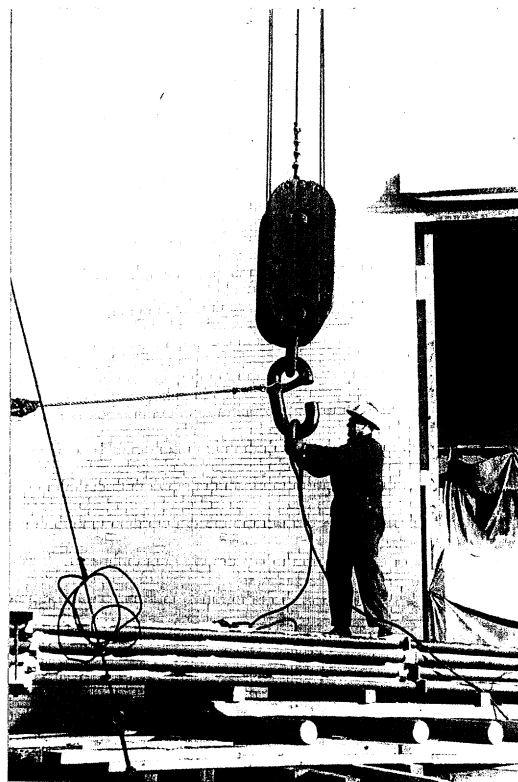


Figure 95

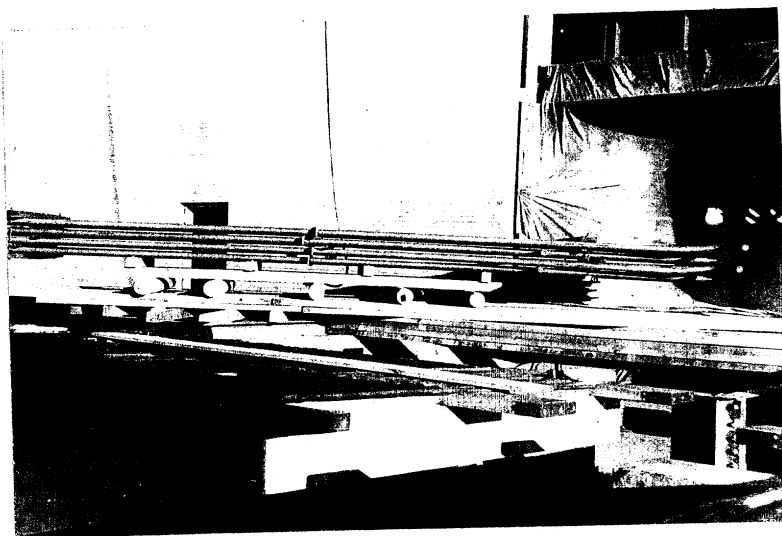


Figure 96

The final enclosure of tubes is pictured in Figure 97 with the boilermakers and welders closing the joints on the exterior sections. This narrow working space is provided from the ground floor to the top section of the boiler and provides the separating section of the boiler passes. The gases are thus forced up through the boilers and turned at the main drum and then forced back down through the air heaters and into the dust collection section.

The main problem of the initial construction of the boilers is that of raising the boiler drum to the top of the building and setting it in its permanent hangers. The drum was transported to the job site on a low bed trailer which was also pulled and held back on hills by two additional trucks one in the front and one in the rear of the main trailer. Figure 98.

The rigging used to raise the drum is pictured in Figures 99 & 100 along with the supporting members in the top of the building. Later views of the drum in position in its permanent supporting hangers are shown in Figures 101 & 102. These hangers are "U" shaped and support the drum directly from the main structural members above the boiler. The drum is also supported laterally to prevent any side swaying due to construction loads, or possible shifts in the steel due to failure.



Figure 97

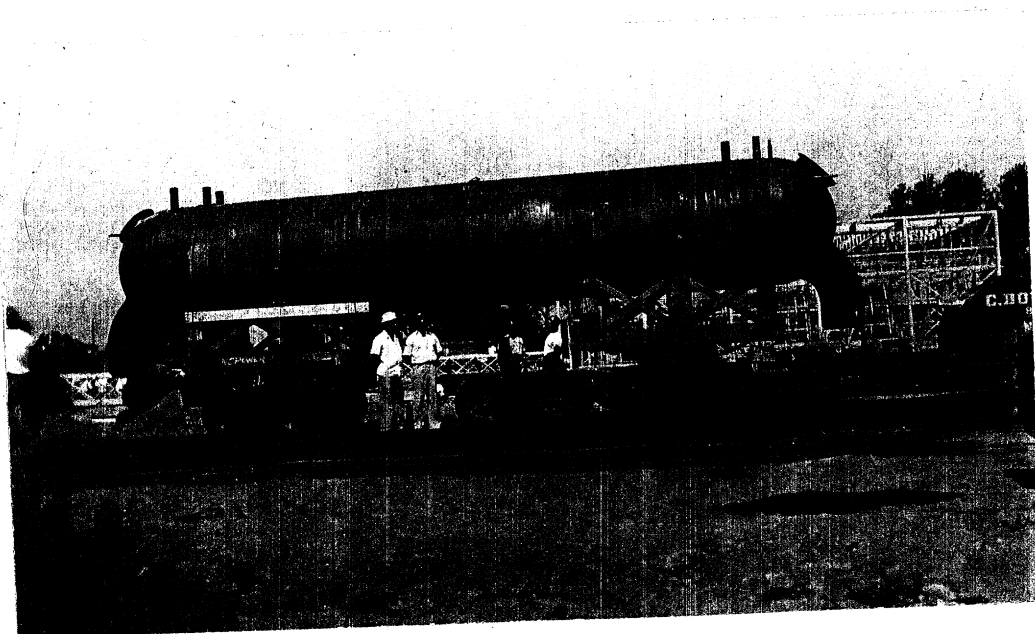


Figure 98



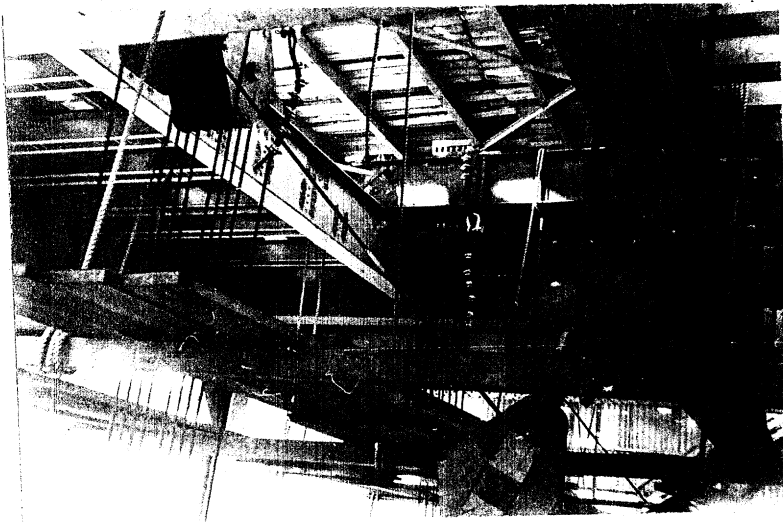


Figure 99

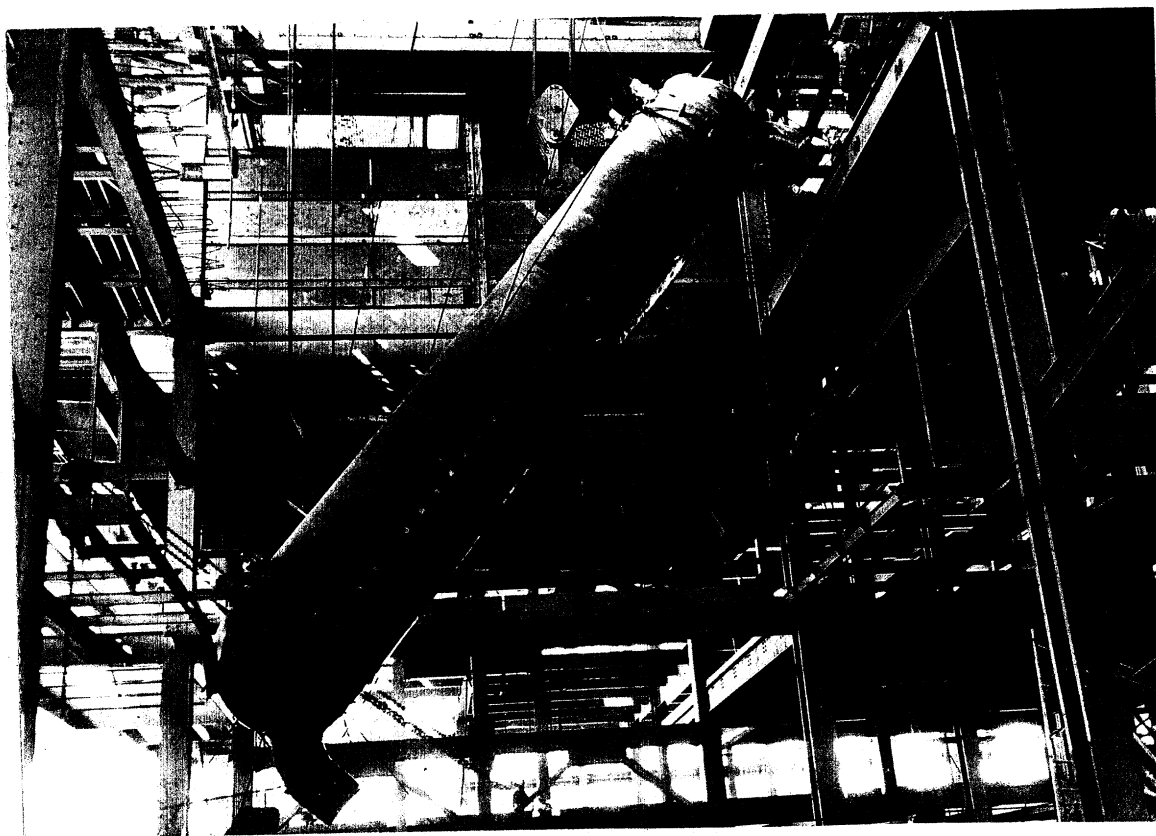


Figure 100

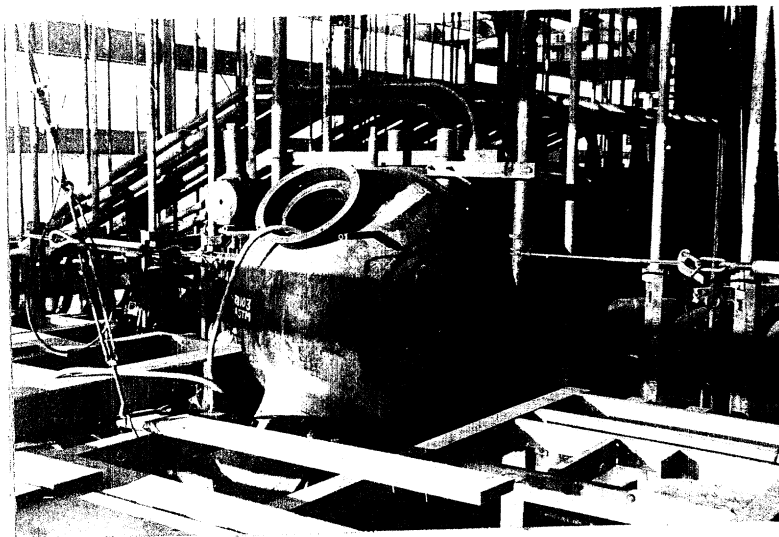


Figure 101

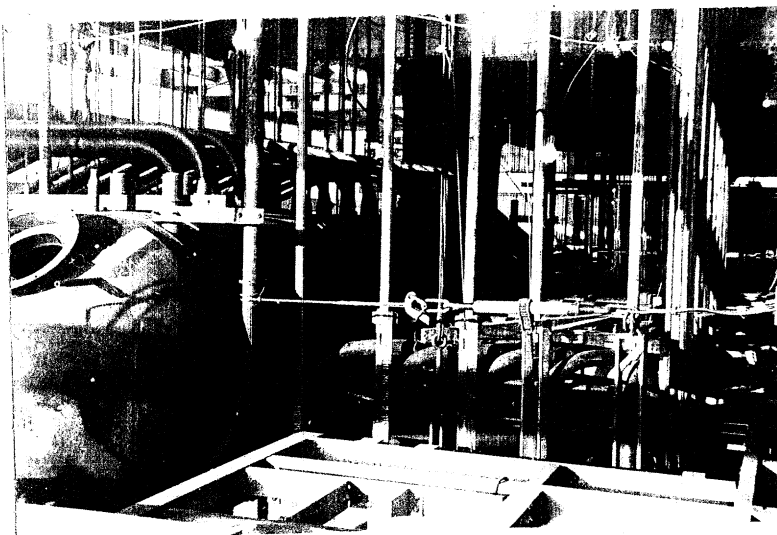


Figure 102



Figure 103

The tubes come out of the drum radially in all directions with exception of the top back section. These are all turned down into the boiler sections and provide the only connections to the drum except for the main down-comers. Figure 103 shows the interior section of the drum with the workmen completing the joints of the tubes entering the drum. Other views of the tubes and their supporting members are shown in Figures 104 & 105.

The control and safety equipment was constructed at a later time but is directly related to the drums. Figure 106 shows the safety blow-off valves and the instrument piping at the drums. The welding at the safety valves must be done by preheating and stress relieving also and Figure 107 shows the coils in position prior to the welding operations.

In connection with this process the main welding job as to difficulty and importance was the welding of the down-comers from the main steam drums. These were constructed in three sections requiring two welds on each down-comer. The sections were first supported as shown in Figure 108 which provided support during all construction and welding work. Preparation for welding included preheating by use of electrical induction coils. These coils were placed on the pipe in such a way as to insure positive heating action throughout the welding process. Figures 109-111 show the process partially completed with several passes

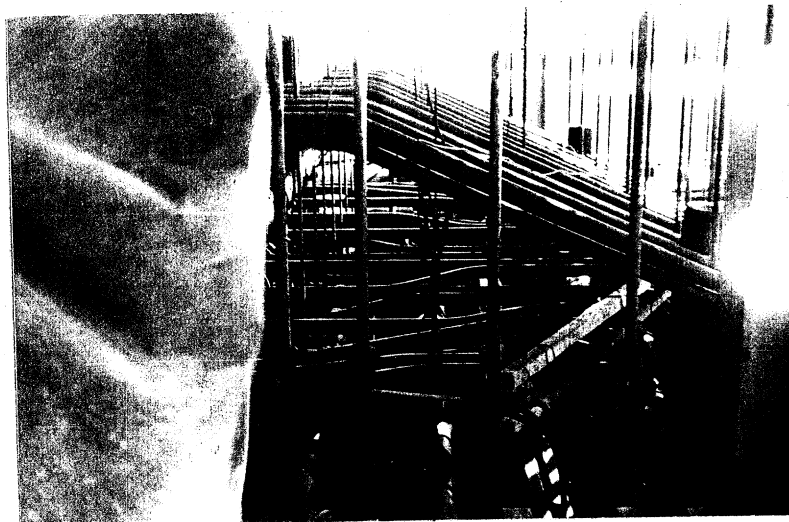


Figure 104

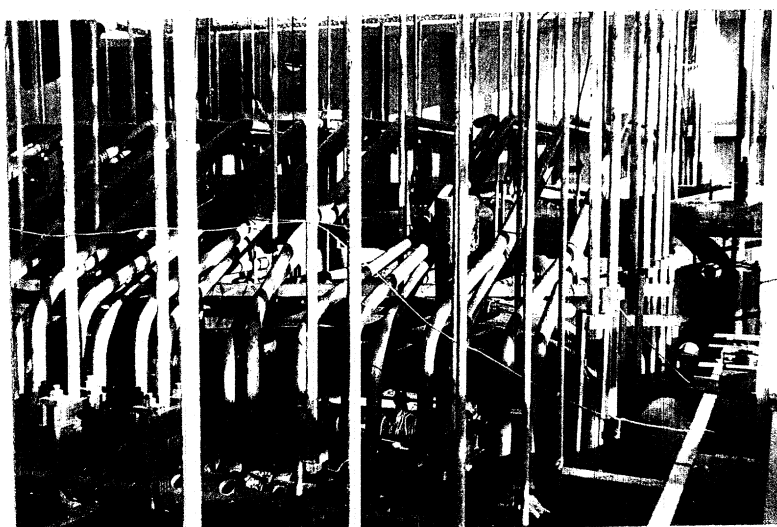


Figure 105

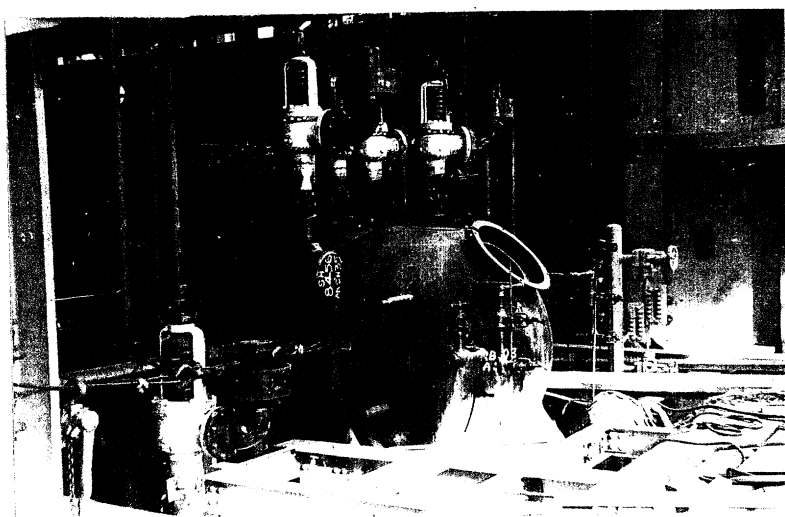


Figure 106

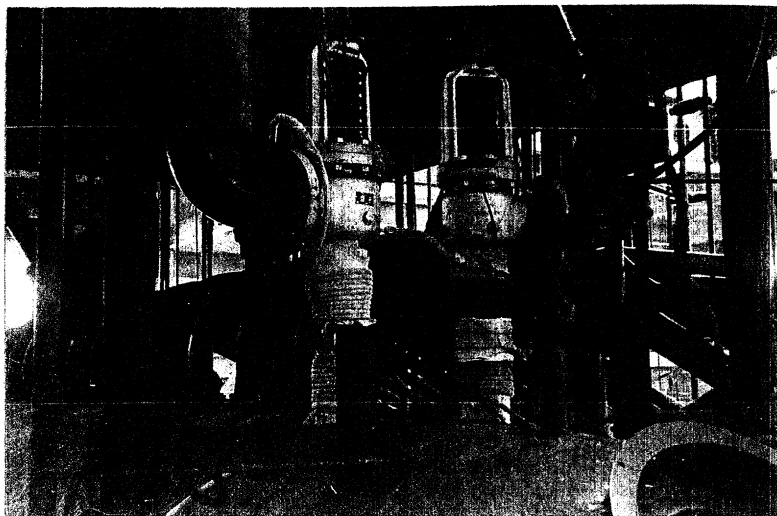


Figure 107



Figure 108



Figure 109



Figure 110



Figure 111

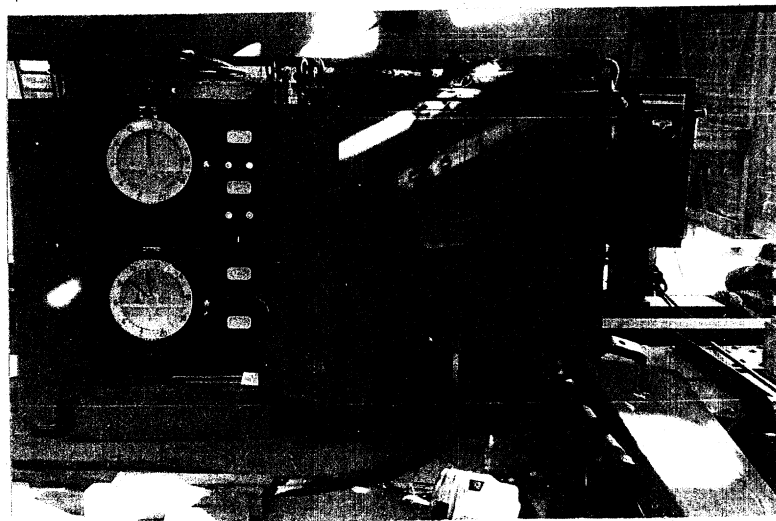


Figure 112

of the welding already made, and again after completion. The process had to be continuous from the time the preheating was started and thus often required overtime work due to the large number of passes required on pipe of this size. The control and recording equipment used in preheating and stress relieving is same as that used throughout the job on all piping and boiler work and is shown in Figure 112.

The construction of the boiler water walls and tubes was carried on in sections according to type and location. The tubes from the drum were carried down first and the walls were built in toward the center with the interior sections being constructed by the use of hanging scaffolding from the top of the boiler. The section on the bunker's side was started first, as shown in Figure 113. Figures 114-116 also show different views of the tube construction as it progressed around the different sections.

The entire interior section of the boiler is built up with tubes in such a way as to direct the hot gases around as many tubes as possible on their way out to the stacks. The various shapes and bends are shown in the picture of the interior sections of Figures 117-119. Note should be made of the supporting members and their location with respect to the boiler tubes and the economizer and heater tubes. These serve as working members

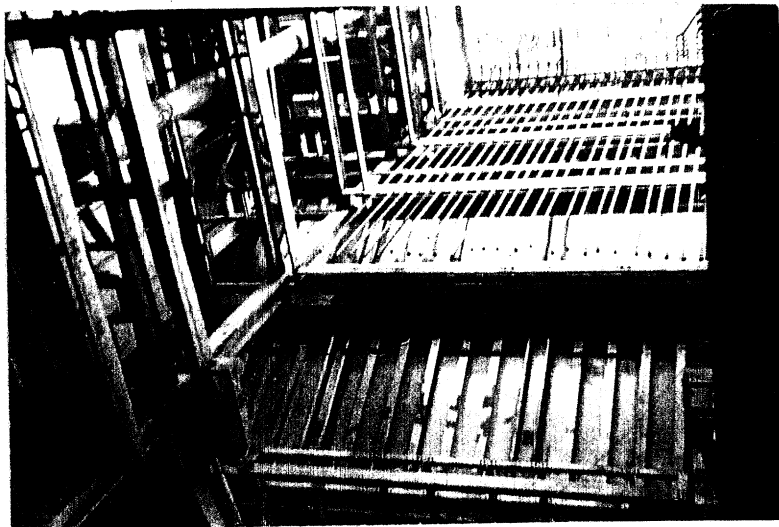


Figure 113

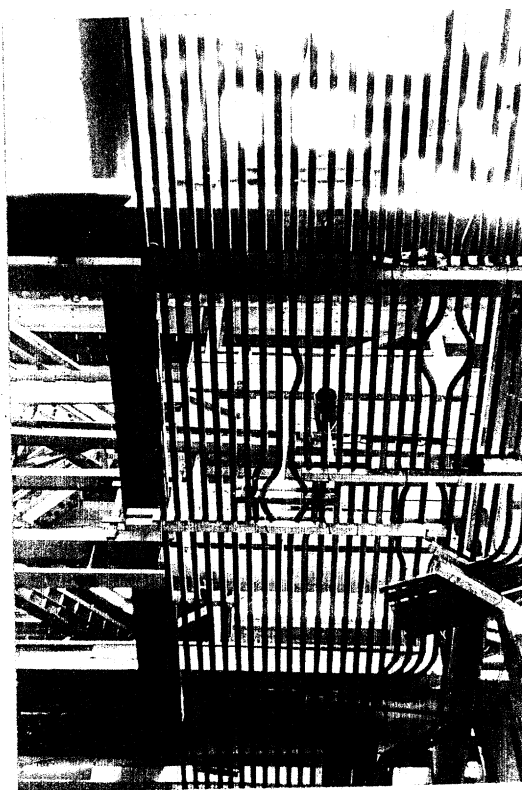


Figure 114



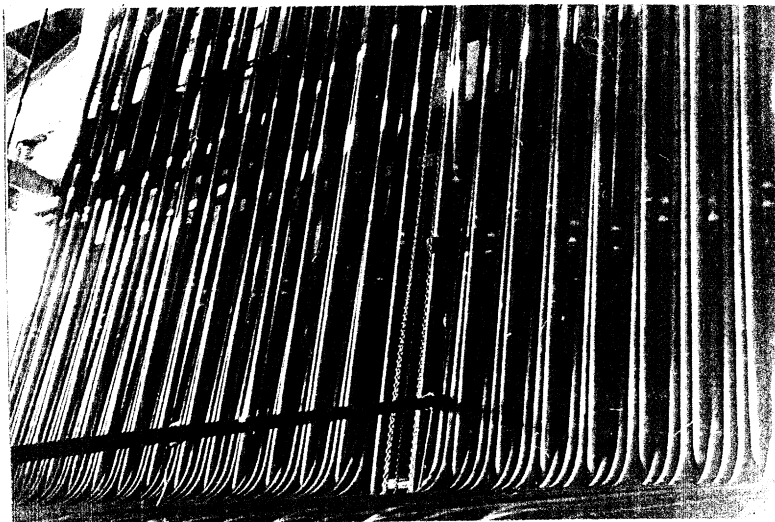


Figure 115

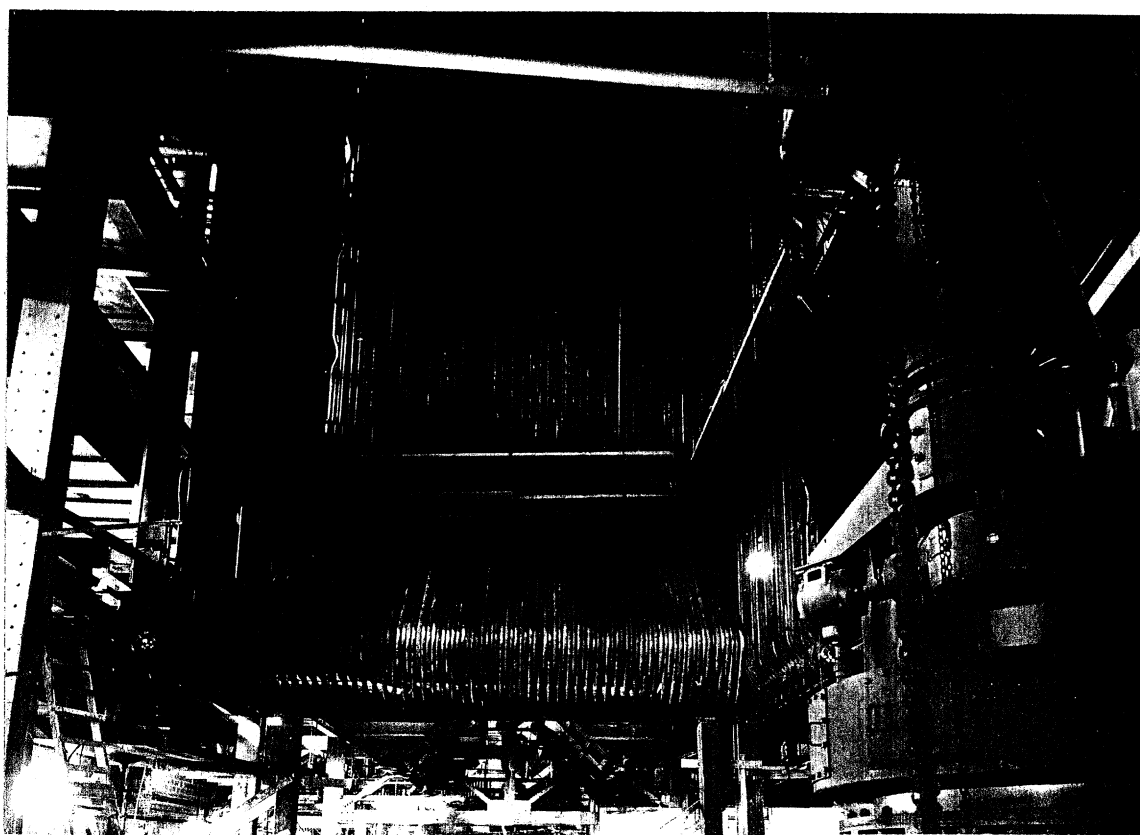


Figure 116

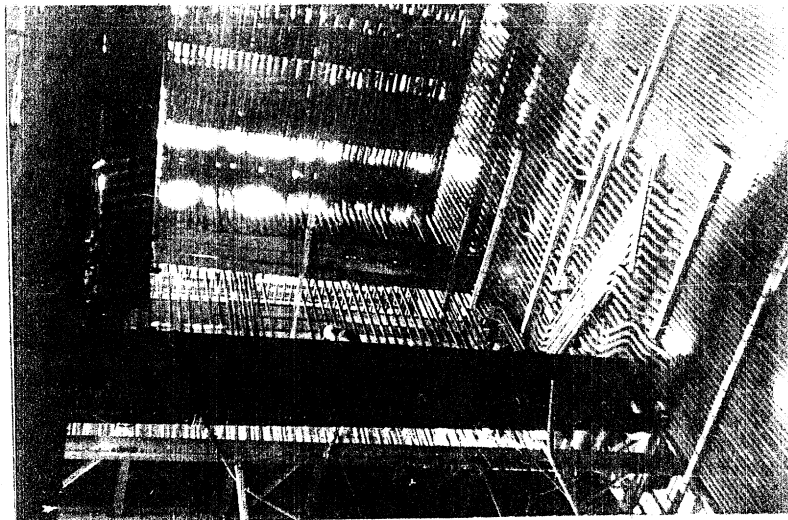


Figure 117



Figure 118

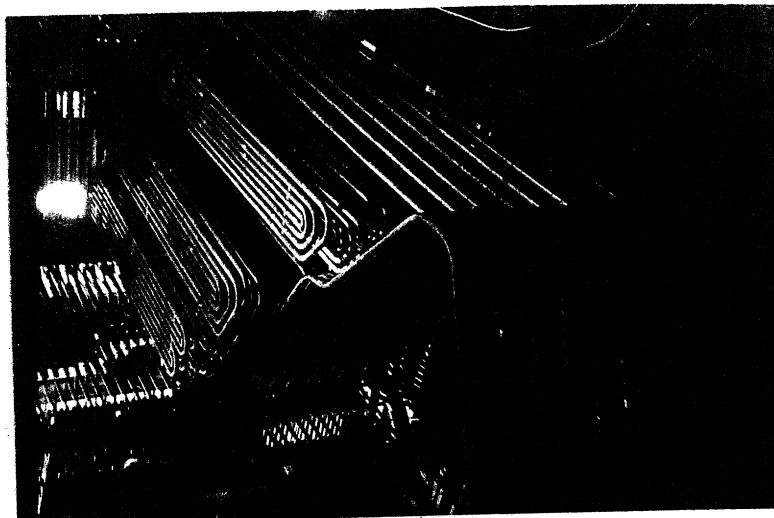


Figure 119

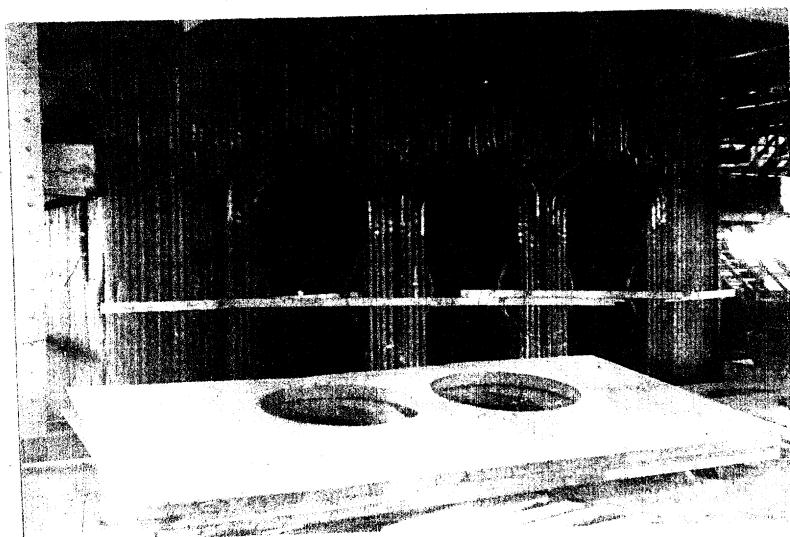


Figure 120

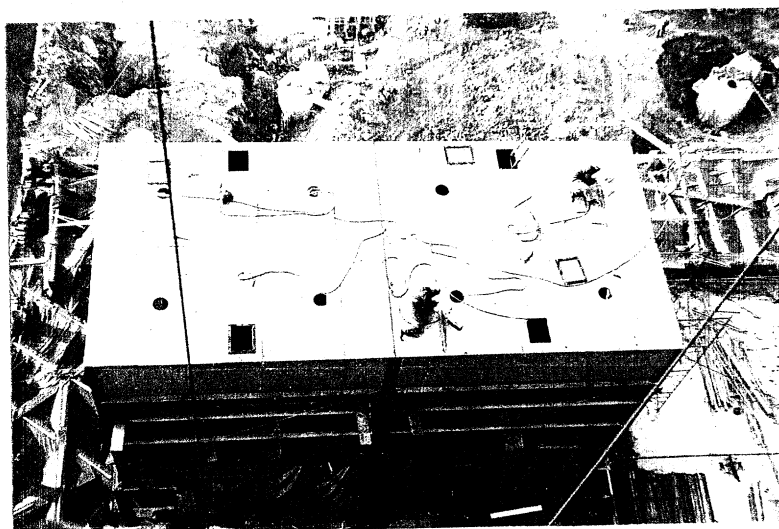


Figure 121

during the construction and also for the main setting and casing of the boiler proper.

The air driven hoist located within the boiler setting on the support members was used for interior hoisting within the boiler and also the heater areas. All tubes and headers were raised by use of this hoist.

Figure 120 shows the tube construction at the fire boxes on the bunker side of the boilers and also the casing plates which were not yet raised into position. There are two such sections included within the entire fire box system.

The dust collecting system was started in connection with the air heaters and was continued at the same time as the work on the heaters and the boiler. The dust collectors on the fan house roof were constructed first and the ducts were run as the materials were received. Most of this work was done with the aid of the boiler room roof crane and with a long boom crane on the ground. The exterior and interior welding was completed first as shown in Figures 121-125. Note the interior separating fins in the turning sections of the ducts.

The bunkers for handling the dust collected in the above mentioned equipment were constructed within the fan house upon the completion of the lower section of the dust collectors. These are pictured in Figure 126.

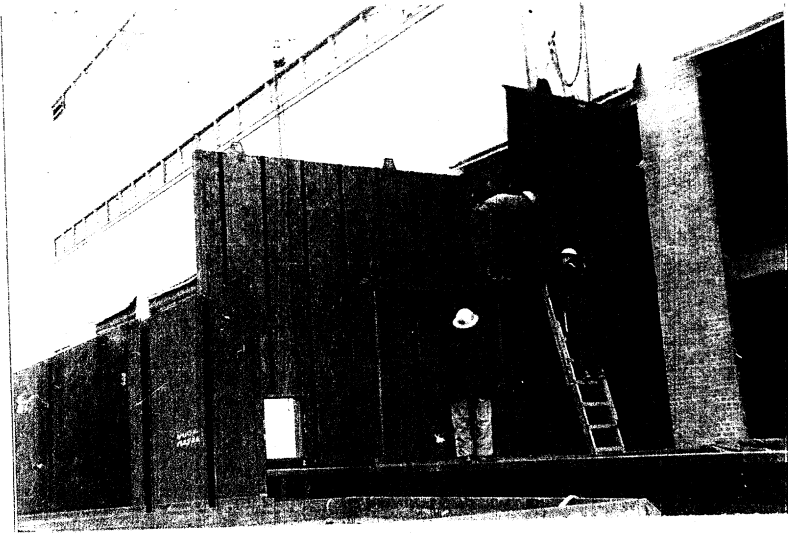


Figure 122

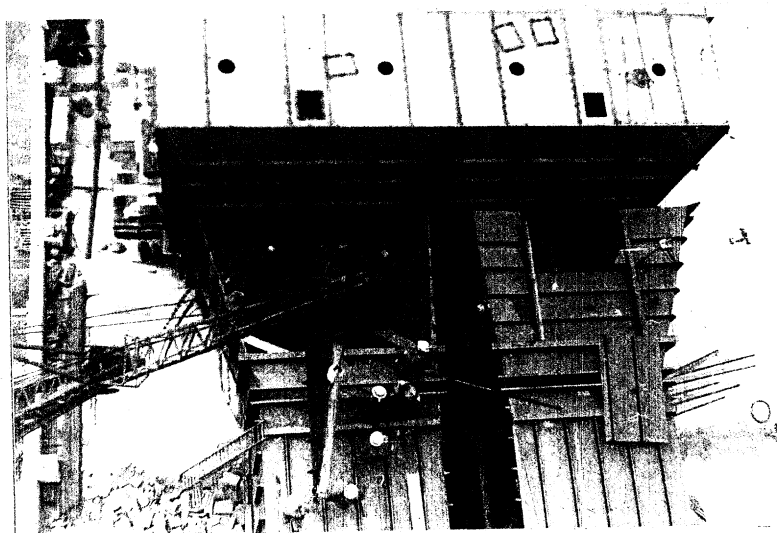


Figure 123

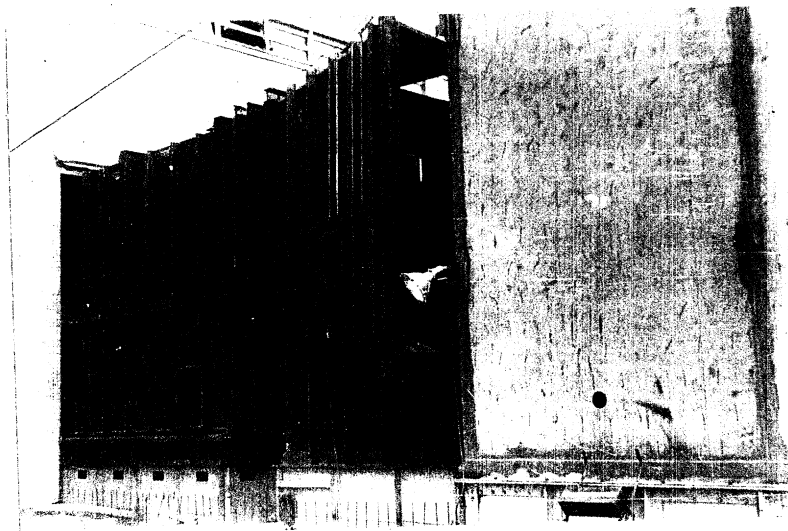


Figure 124

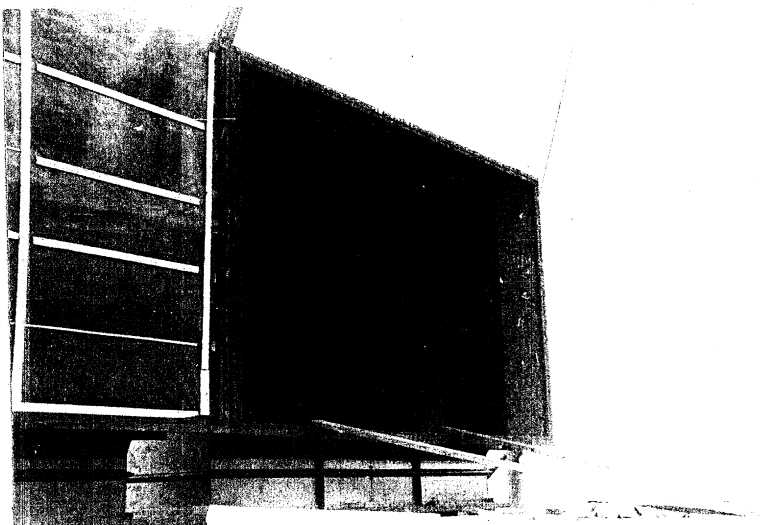


Figure 125

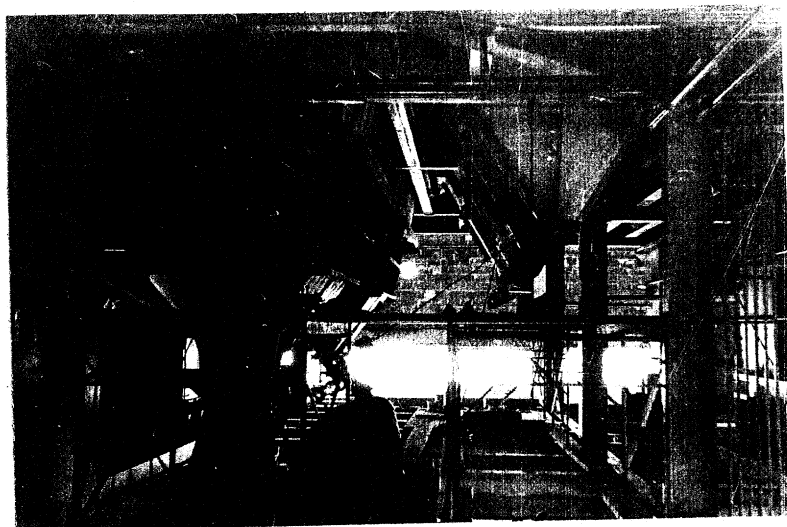


Figure 126

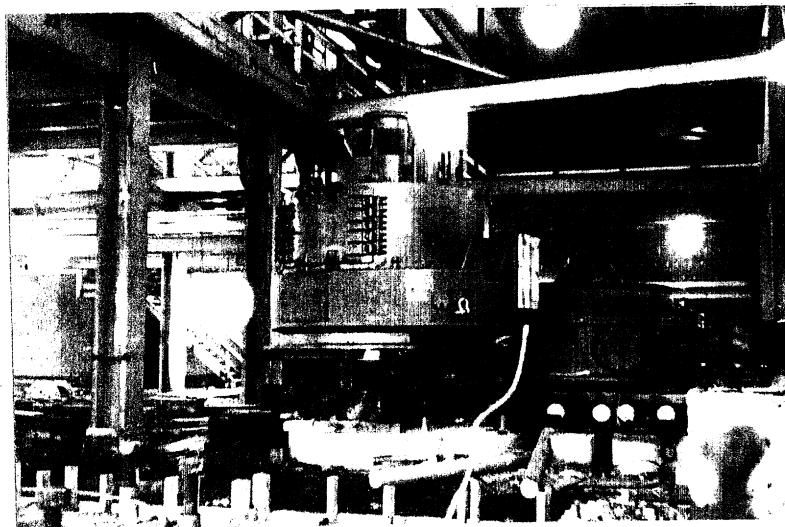


Figure 127

Another phase of the boiler equipment is the pulverizers which are located on the ground floor at the base of the boilers. There are four pulverizers for each boiler and each one feeds directly into the fire box of the boiler through the coal handling tubes. The first of these was brought into the ground floor area and set upon its foundations prior to the erection of the main water wall in the boiler, but the rest of the pulverizers were held until most of the boiler work was brought into the area and raised into position.

Figure 127 shows the first of the pulverizers in position on its foundations with the top section still to be placed in position. A frame or rail system was constructed on the unit #2 side of the pulverizer first placed in position, in an effort to reduce the work required to bring the rest of them into position. This proved effective but had to be removed before all of the units were in place. Some of the rigging used is pictured in Figures 128-130.

The remaining sections of the boiler system includes the fan system. Both the induced and the forced draft fans are located in the fan house section above the maintenance shops. The forced draft fans receive the heated air from the air heaters and force it back around to the fire box section of the boiler. The induced draft fans pull the air through the boiler system and the dust

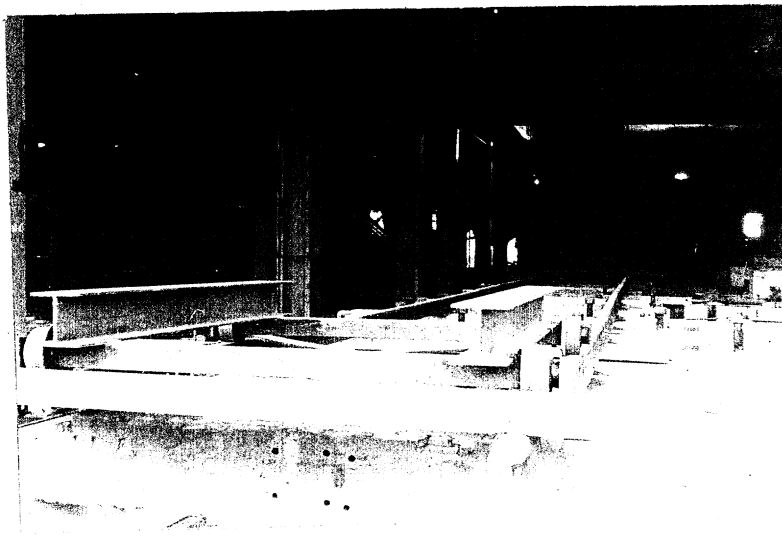


Figure 128



Figure 129



Figure 130



collectors and assist the natural draft of the stacks in removing the hot gases from the entire system.

These induced draft fans are constructed in sections of the rotors and the exterior housing. The rotors are set in the bearings by the millwrights and the casings are set by the iron workers. The details of the construction design can be seen in Figures 131-133.

The duct work from the fans to the boiler sections was carried on simultaneously with the rest of the boiler work and iron work on the job. Most of the duct work was shipped to the site in rather large sections, so that construction seemed faster than some of the other work. An example of the typical duct construction is pictured in Figure 134.

#### Turbo-generators

The foundations for the turbo-generators were sublet to the American Bridge Company rather than being constructed along with the structural steel, because of the extensive amount of heavy steel plate work that is not common to skeleton steel construction. The completed foundations are shown in Figure 53. Note should be made of the generator supports and the opening for the main section of the condenser. The entire foundation is completely separate from the structural frame that surrounds it, so that stresses or vibrations caused by the operation of the turbo unit will not be transmitted in any way to the

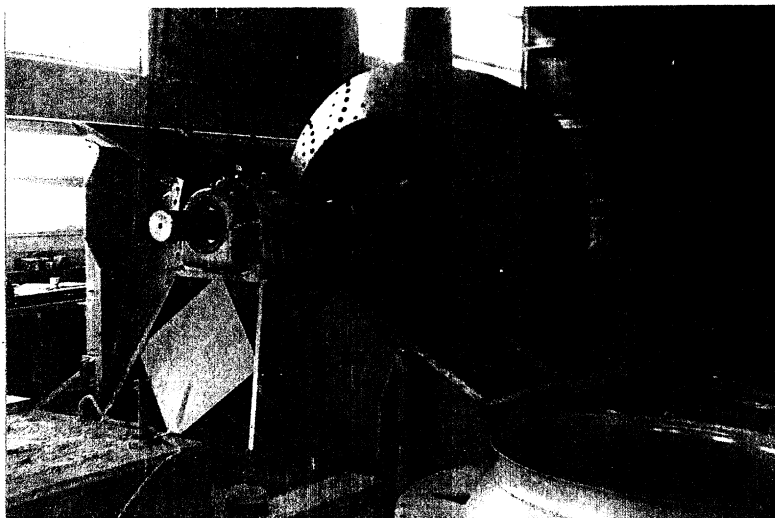


Figure 131

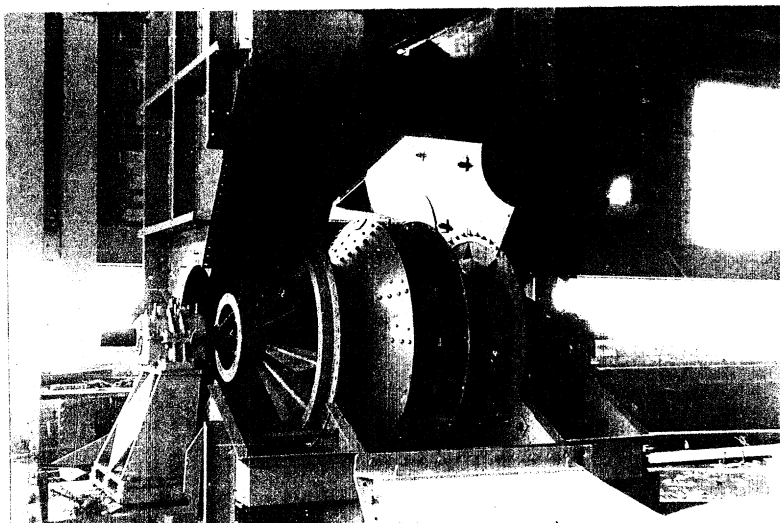


Figure 132



Figure 133

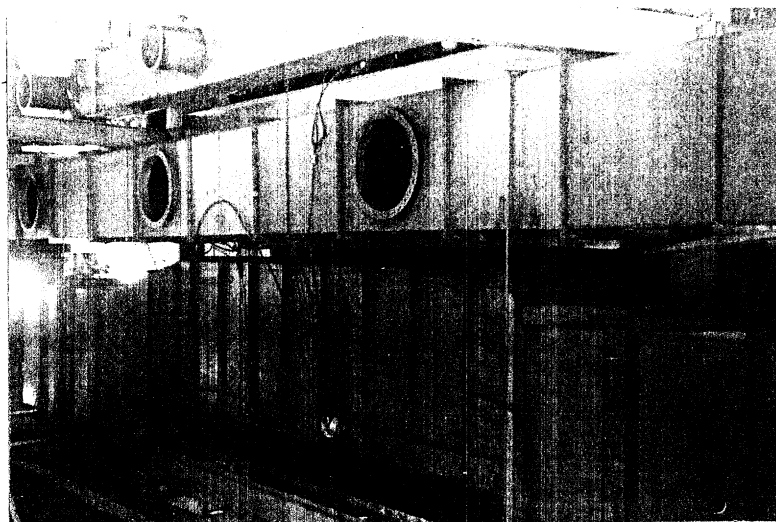


Figure 134



Figure 135



Figure 136

building frame. This aspect of the design is of particular importance and should be kept in mind throughout the discussions on the procedures in this section of the construction activities.

The first section of the condenser was raised into position as soon as it was received on the job, and the necessary piping was completed under the turbine section. There are several pieces in the condenser proper, but each of these is designed to be erected and jointed with a minimum of fitting, and had already been shop-fitted. Figure 135.

Very little of the auxiliary equipment for the turbo-generators had been started, but it includes the lubricating oil system, the condensate pumps, and the air ejectors. The condensate pumps are located in the area beneath the condensers, so will not be started until completion of the condensers. This location can be seen in the general layout plan of Figure 2.

#### Station Miscellaneous Equipment

There are two main items of the station service equipment that were constructed as soon as possible, so that they could be used during the construction of the rest of the station. The first of these was the large station air compressors which were constructed prior to the completion of the foundation and substructure work, in order that they could be used to supply all the air needed

during the rest of the construction activities. These were built on permanent foundations and were protected by temporary siding and roofing. Temporary piping was also installed to serve the entire station area including the temporary buildings where needed.

Since all concrete work had to be protected during cold weather placing, it was necessary to have live steam on the job from the early stages of the substructure work in October 1949. This was first supplied by a temporary boiler constructed on the outside of the building in such a way as to use the same stack system as would be used by the station heating and domestic boiler. This boiler was coal fired and can be seen by referring back to Figure 22. The stack has been removed in this picture, since it went through the wall and the siding could not be cut.

The station heating and domestic boiler was erected as soon as its foundations could be completed, since its use would eliminate the need for the temporary boiler. The main station heating boiler is oil fired and is pictured during construction in Figure 136. The boiler was completely insulated and piped prior to starting and was later protected by a temporary enclosure similar to that of the compressors. At full capacity operation this unit serviced the entire construction area with steam for heating and steam equipment operation. All the temporary buildings were heated and

likewise some of the important construction areas that could be enclosed. The main use was again for heating the concrete being placed throughout the station and yard areas.

The compressors for soot blowing and for air control are also included in this equipment but were not started until considerably later than the above mentioned equipment. These are all located in the same line in the boiler room but each is of a different design, so as to provide air at required conditions. The station compressors are the largest of the compressor units.

The service water and screen house pumps are also included in this equipment but had not been started at the time of this report. All minor equipment for the laboratories and shops should also be included, but this equipment will likewise not be installed until considerably later.

Figure 137 shows some of the equipment being raised through the boiler area for unit #2. The main rigging is from an air hoist located on an elevation higher than that at which the equipment is being landed. Several chain falls are being used in the process of pulling the box onto the floor level and to prevent it from swaying. This type of rigging was used on the majority of the hoisting work throughout the job, and several air hoists were constructed and maintained in favorable locations in the building proper.

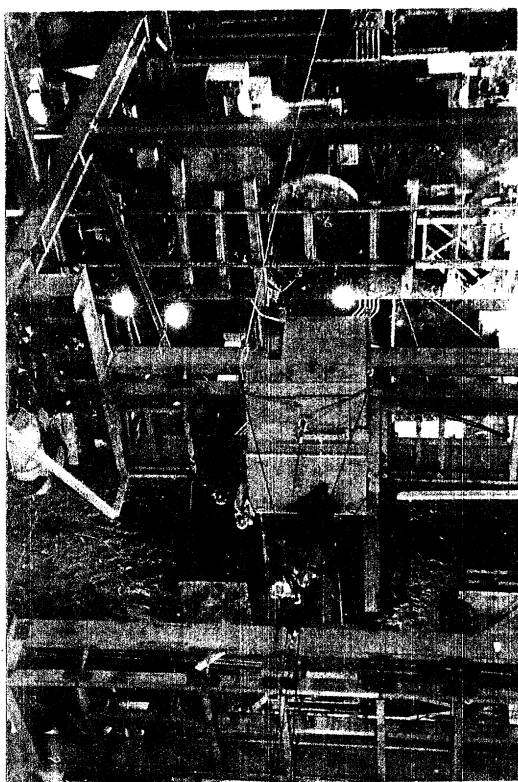


Figure 137

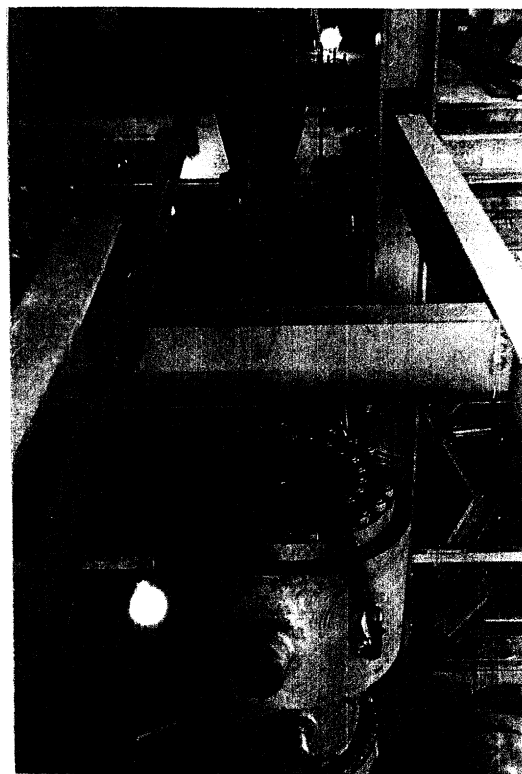


Figure 138

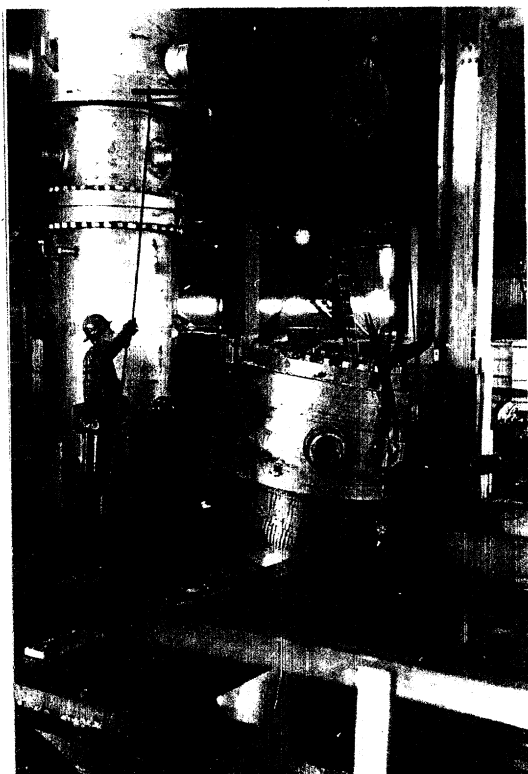


Figure 139

### Feed-water System

Most of the feed-water system will be discussed in connection with the heat cycle piping, but the other equipment shown in the Flow Diagram as included with this system should be mentioned.

The heaters and tanks were constructed first. All of the heaters in the heat cycle section were raised and erected one by one for the unit #1 section. The rigging details and erecting problems due to the closeness of the structural steel members are pictured in Figures 138 & 139. These tanks were raised directly from the floor below in one operation with the exception of the shifting and setting that was required after they were raised.

These heaters and the evaporators which are located on Elevation plus 16'-0" were all brought into the building and to their respective positions for erection on preconstructed platforms which were used to support the rollers under the equipment skids. Wooden rollers were used throughout these operations which are pictured in Figure 140. The evaporator has just been brought into the building and removed from its skids in this view.

The boiler feed-water pumps and drives are also located on the ground elevation and consist of three units for each boiler. These units are constructed on separate foundations, though each unit of drive and pump are



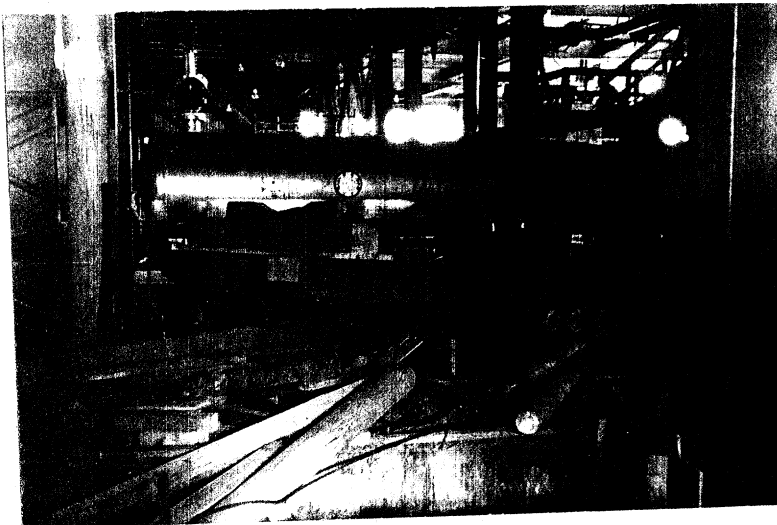


Figure 140

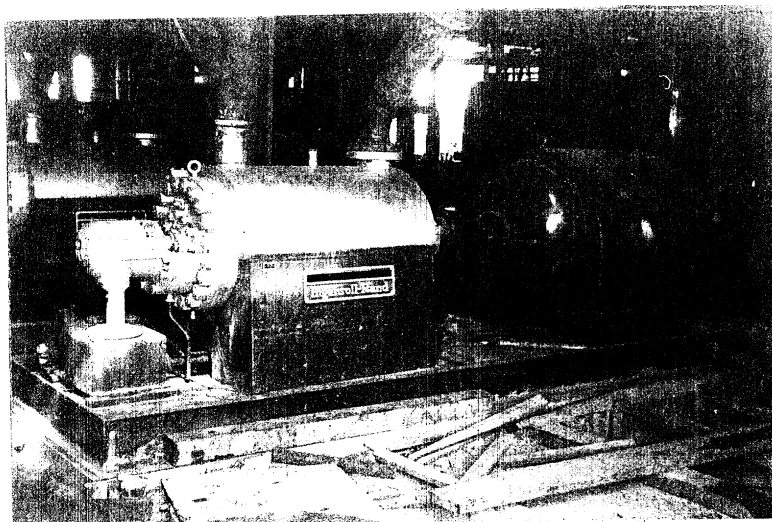


Figure 141

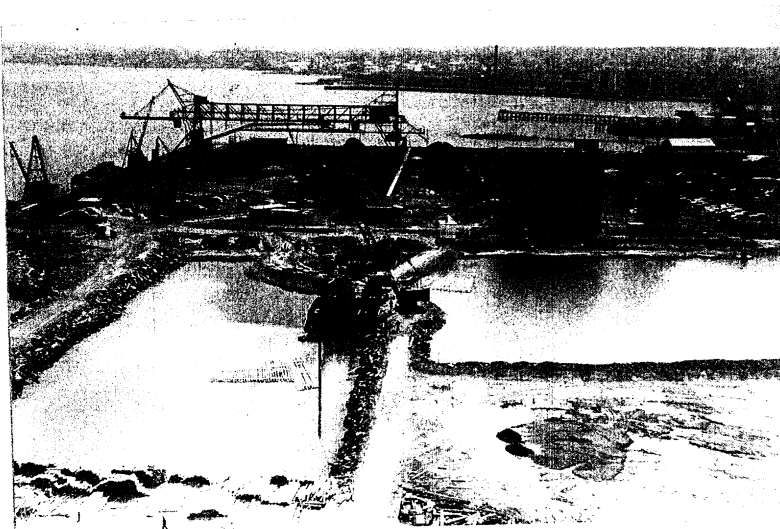


Figure 142

constructed together. Figure 141 shows one unit in position and partially piped for operation.

The feed-water treating system is located on the turbine side of the boiler room above the heat cycle piping. It consists of the storage tanks of which there are three for each unit, the softener, and treating tanks and the piping to the pumping system. The details of this section have been given with reference to its make-up and operation. As to construction, it should suffice to mention that the small units were hoisted as described, and that the large tanks for storage were erected on their foundations in sections and welded.

#### Coal and Oil Handling Equipment

The bunkers were constructed in connection with the structural steel and will not be discussed here. Of the equipment needed to fill these bunkers the exterior conveyors and equipment were started first. Most of this equipment is located on the terminal site, but the portion necessary for boiler operation will be discussed herein.

This entire system can be seen in construction in a view of the whole layout from about the building location at which the conveyors will enter the boiler room. Figure 142. All of this work is being constructed by the W. T. Donovan Company which has a job office on the terminal site as shown in Figure 143.

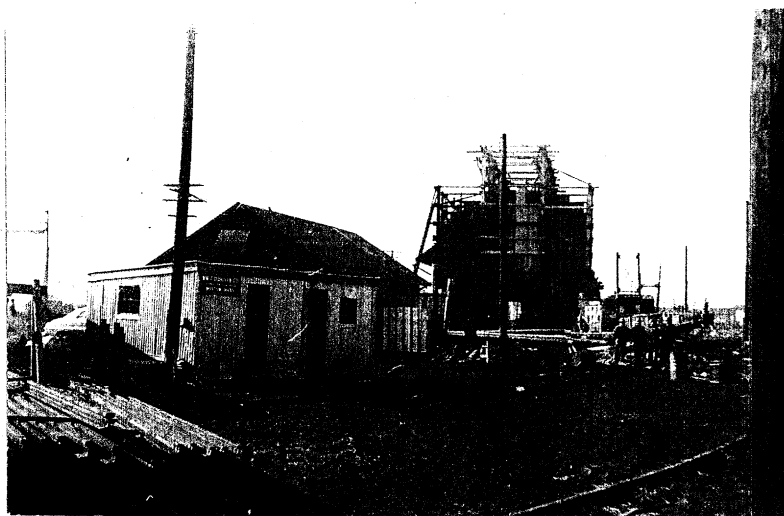


Figure 143

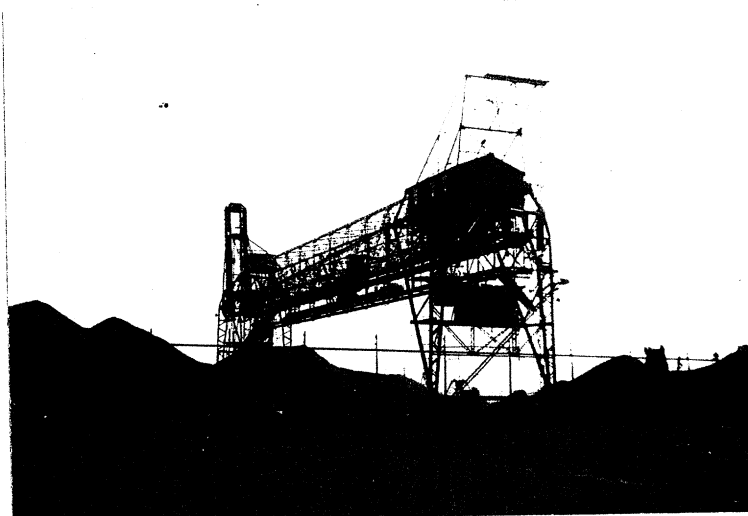


Figure 144

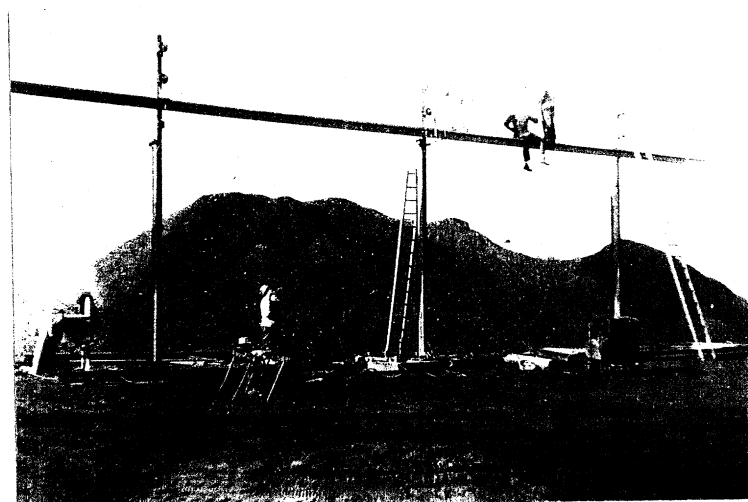


Figure 145

Tracing the coal from the unloading equipment at the wharfs, it will be first handled by the overhead gantry crane and loaded into a traveling hopper which feeds a traveling conveyor system. The gantry was existing equipment at the time of the beginning of construction activities on the exterior handling equipment. The gantry electrical system is being reconstructed in connection with the conveyor work at the north rail system. Figures 144 & 145.

The conveyor pit was constructed first at the station end of the coal storage areas. This pit serves to transfer the coal from one conveyor to a second which will lift the coal to the junction house. The transfer pit is constructed of reinforced concrete as shown in Figures 146 & 147. Figure 147 also shows the conveyor base completed and ready for the addition of the conveyor supports.

The rail system for the traveling hopper was constructed upon the completion of the conveyor base steel, and is shown in Figure 148. A close-up of the hopper as partially completed shows the main structure and make-up. The wheels will be similar to those used on the gantry crane. Figure 149.

The junction house will be the next main item in the system. It serves to separate the coal and to reload it on the proper conveyors for either the coal pocket or the bunkers in the station. The soil conditions required that piles be driven to support the building structure,



Figure 146



Figure 147



Figure 148

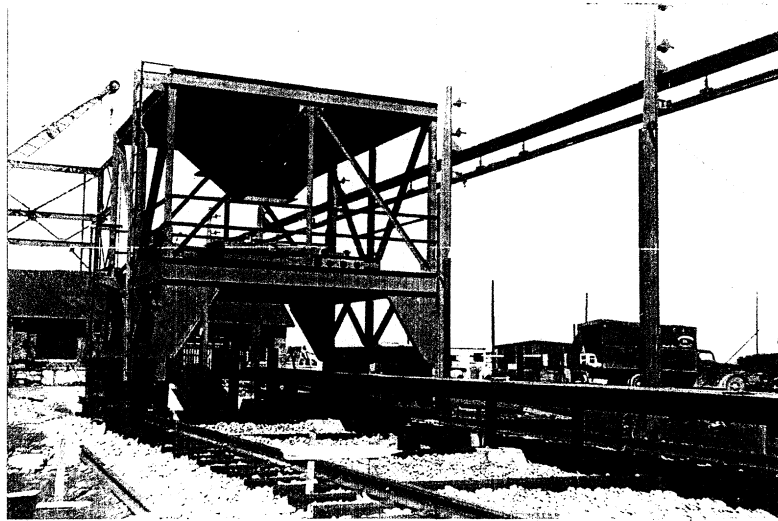


Figure 149

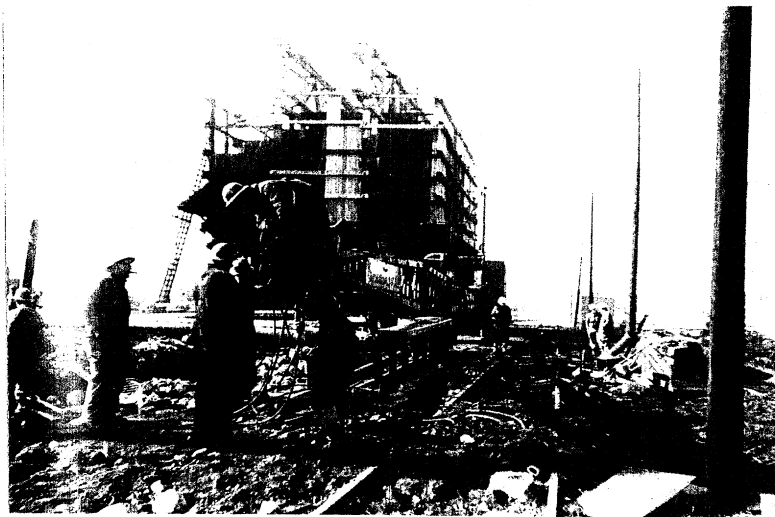


Figure 150

but the location of the water table was such that wooden piles could be driven in so that they were completely below the water table. The pile driving equipment and its use are shown in Figures 150-152. These piles were cut off and the area refilled so as to provide some support for the pile caps and foundation work. Figure 153.

The junction house forms and reinforcing were placed in a manner similar to that previously discussed. Figure 154. The steel work was erected by truck crane as shown, with the entire frame work being completed prior to the installation of any equipment. Figure 155.

The conveyor from the junction house to the station will pass through the Crusher House before starting across the cove. This crusher house is designed to crush the various sized coal to about the  $3/4$ " size that can be handled in the coal pulverizers. By crushing the coal on this side of the cove and before storing it in the bunkers, a considerable amount of the handling difficulties can be reduced or eliminated.

An earth dike was used in this case due to the shortage of steel piling, and since the permanent and auxiliary dikes already constructed could be used in part to form the enclosure. Wooden piles were also driven here, and the same equipment was used as on the junction house foundations. The driving was started before the dike was completed and the area pumped out. Several groups of piles were driven as shown. Figures 156-158.

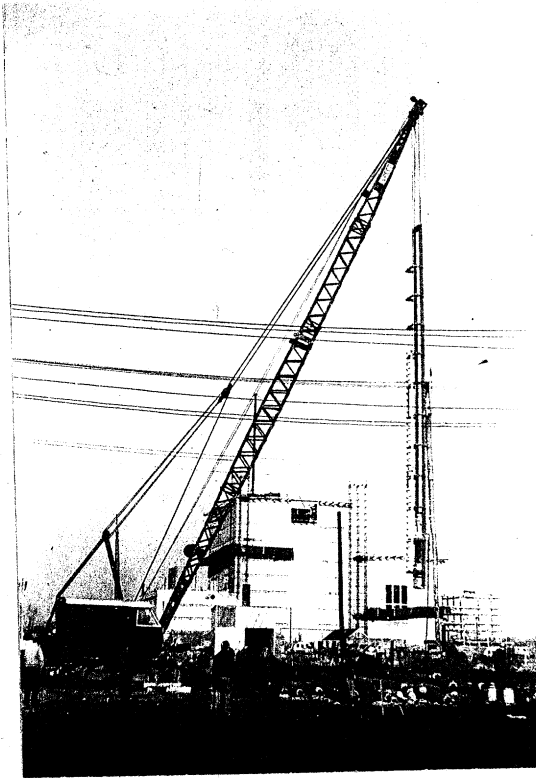


Figure 151

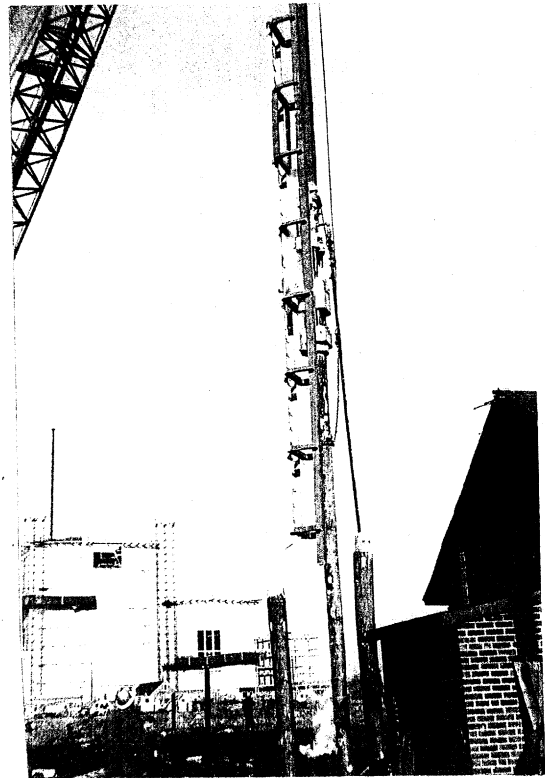


Figure 152



Figure 153



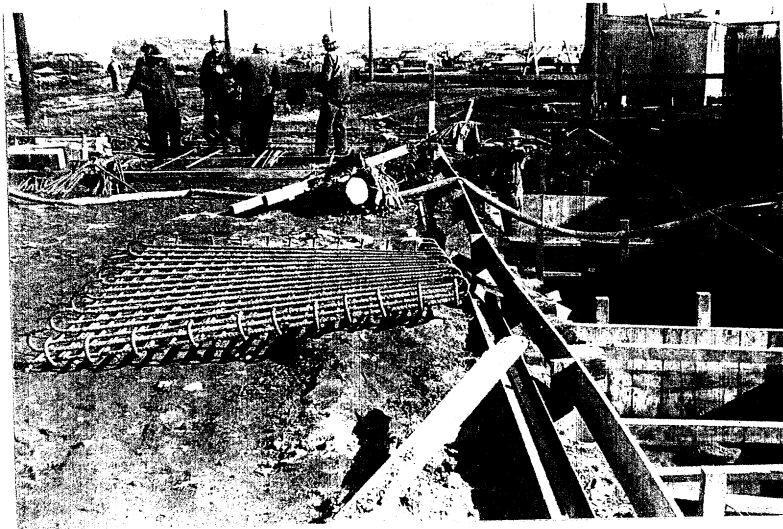


Figure 154



Figure 155

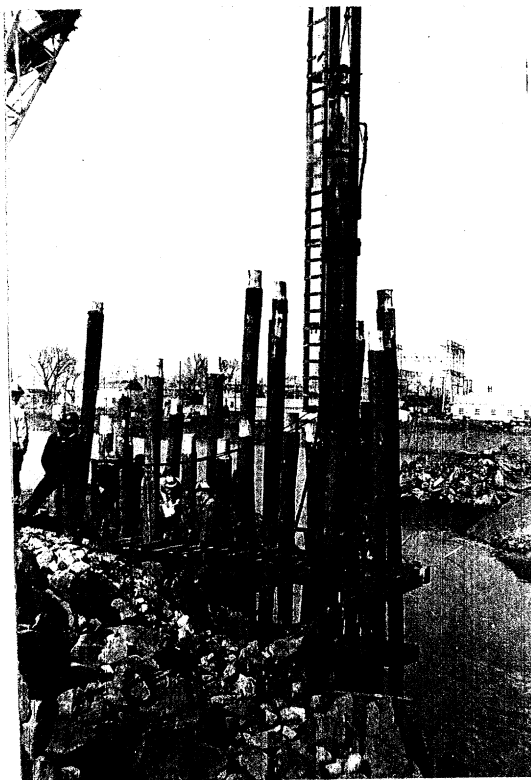


Figure 156

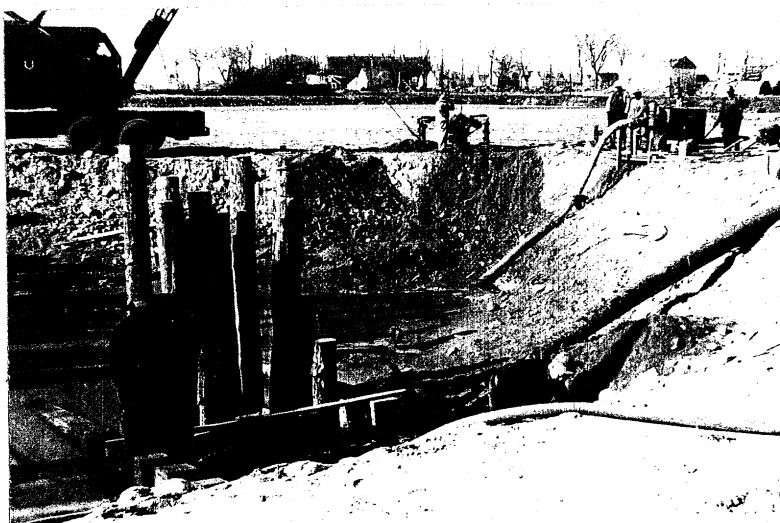


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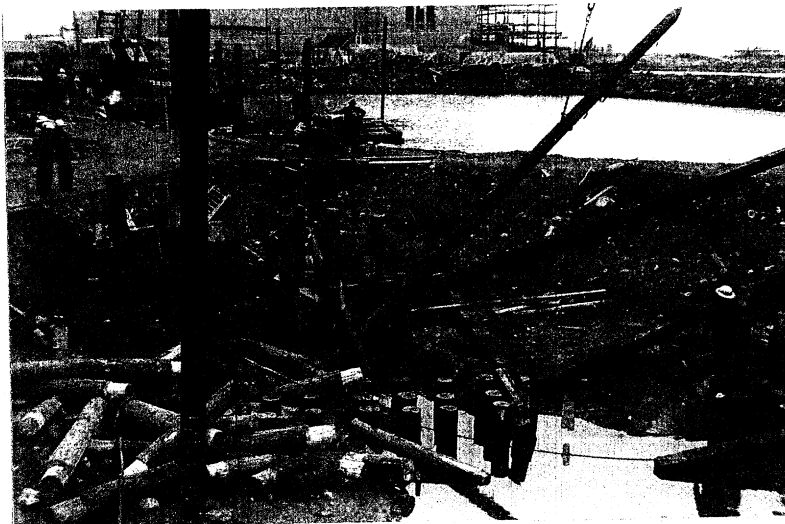


Figure 158

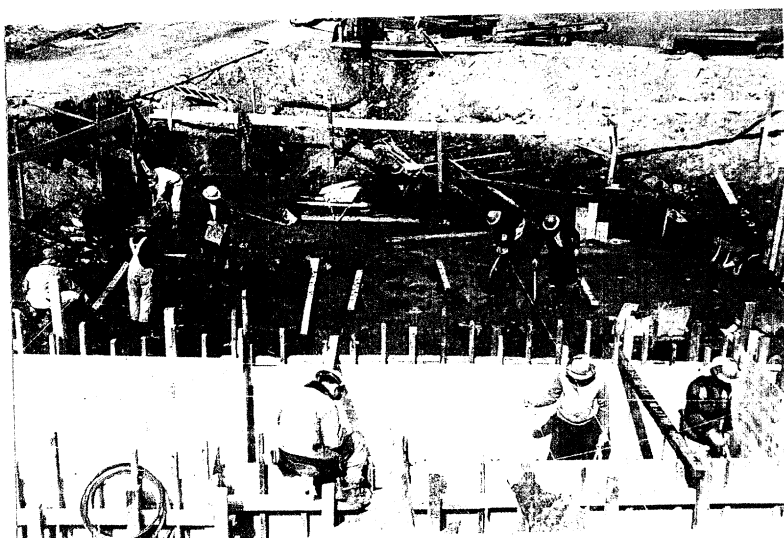


Figure 159

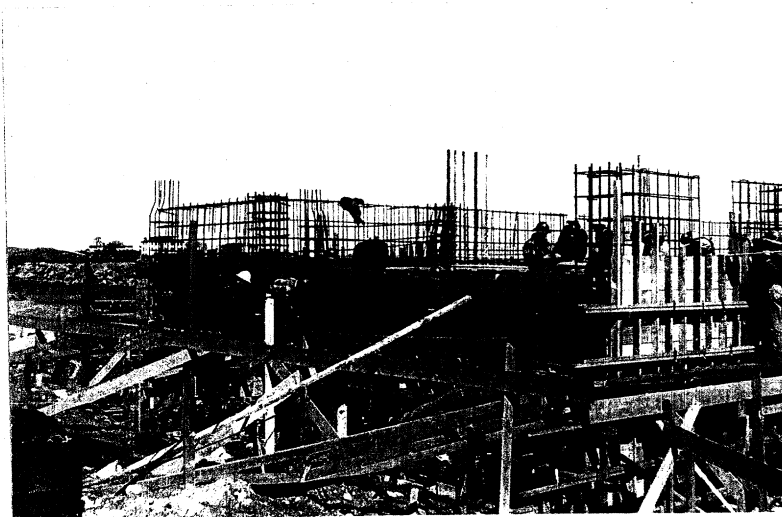


Figure 160

The forms and reinforcing details are also shown in Figures 159-161. Note should be made of the bracing details on the forms.

The remainder of the coal handling system is made up of the conveyors to the station and the hoppers used over the bunkers to make it possible to unload at any one particular section at one time. This section had not been started with the exception of the foundations for the conveyor supports. A temporary steel piling cofferdam was constructed around each foundation area so that the piling and concrete work could be completed. Frames were constructed to brace the sheet piling as it was driven, and double acting steam hammers were used for all driving. The equipment and frames are pictured in Figures 162 & 163.

The wooden piles were driven through the frames constructed for their bracing and spacing by the same equipment used previously. Figure 164. The close-up in Figure 165 shows the structure of the cofferdam and the framing used within.

The oil handling equipment being erected includes only the storage tanks, since the remainder of this equipment has yet to be started. All the oil storage facilities are located on the filled area of the cove. Some of the early rock and earth fill came from the excavation work in the station and yards, but the greater part had to be hauled in from off the site over a distance of about six miles.

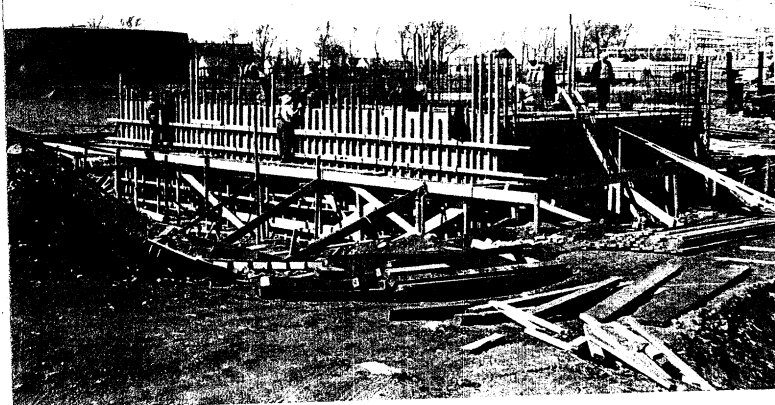


Figure 161

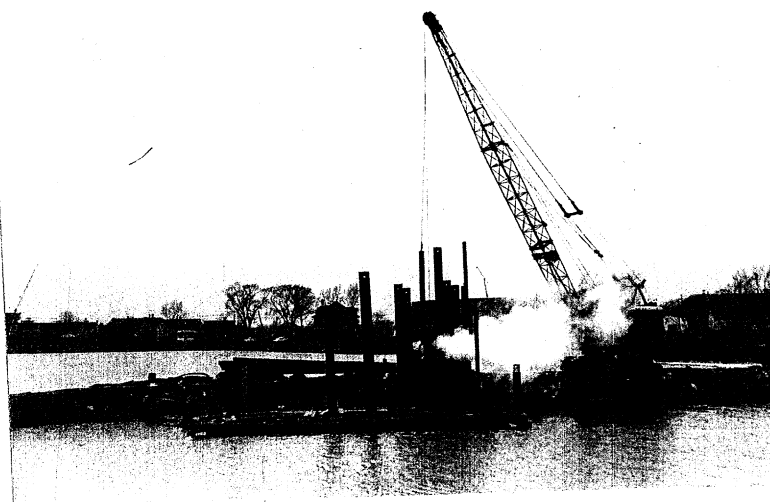


Figure 162

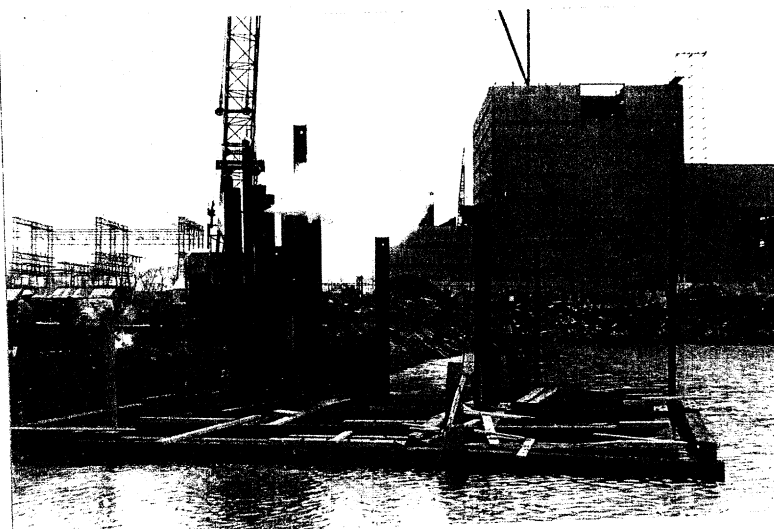


Figure 163

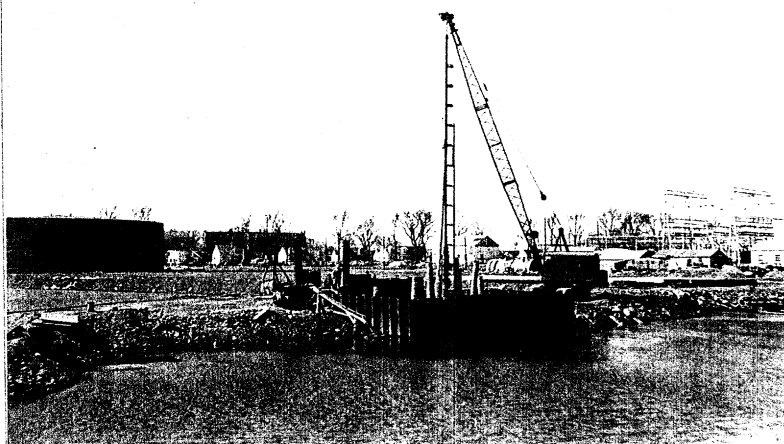


Figure 164

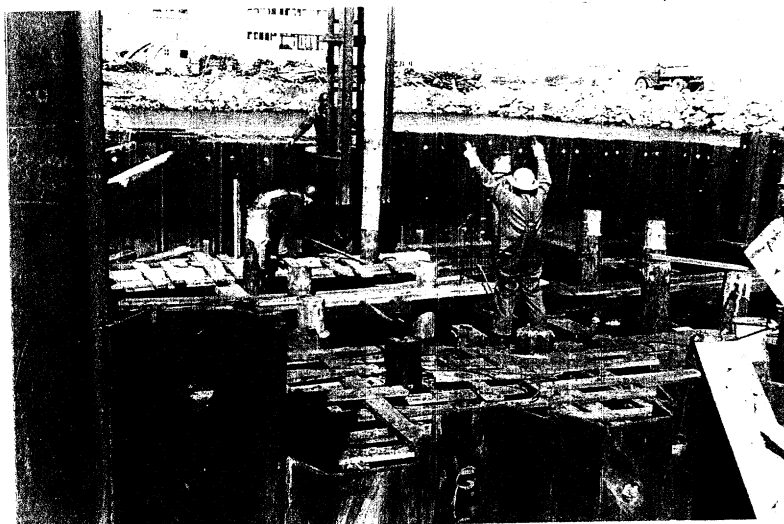


Figure 165

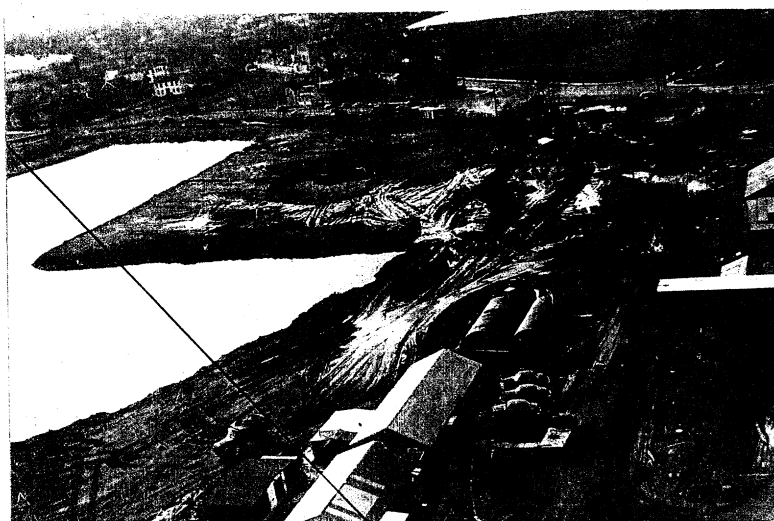


Figure 166

For this purpose about twenty trucks were kept on the road at all times between the supply and the site. The extent of this fill is shown in Figure 166. The entire area will be filled, with a small section above the auxiliary dam being left open to be filled with fly ash from the station.

One of the storage tanks was started as soon as weather permitted in the spring. The base was built up of a quarter million cubic yards of sand, packed and impregnated with heavy oil to ensure compaction and to help prevent rusting of the base plates of the tank. This 3" sand layer was laid on a 9" gravel base which was shaped in a 178'-0" diameter with a 1'-0" drop taper from the center out to the edge of the tank base and then tapering off to provide drainage. Figure 167 shows this base being rolled.

The tank is constructed of steel plates welded together to form the bottom, sides, and roof. The bottom plates are all 5/16" thick and are laid directly on the oil impregnated sand base and welded together with the exterior plates being cut to shape in the field. These plates are lapped and tacked first so that any distortions caused by construction loads and/or distortions can be eliminated before the welding is completed.

The sides are constructed of 5 eight foot rings which vary in thickness according to the following:  
#1 - 1.0", #2 - 0.80", #3 - 0.59", #4 - 0.38", and #5 - 0.25".  
These are all welded together by double "V" vertical joints



Figure 167



Figure 168



and double bevel horizontal joints. The vertical joints require four weld passes on each side and must test for full penetration. These members are erected by use of an "A" Frame crane which is pictured in Figures 168 & 169. Each ring is erected and welded before the next is started.

The roof section is constructed in the same way as the bottom and is supported by an interior column system made up of two rings and a center column. Girders join the tops of these columns and beams are used to support the roof plates from the sides to the girders, girders to girders, and girders to center column plate support. The construction of these members is shown in Figures 170-172. A curb angle will be used to complete the join between the sides and the top plates. The roof plates and vents are shown in Figure 173.

Figure 174 shows the stairs to the roof section and the depth gauge holes. This stairway is welded, cantilevered to the side of the tank for its entire length.

This tank had to be constructed according to the American Piping Institute Specifications for Welded Oil Storage Tanks. This requires that the bottom and roof plates be vacuum tested with soap and water and that the entire tank shall be tested with a water hydrostatic test.

#### Ash and Dust Handling Equipment

The greater part of this equipment will not be constructed until the completion of the boilers. The ash

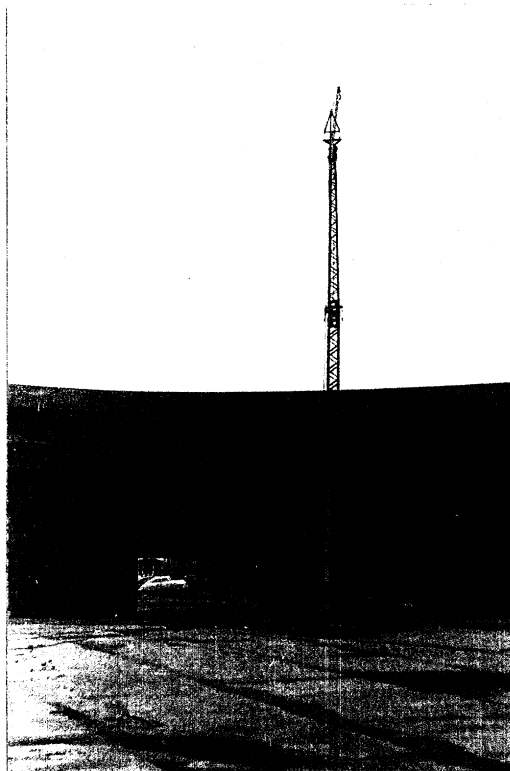


Figure 169



Figure 170

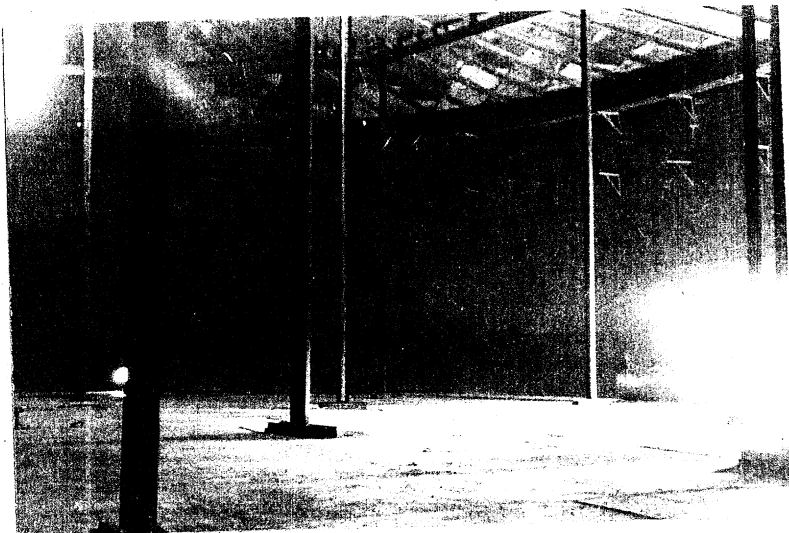


Figure 171

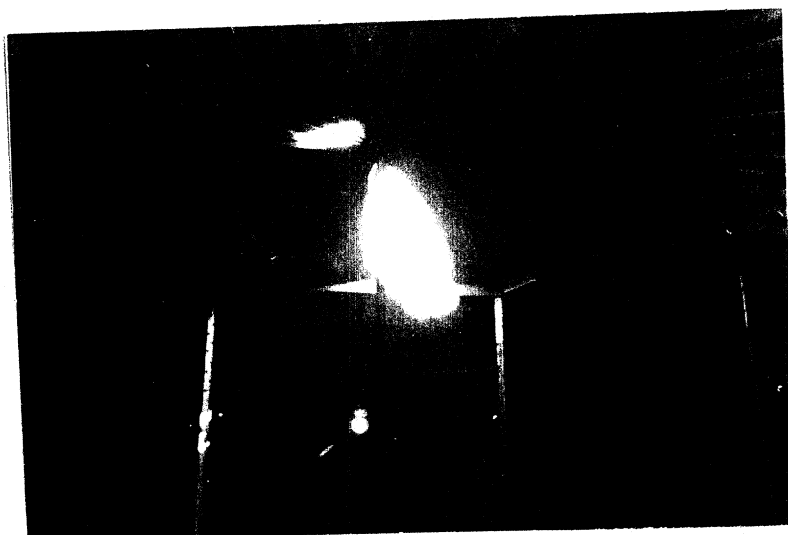


Figure 172



Figure 173

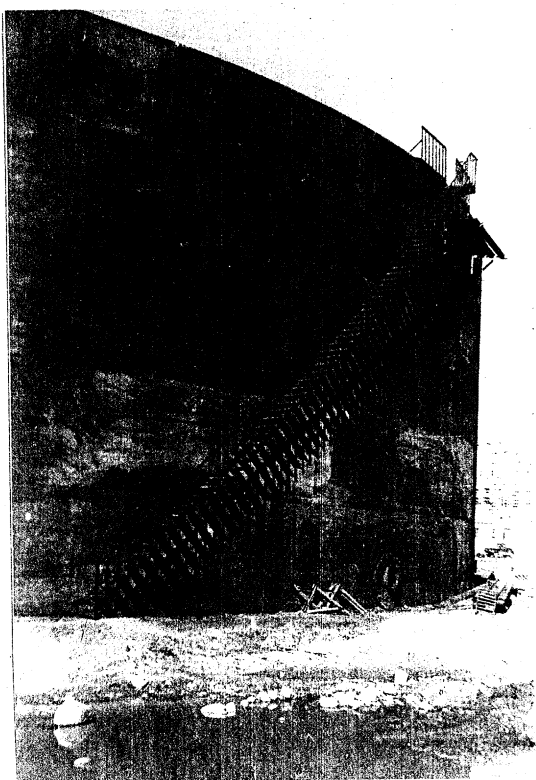


Figure 174

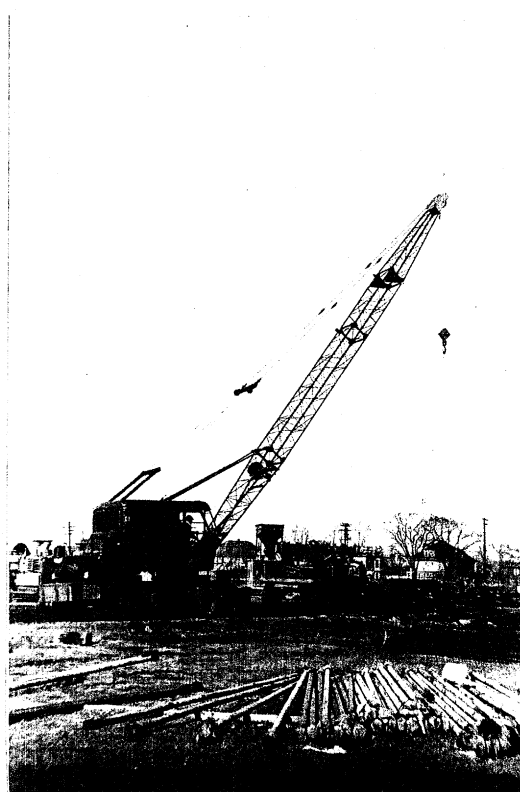


Figure 175

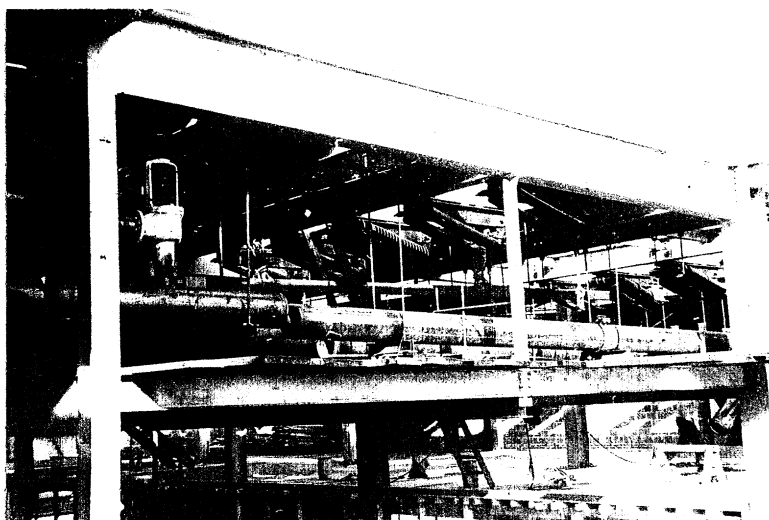


Figure 176

hoppers are located at the bottom of the boiler sections so that all fly ash can be collected below the fire boxes.

The dust handling equipment has been discussed in connection with the dust collecting system in the fan house section.

### Piping

All of the piping work is being erected by the Hartwell Company in accordance with standard piping specifications. This piping includes that for the main steam and reheating, condenser circulating water, power control, boiler feed, bleeder steam, and condensate, and all insulation and instrumentation required.

All of the piping was first received at the terminal storage areas and sorted according to fabrication sketches there, so that the pieces could be brought over to the station as needed during construction and could be erected directly without further storage. All of this hauling was handled by one truck by careful planning of each trip. The pipe was loaded and unloaded by means of truck cranes, or other equipment available in the case of unloading at the station. Figure 175.

Construction scheduling was geared essentially to the materials as they arrived on the job, and pieces were erected in part as they were received. Though this quite often left pieces hanging in the air unconnected at either end, it did get as much of the piping in position and in

the hangers as possible in the time allotted. As more of the pieces in a certain system were received the work was tack welded, and upon completion of the entire system the final welding operations were completed as scheduled. All of the welding was done with about 25 welding machines and 3 operating stress-relieving units similar to those discussed in connection with the boiler welding.

The main steam and reheat piping runs from the boiler to the turbine sections and return for reheating. This is the main piping in the station and is constructed, as indicated under the discussion of the subcontract on piping, of thick wall pipe requiring the strictest supervision during construction and welding. All welding must be done continuously through the preheating and stress relieving cycles. The hangers were erected from the supporting steel above the area between the boilers, and the turbine and the piping was erected within these hangers as soon as possible. Figure 176 shows one section of these hangers in position and the piping set in temporary hangers ready to be connected. An indication of the relative weights of the various piping can be obtained by reference to the relative sizes of the hangers. The main steam valve and the type of elbows used on this 2" wall piping are shown in Figure 177.

The boiler feed piping includes all of the pipe work between the pumps, treating systems, heaters and the

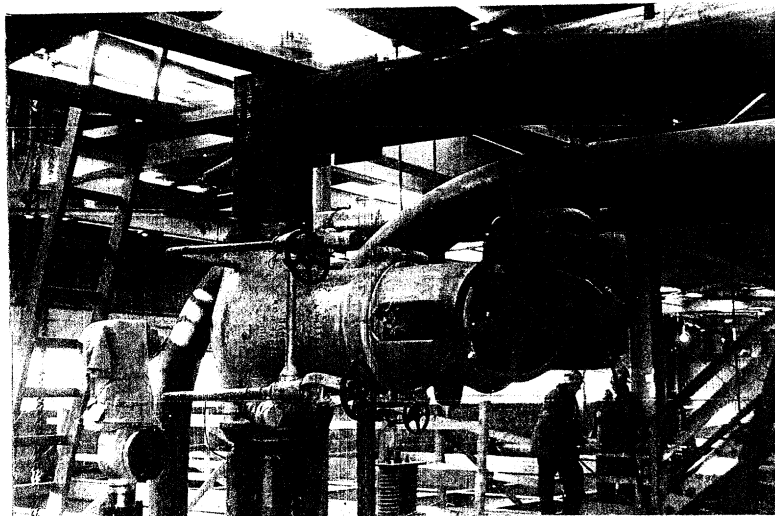


Figure 177

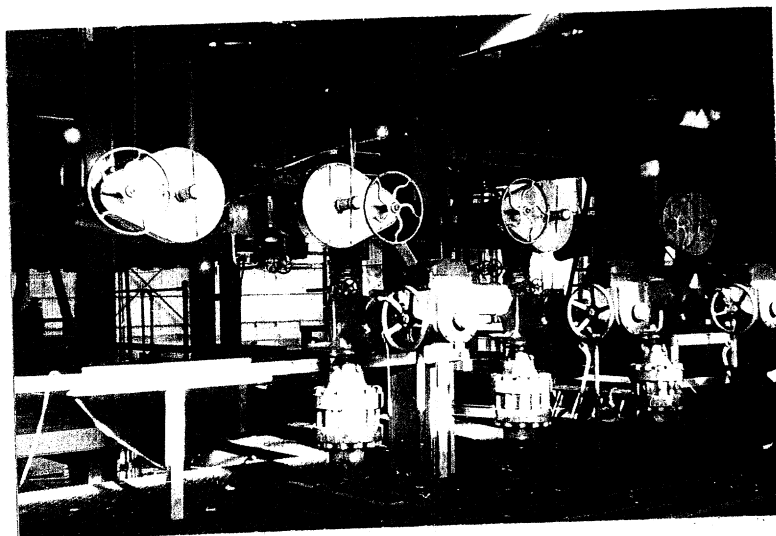


Figure 178



Figure 179

boilers. This includes the heat cycle piping at the closed feed-water heaters. All of this piping will be constructed as discussed and will be completed and tested as the fabricated pieces arrive and are erected.

The bleeder steam piping runs from the stages of the turbine to the heaters and de-aerator and carries the partially used steam and condensate. The condenser circulating water and condensate piping includes that from the condenser hot well back to the #6 stage heater and any auxiliary piping in connection with this operation. All of this piping will be erected in sections and welded according to the specifications given. Figure 178 shows a typical view of piping and valves with the necessary hangers and supporting members.

All insulation will be put on after the completion of each of the systems and will be composed of high temperature and/or magnesia pipe covering sections. This will be covered with sewn canvas or, if there is danger of fire, it will be covered with asbestos.

#### Electrical Work and Yards.

It becomes necessary to go back to the early stages of the job to discuss the construction of the yard work and the electrical facilities in the yards.

The actual yard work started with the construction of the temporary access road to the various sections of the job site. These roads were originally leveled dirt but were



treated and graveled after the rain in the spring. During the initial blasting and excavation work, preparations were made for grounding and laying the conduit and cable ducts. The duct manholes and stack foundations were also constructed during the early concrete work.

All the sewer and drainage systems were installed throughout the yards and where needed around the building. The sewers included are the 48" city sewer extension and the sanitary sewers for the station. The fire protection piping and the city water supply lines were also laid during this work.

The blasting operations continued in connection with the yard work long after most of the steel and concrete work had been completed. Heavy steel nets were used to prevent flying particles and blasting damage during these operations. These are pictured as used in Figure 179.

The greater part of the excavation work was done by truck cranes loading into trucks which hauled the dirt and rock away. Some air hammer work was required in connection with the large rocks and boulders in the area, but these could usually be broken up and required little blasting. Figures 180 & 181.

The piers and column bases were laid out and constructed in connection with the support foundations for the electrical equipment. These forms and a portion of the completed work are pictured in Figure 182.

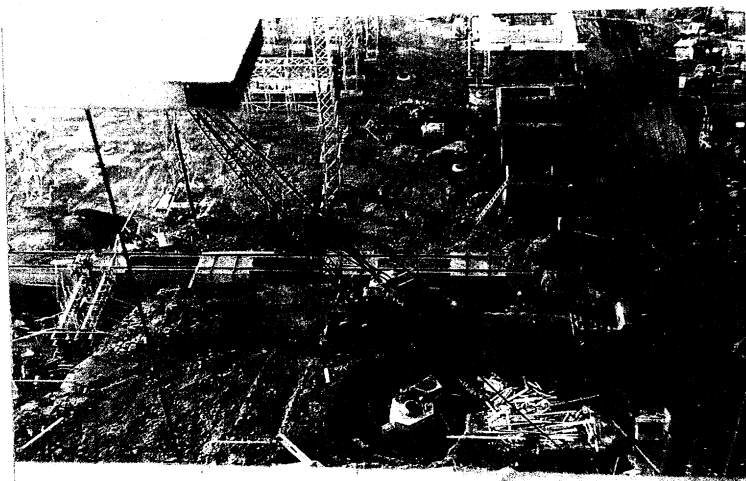


Figure 180

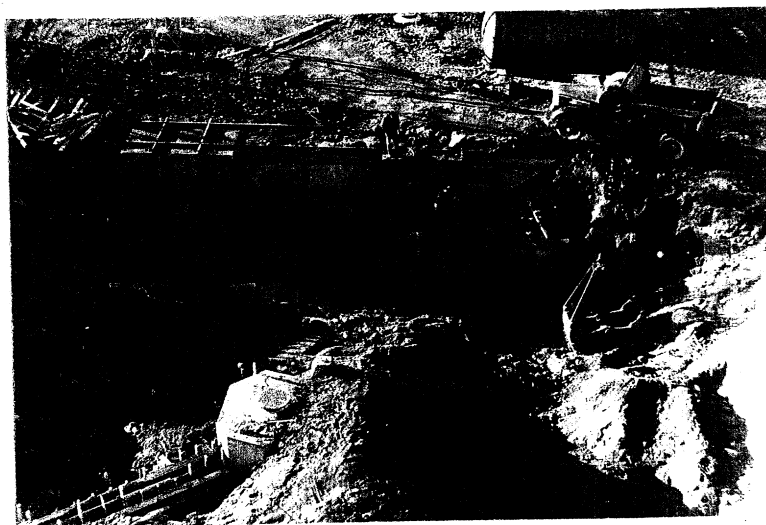


Figure 181

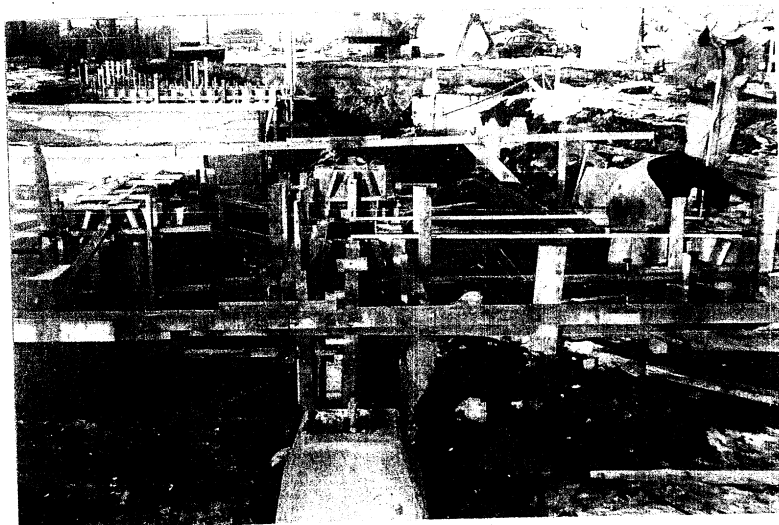


Figure 182

All of the electrical steel was constructed by the electrical workers on the foundations and piers provided by the United Engineers. These structures support the switches, breakers, and buses of the electrical yard systems, and will be pictured later in general views of the yards.

One of the heaviest and largest pieces of equipment in the electrical yards is the main station transformers. These are oil cooled transformers and require cooling oil piping. A system must also be provided to enable them to be moved out of position and replaced, should repair and maintenance be required. A rail system was designed and erected to accomplish this purpose. Each of the transformers is set on wheels on this permanent rail system and can thus be rolled out of position and back onto a main line, replaced and moved out of the way for work. Figure 183 shows a detailed view of the cross switches. These transformers were shipped to the site on low bed trailers, and were removed from these directly onto the rail systems. They were all shipped with the oil cooling fins removed, so as to make the base unit as small and as light as possible. The rigging used to transfer these units to the rail system is pictured in Figure 184.

The station service transformers were shipped and unloaded in a similar way, but in this case they are set directly on their foundation bolts. The steel was erected around the units after they were in place. Figures 185-187.

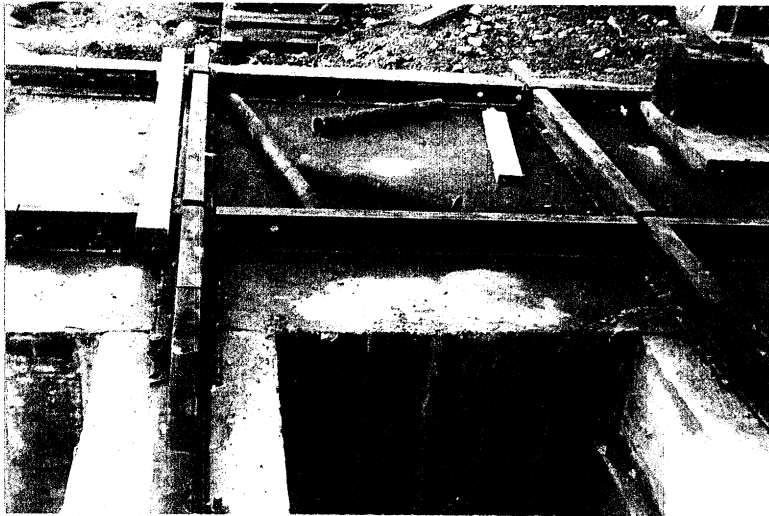


Figure 183

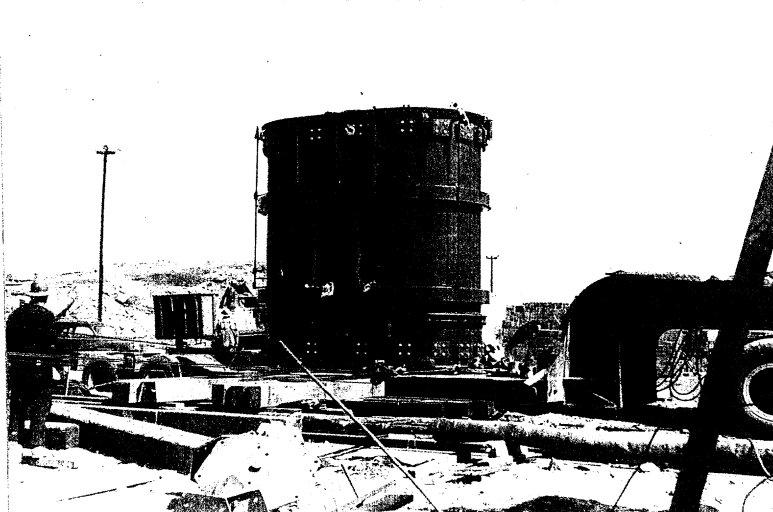


Figure 184

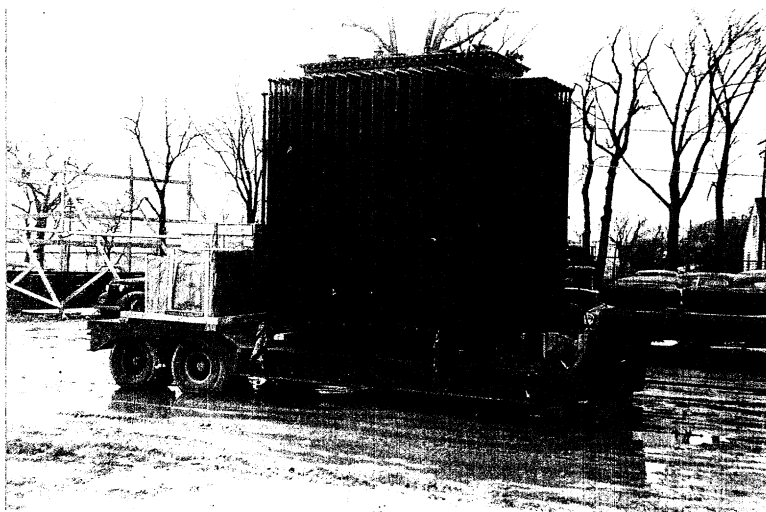


Figure 185



Figure 186

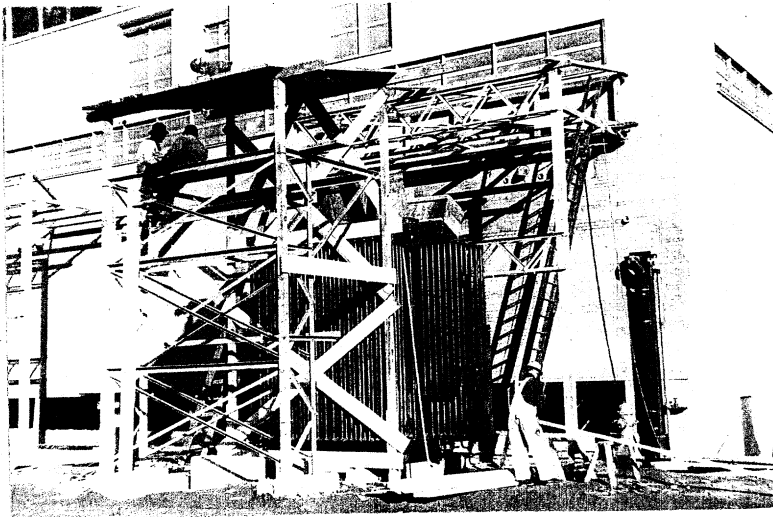


Figure 187

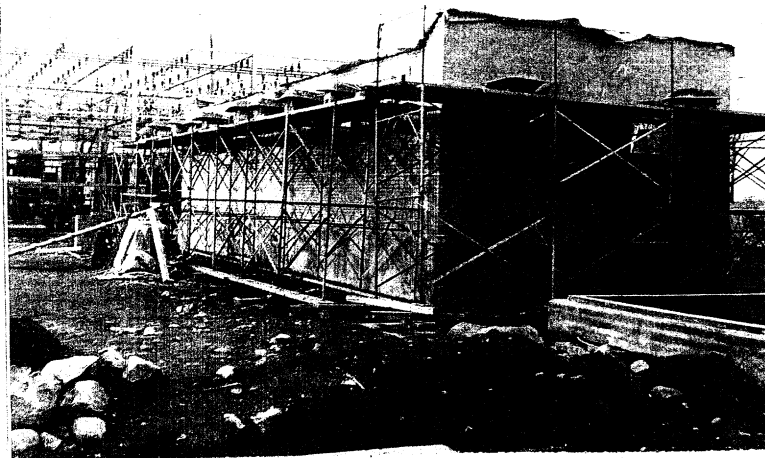


Figure 188

All of the electrical work is scheduled to be completed by working first on the foundations and duct work, then continuing with the conduit runs, manholes, 2300<sup>v</sup> yard, and finally the 115<sup>kv</sup> yards, completing the work towards the station last with the connection of the station service transformers.

The yard work also includes the piping and pumping equipment for the cooling oil for the transformers and oil equipment. This equipment and the steel work is pictured in the rest of the views of the yard work. Figures 188-191.

The final phase of the yard work will be work on the grounds removing extra soil, filling in some areas, and general leveling. About three feet of rock and earth still had to be removed from the area between the temporary buildings and the station proper to bring this area down to grade. This was started after most of the heavy equipment and installations were made on that side of the building. These last leveling operations required some blasting, but most of the rock could be broken up with the heavy shovel used. Figure 192 shows the shovel in operation on the excavation in this area.

#### Terminal Equipment

The section which remains to be discussed is the improvement and reconstruction work being carried on at the terminal site in connection with the coal pocket and

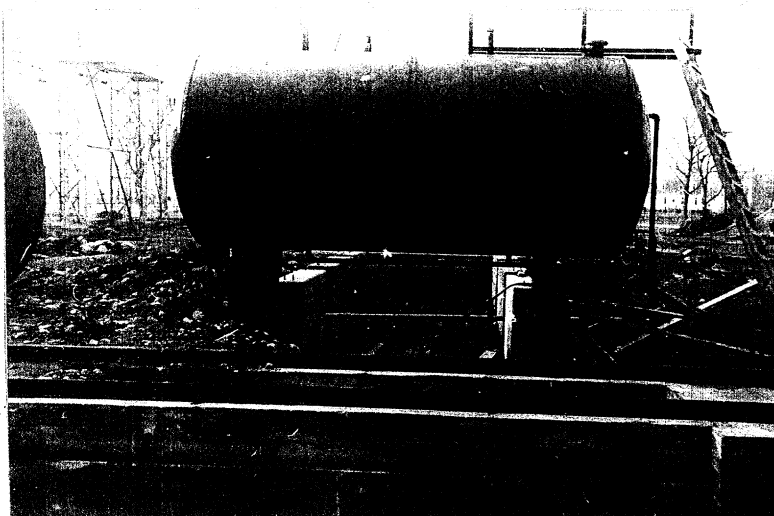


Figure 189



Figure 190



Figure 191

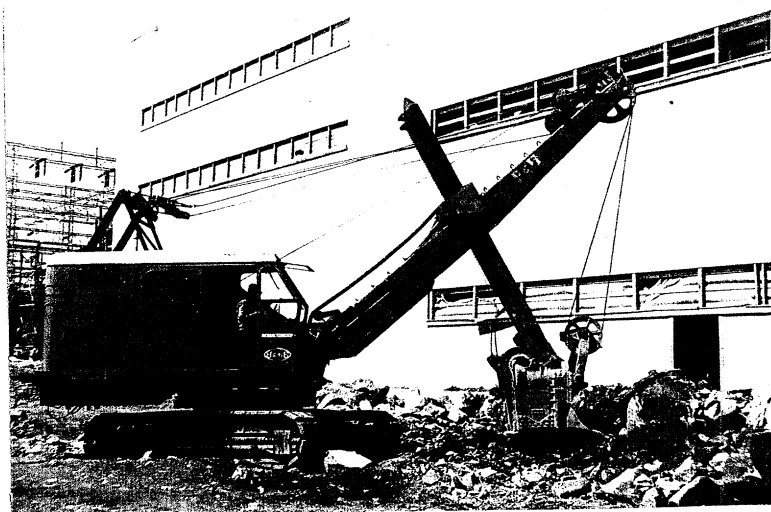


Figure 192

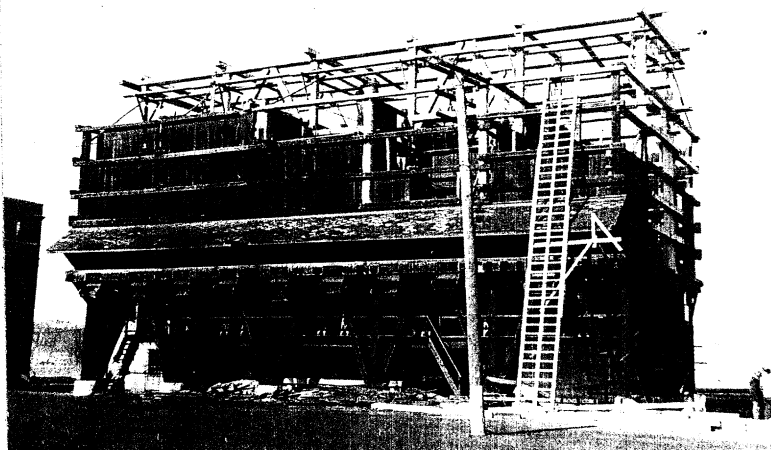


Figure 193

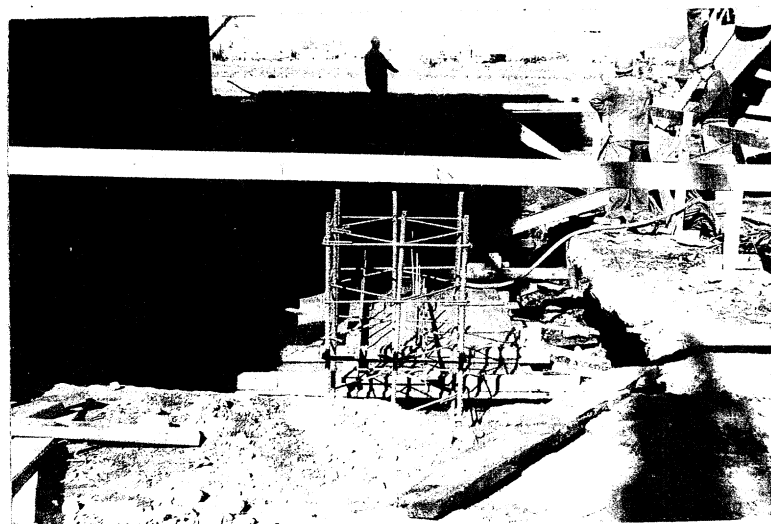


Figure 194



the wharf system. The coal handling system up through the junction house is common to both the station coal handling equipment and the coal pocket equipment which is used for commercial distribution.

The junction house will feed the coal from the supply conveyor to the pocket conveyor as well as to the station conveyor, so that it is merely a matter of switching to fill the pocket. This conveyor from the junction house raises the coal to the top of the coal pocket where it passes along the top of the various bins.

A fire in the coal pocket made it necessary to reconstruct a large portion of the equipment also. This reconstruction is shown in Figure 193. The new conveyor equipment required new foundation supports, and a new system for separating and unloading at the top of the bins. The support foundations were constructed between the pocket and the junction house. Figure 194. The steel sections of the new top for the pocket are shown in Figure 195. There will be a traveling hopper constructed similar to those used over the bunkers to unload the coal at any particular section of the bins.

The reconstruction of the wharf facilities at the terminal is being carried out in order to modernize this equipment and make it possible to handle the largest ships now used to carry coal and oil. All of the work on the wharf is being done by Marrit, Chapman, and Scott Company.



Figure 195

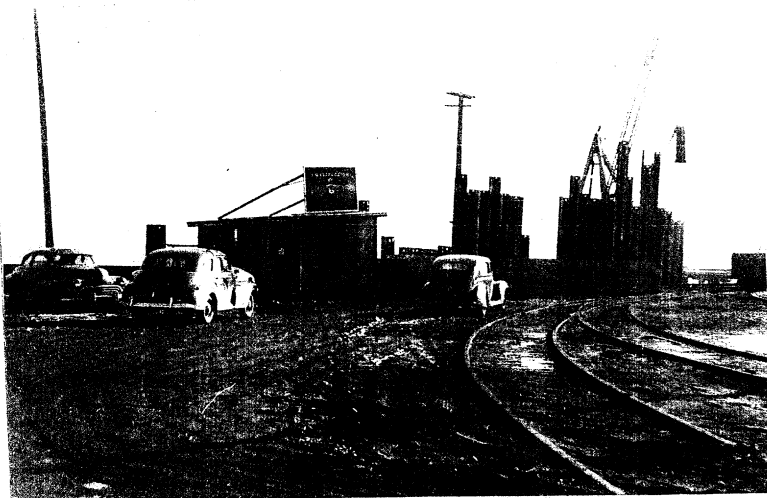


Figure 196

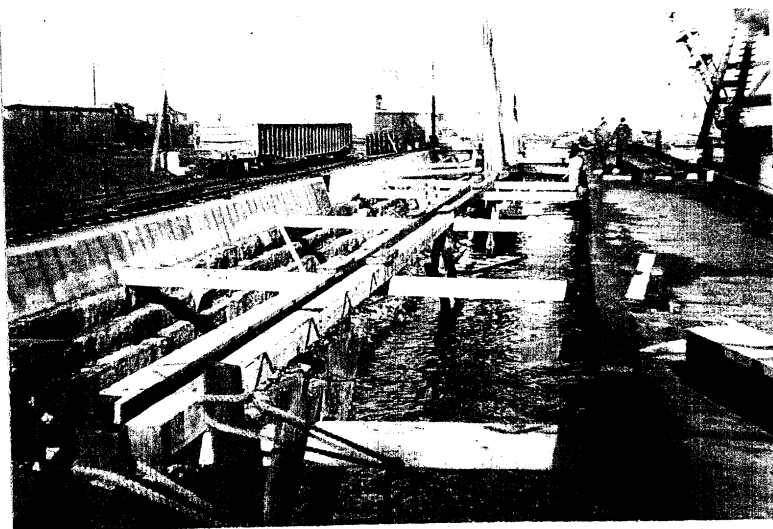


Figure 197

The general layout of the construction area is pictured in Figure 196. Note that the piles and "H" sections are unloaded directly from the freight cars to the area between the tracks and the wharf, where they can be reached with the equipment driving the piles.

The old wharf section was left intact so that it could be used both for tying the floating construction equipment and for bracing the new sheet piling during driving. The general shape and size of the bracing used is pictured in Figures 197 & 198.

The piling being used is "Z" type, which is the strongest of the shapes used in steel piling work. It is driven one section at a time, as shown, with a double acting steam hammer which is rigged to a floating crane. This equipment in operation is pictured in Figures 199-202. The steam hammer and anvil used to drive the piling is shown in a close-up in Figure 202.

Steel "H" sections were used to brace the piling as explained in the section on design. These were driven after the completion of a large section of the piling. The slope and the details at the dolphins are shown in Figures 203 & 204. These "H" sections were driven with the same type of hammer, except that in the case of the batter piles, a casing was required to direct the blow of the hammer, since it could not be in a vertical plane. This is shown in a close-up of the hammer, Figure 205.

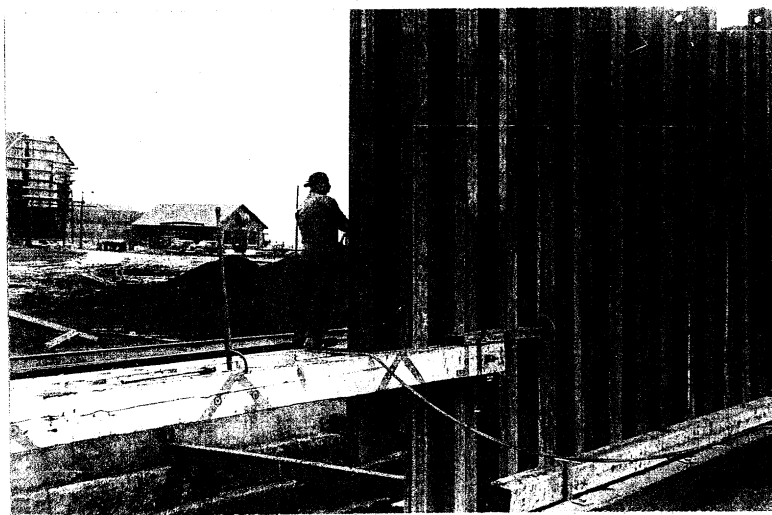


Figure 198

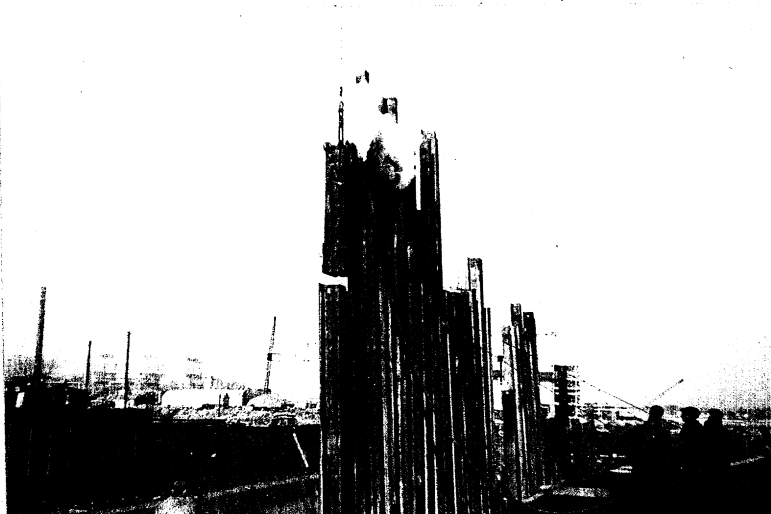


Figure 199

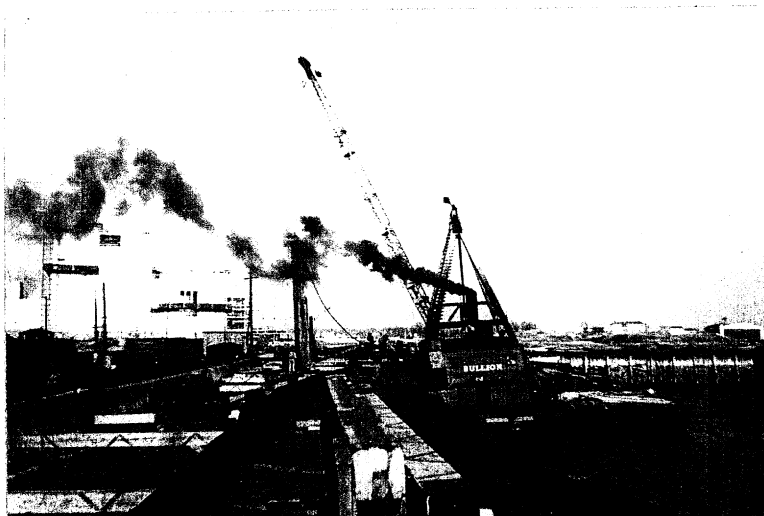


Figure 200

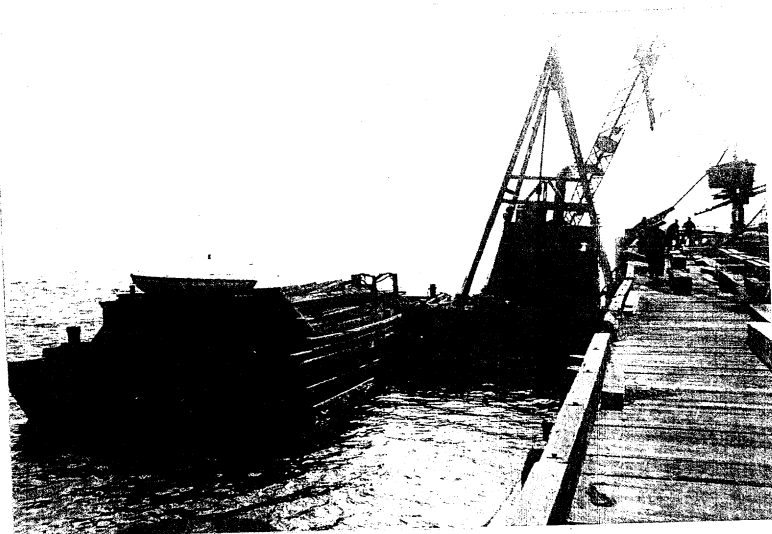


Figure 201

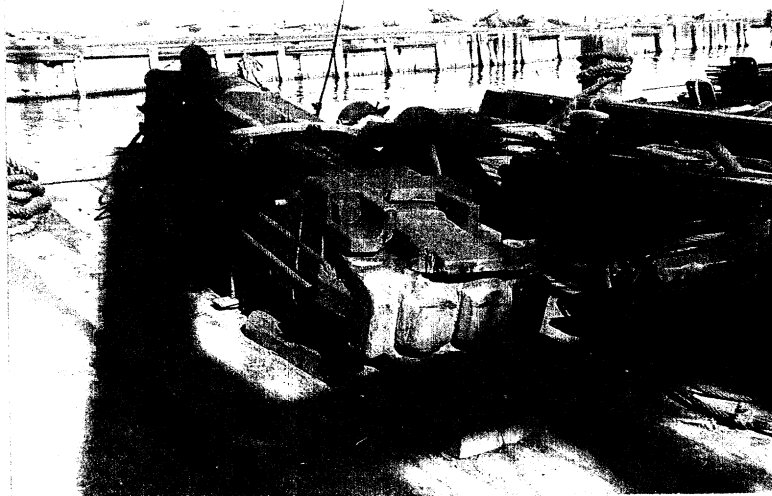


Figure 202



Figure 203

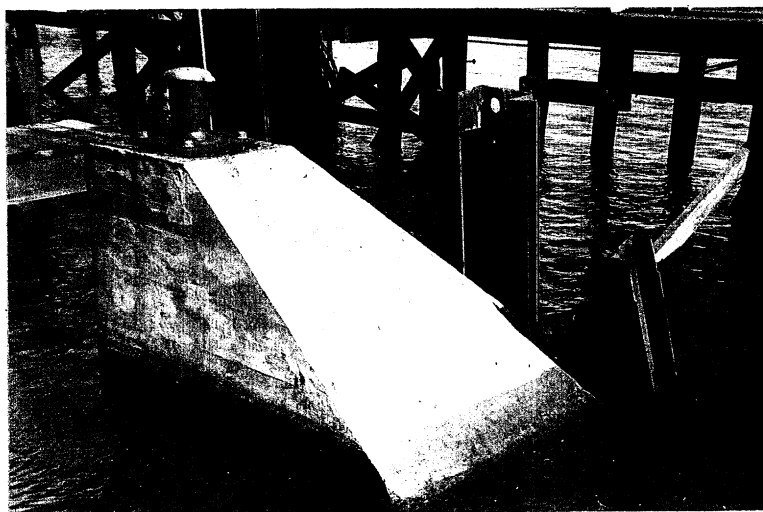


Figure 204



Figure 205

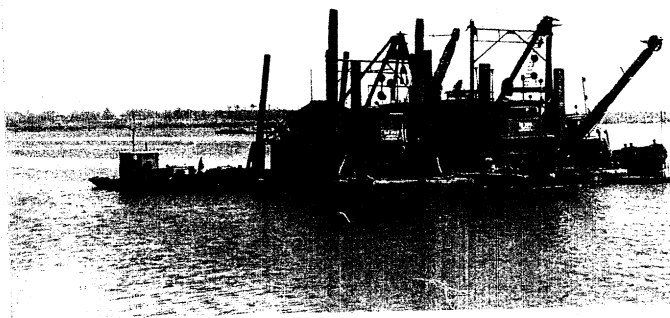


Figure 206

After the completion of the bracing of the new wharf section, the area will be ready for dredging. This will not be started for quite some time, but the dredging equipment that will be used in the wharf area and also in all probability in the area near the screen house is pictured in Figure 206.



### CONCLUSION

In the opinion of the author a great amount of both background knowledge and actual operational experience has been gained in the time spent in preparing this thesis. The project chosen has offered excellent facilities for familiarization with the job organization, management, and construction procedures. A great number of different design and construction problems have been encountered. To see these problems solved in the field by the field engineering and construction forces has given the author a vast amount of information.

The specific organization and management procedures used on this project may never be followed again, but they will provide excellent background for experience of how one system has been set up and used. The advantage and disadvantages of that system as they have become apparent during the operation and functioning of the job. The specific procedure may likewise never again be used since every construction project presents different problems with relation to how the job must be set up and how the work must be completed. Information so obtained will provide background reference as to how certain specific or related problems have been handled and could provide one method of handling similar problems in the future.

The author feels that this thesis has been a very worth while project and that he has made vast gains to understand the practical application of building construction in the field of his principal interest.

APPENDIX A

## Sample Forms Used in Engineering Control

The Thompson & Lichtner Company, Inc. has exercised control only over the concrete mixing and placing on this project. Sample forms that have been used in taking data and in reporting test results in connection with this activity have been included herein.

Other sample forms that are used in connection with control of the other construction activities have also been included for future reference.

THE THOMPSON & LIGHTNER CO., INC.

ENGINEERS  
BOSTON, MASS.

FILE NO. \_\_\_\_\_

REPORT NO. \_\_\_\_\_

SHEET NO. \_\_\_\_\_

PROGRESS REPORT \_\_\_\_\_ 19 \_\_\_\_\_

OF  
AT  
FOR

Certified Correct

THE THOMPSON & LIGHTNER CO., INC.

*THE THOMPSON & LIGHTNER CO. INC.~CONCRETE CONTROL*

PLANT. _____	DATE. _____
PROJECT. _____	CLIENT. _____
LOCATION. _____	
OPERATOR. _____	
INSPECTOR. _____	
ARRIVED. _____	
DEPART. _____	
INSP. START. _____	
INSP. END. _____	

<u>ORDER:</u>	WEATHER _____ CEMENT. _____  SCALE CH. _____ ORGANIC OBT. FA _____ CA ORGANIC ANT. _____
---------------	---

MIX		DRY BATCH WTS.		% MOIST. ADDED	NET WTS.	( Yds.)	( Yds.)
		( C.Y.)	( C.Y.)	EST. TEST. WT.	TO USE.		
	C						
DATA	FA			X =			
SHEET	CA			X =			
No.	WT			Q.3)			

[illegible]

GRAVEL GRADING							SAND GRADING								
3															
2															
1 1/2															
1															
3/4															
1/2															
3/8															
#4															
F.M.															

0

50

100

3

1 1/2

3/4

3/8

#4

8

16

30

50

100

# DAILY LOG OF CONCRETE CONTROL

REPORT NO.

Site )  
 Dry Batch )  
 Central Mixed )  
 Truck Mixed )

For

Project

Inspection at:

Class of concrete

Location of  
 Concrete Placed

Date

Weather

Slump

Cement

Source

Car

Plant Seals

## BASIC CONTROL DATA

Aggregate	Name or Source	Wt / Cu. Ft.	Sp.	%	F.M.
		Dry Loose	Gr.	Abs.	

Proportions, dry loose vols.

Max. W/C ratio, g/s

Batch Volume, C.Y.

Basic Dry  
 Quantities

{ C  
 FA  
 CA  
 W

## ACTUAL BATCH QUANTITIES

Time	Mix	WEIGHTS MOIST AS USED			Gals water Added at	% Total Moisture	
		C	FA	CA		FA	CA

Total 3 in.  
 Net 2 1/2 "  
 gals/ 2 "  
 sack 1 1/2 "

## GRAVEL ANALYSES

1 "  
 3/4 "  
 1/2 "  
 3/8 "

No. 4  
 F.M.

Organic

## SAND ANALYSES

No. 4  
 8  
 16  
 30  
 50  
 100

F.M.

Organic

Scales Checked

\* Indicates estimated moisture

Inspection started  
 No. loads inspected  
 T. & L. Inspection  
 Ticket Numbers

Finished

Bbls. cement used  
 Cu. yds. inspected this date

Cu. yds. total to date

Remarks:

Test  
 Specimens

Copies to:

Certified Correct  
 THE THOMPSON & LICHTNER CO., INC.

Per

THE THOMPSON &amp; LIGHTNER CO., INC.

ENGINEERS

RESEARCH LABORATORY

8 ALTON PLACE, BROOKLINE, MASS.

## REPORT OF TEST OF CEMENT

FOR \_\_\_\_\_

FILE No. \_\_\_\_\_

SHEET No. \_\_\_\_\_

DATE \_\_\_\_\_

Description						
Brand						
Source						
Shipped to						
Samples received						
Samples taken						
Sampled by						
Barrels						
Test Number						
Date Made						
Temperature °F. & % Rel. Humidity						
Per cent water ( <i>Nor. Consis.</i> )						
tested days						
lb. per. sq. in.						
Mix:						
tested days						
lb. per. sq. in.						
Mix:						
Initial Set (Gillmore needle)						
Final Set (Gillmore needle)						
% Vol. Change (Autoclave)						
Soundness (Atmos. Steam)						
Surface Area, sq. cm./gm.						
% passing No. 200 sieve						
Oxides, Si O <sub>2</sub>						
Fe <sub>2</sub> O <sub>3</sub>						
Al <sub>2</sub> O <sub>3</sub>						
Ca O						
Mg O						
SO <sub>3</sub>						
Loss on Ign.						
Insol. Residue						
Compounds C <sub>2</sub> A						
C <sub>3</sub> S						
C <sub>2</sub> S						
Al <sub>2</sub> O <sub>3</sub> /Fe <sub>2</sub> O <sub>3</sub>						

Remarks:

Certified Correct

THE THOMPSON &amp; LIGHTNER CO., INC.

**ENGINEERS**

RESEARCH LABORATORY

620 NEWBURY ST., BOSTON, MASS.

# REPORT OF TEST OF CEMENT

FOR  
AT

FILE NO.

DATE \_\_\_\_\_

**SHEET NO.**

BRAND

BIN

**BARRELS**

**SAMPLES TAKEN**

**SAMPLES RECEIVED**

DATE BRIQUETS MADE

TEMPERATURE - LABORATORY

## STORAGE

HUMIDITY - LABORATORY

## STORAGE

## PHYSICAL TEST

[illegible]

# CHEMICAL ANALYSIS

TEST NO.	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO [ < 65.00 ]	MgO < 4.08 %	SO <sub>3</sub> < 1.75 %	LOSS ON IGNITION < 0.99 %	INSOLUBLE RESIDUE < 0.30 %	MOLECULAR RATIO < 2.60 %	LIME SILICA RATIO < 2.90 %	ALUMINA IRON RATIO 1.20 - 1.80	ALKALINITY < 3.8 %	FREE ALKALI < 3.5 %
	> 21.50 %	< 4.67 %	< 5.60 %	[ < 65.00 ]	< 4.08 %	< 1.75 %	< 0.99 %	< 0.30 %	< 2.60 %	< 2.90 %	1.20 - 1.80	< 3.8 %	< 3.5 %

## REMARKS

SUGAR TEST					
1ST OR PHENOLPHTHALEIN END POINT < 8.0			2ND OR FINAL CLEAR POINT < 10.0		
TEST NO.					
1ST END POINT					
2ND END POINT					
TEST NO.					
1ST END POINT					
2ND END POINT					

Values in [ ] are not specification limits.

**Certified Correct**

THE THOMPSON & LIGHTNER CO., INC.



# Soundness Test of Sample of Coarse Aggregate

Test Number

Date Received

Source

Sample

Test Procedure - A. S. T. M. Specifications C 88-44 T using magnesium sulphate, five cycles

Results:- The following data have been obtained:

Sieve Size		Grading of Original Sample	Weighted Average Loss
Passing	Ret. on		
3"	1-1/2"	%	%
1 1/2	3/4		
3/4	3/8		
3/8	# 4		
Totals		%	%

Soundness -----

---

Soundness Test of Sample of Fine Aggregate

---

Test Number

Date Received

Source

Sample

Test Procedure - A. S. T. M. Specifications C 88-44 T using  
magnesium sulphate, five cycles

Results:- The following data have been obtained:

<u>Sieve Size</u>		<u>Grading of</u>	<u>Weighted</u>
<u>Passing</u>	<u>Ret. on</u>	<u>Original Sample</u>	<u>Average Loss</u>
3/8"	#4	%	%
#4	8		
8	16		
16	30		
30	50		
Totals		%	%

Soundness -----

THE THOMPSON & LIGHTNER CO., INC.  
ENGINEERS  
BOSTON — CHICAGO  
RESEARCH LABORATORY  
620 NEWBURY ST., BOSTON, MASS.

# REPORT OF TEST OF FINE AGGREGATE

FOR \_\_\_\_\_

FILE NO. \_\_\_\_\_

DATE \_\_\_\_\_

Description

Samples taken						
Samples received						
Sampled by						
Clients' Mark						
Test number						
Date made						
Temperature						
Humidity						
Cement						
Aggregate						
Water						
7 days						
lb. per sq. in.						
28 days						
lb. per sq. in.						

Remarks

Certified Correct

THE THOMPSON & LIGHTNER CO., INC.

ENGINEERS  
RESEARCH LABORATORY  
8 ALTON PLACE BROOKLINE, MASS.

FOR \_\_\_\_\_

FILE No. \_\_\_\_\_

DATE \_\_\_\_\_

## Description

Date received

Air Temp.

Mix "

Storage

Date made

Date tested

Slump

Load

Age

W/C Ratio

Mix

## Materials:—

C

FA

CA

Admix.

Mixer

Design Requirements

Test No.DimensionsWt. per cu. ft.
Strength  
Lbs. per sq. inch

1.

2.

3.

4.

5.

6.

Average

## Remarks:

Source

Condition of specimen

Type of break



1



2



3



4



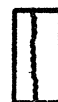
5



6



7



8



9

Strength

Certified Correct

THE THOMPSON &amp; LIGHTNER CO., INC.

Date Specimens Made \_\_\_\_\_

Report to Accompany Field Specimens and to be Delivered to  
THE THOMPSON & LICHTNER CO. INC., 8 ALTON PLACE, BROOKLINE,  
MASS.

PROJECT \_\_\_\_\_

CLIENT \_\_\_\_\_

LOCATION OF PLACEMENT \_\_\_\_\_

TICKET NUMBER \_\_\_\_\_

TRUCK (Plant & No.) \_\_\_\_\_

LOAD NUMBER \_\_\_\_\_

TRUCK (Time Left Plant) \_\_\_\_\_

MIXTURE \_\_\_\_\_

CUBIC YARDS \_\_\_\_\_

CEMENT (Wt. & Brand) \_\_\_\_\_

SAND (Wt. & Source) \_\_\_\_\_

*Stone (wt. & source)*

WATER (Gallons) \_\_\_\_\_

ADMIXTURE (Type, Amount) \_\_\_\_\_

TIME CONCRETE SAMPLED \_\_\_\_\_

WEATHER (Fair, Rain) \_\_\_\_\_

AIR TEMPERATURE \_\_\_\_\_

CONC. " \_\_\_\_\_

SLUMP (Test or Est.) \_\_\_\_\_

APPEARANCE \_\_\_\_\_

BEAMS OR }  
CYLINDERS } (No. & Mark)

STORAGE (Loca. & Protec.) \_\_\_\_\_

Plant Inspector \_\_\_\_\_

Cyl. Made By \_\_\_\_\_

Aggregate

W D L

Sp. Gr.

Absor.

F.M.

$$C = \frac{x \cdot 94}{3.15 \times 62.4} =$$

$$W = \frac{x}{7.48} =$$

27.00

FA+CA

DLV= 1 - -

PROJECT

Class Concrete

Proportions ----

C. F. (sacks)---

W/C, gal/sack--

F.A. % -----

Slump

Date

Design

Check

C = x = #

FA = x x x62.4 = #

CA = x x x62.4 = #

W<sub>f</sub> = x = gal

FA x =

CA x =

8.34 ) ( gal

Date

---

Analysis of Asphalt Cement

---

Test Number -  
Date Received -  
Source - Sampled by from  
  
Sample - One quart of asphalt cement  
in bituminous concrete  
for the above project. Sample  
  
Test Procedure - Analysis as shown below in conformity  
with standard methods.  
  
Results - The following data have been obtained: -

Appearance	Satisfactory
Water	None
Specific Gravity	1.0
Flash Point	°F
Softening Point	°F
Penetration	
Ductility	cm
Loss on Heating	0.
Pen. of Residue	%
Bitumen So. in CS <sub>2</sub>	%
Insoluble Organic	Less than 0. %

This material satisfies the requirements of the project and  
specifications for  
asphalt cement.

C C  
T & L

# ENGINEERS

**BOSTON, MASS.**

**FILE NO.**

**REPORT NO.**

**SHEET NO. -**

DATE.

THE MATERIALS LISTED BELOW HAVE BEEN TESTED AND INSPECTED IN ACCORDANCE WITH SPECIFICATION  
MANUFACTURED BY \_\_\_\_\_ FOR \_\_\_\_\_  
CONSIGNEE TO \_\_\_\_\_

**THE THOMPSON & LIGHTNER CO., INC.**  
CERTIFIED CORRECT



## MECHANICAL ANALYSIS

File

Date

TEST MADE FOR

DESCRIPTION

SAMPLES TAKEN (DATE)

SAMPLES RECEIVED (DATE)

CLIENT'S MARK

LABORATORY MARK

Size of Sieve		Per cent Finer Than	Per cent Coarser Than	Per cent between Sieves	Per cent Finer Than	Per cent Coarser Than	Per cent between Sieves	Per cent Finer Than	Per cent Coarser Than	Per cent between Sieves
Size	Opening in inches									
3 inch	3.00									
2 inch	2.00									
1½ inch	1.50									
1 inch	1.00									
¾ inch	0.75									
½ inch	0.50									
⅜ inch	0.375									
No. 4	0.1875									
No. 8	0.0937									
No. 16	0.0469									
No. 30	0.0232									
No. 50	0.0117									
No. 100	0.0059									
F. M.										

GRADING

WEIGHT DRY LOOSE

WEIGHT DRY RODDED

SPECIFIC GRAVITY

VOIDS DRY RODDED

SILT

ABSORPTION

ORGANIC

SOUNDNESS &amp; STRENGTH

COMPOSITION

REMARKS

Certified Correct

THE THOMPSON &amp; LIGHTNER CO., Inc.

By.....

The Thompson & Lichtner Co., Inc.  
Engineers Boston, Mass.

WELDING OPERATOR QUALIFICATION RECORD  
A.W.S. Standard Operator Qualification Procedure

Name \_\_\_\_\_ Date \_\_\_\_\_  
Address \_\_\_\_\_ Project \_\_\_\_\_  
\_\_\_\_\_

TEST RESULTS

<u>Type of Weld</u>	<u>Position of Test</u>			
	<u>Flat</u>	<u>Horizontal</u>	<u>Vertical</u>	<u>Overhead</u>
FILLET				

3/8" BUTT

5/16" SQ. BUTT

1" BUTT

PROCEDURE SPECIFICATION

	<u>Fillet</u>	<u>3/8" Butt</u>	<u>5/16" Sq. Butt</u>	<u>1" Butt</u>
Base Metal				
Edge Preparation				
Preheat				
Electrode				
Amperes				
Volts				
Procedure				
Cleaning				
Peening				
Root Treatment				
Heat Treatment				

Remarks:

The undersigned certifies that the above record is correct and that the test plates were prepared, welded and tested in accordance with the A.W.S. Standard Operator Qualification Procedure.

THE THOMPSON & LICHTNER CO., INC.

THE THOMPSON & LICHTNER CO., INC. - BITUMINOUS CONTROL

DATE \_\_\_\_\_

CLIENT.

INSP. END.

## WEATHER.

**SAMPLES TAKEN**

SCALES CHECKED

ORGANIC-OBT.

SOURCE | BIT.

8 TYPE SAND.

ANT.

AGG.

FILLER.

[illegible][illegible]

**DAILY LOG OF BITUMINOUS CONTROL**  
**REPORT NO.**

**For**

**Project**

**Inspection at**

**Date**

**Weather**

**Location of  
Placement**

**Mix in Place )**

**Central Mix )**

**Hot Mix )**

**Cold Mix )**

**BASIC CONTROL DATA**

Quantities for Classes of Mixtures Shown

Material

Name or Source

(1)

(2)

(3)

**ACTUAL BATCH QUANTITIES**

Pounds as Batched

**Time**

**Mix**

**Materials**

**Temp. of  
Bitumen  
Aggregate  
Mixture**

**Scales Checked**

**ANALYSES OF COMBINED AGGREGATES**

**Class of Mix**

Passing   Ret. on

**Organic, Fig.**

**Inspection Started**

**Finished**

**Samples**

**Total loads shipped**

**No. loads inspected**

**T&L Inspection }  
Ticket Numbers }**

**Tons Inspected this date**

**Remarks:**

**Tons Total to Date**

**Copies to:**

**Certified Correct**

**THE THOMPSON & LIGHTNER CO., INC.**

**Per**

# THE THOMPSON & LIGHTNER CO. INC.

*Engineers*  
BOSTON, MASS.

File No.....

Report No.....

Sheet No.....

REPORT OF FIELD INSPECTION OF BITUMINOUS CONSTRUCTION.....19.....

OF  
AT  
FOR

<u>Item Inspected</u>	<u>Location</u>	<u>Condition or Sq. Yds; Yield</u>	<u>Action Taken</u>
Sub { grade base			
Application			
Prime Coat			
Tack Coat			
Seal Coat			
Penetration			
Placement			
Base			
Binder			
Top			
Joints			
Rolling			
Cleanup			
Samples			

<u>Weather</u>	<u>Temperature</u>	<u>Placement</u>	<u>Inspection</u>	<u>Time</u>
	<u>AM</u> <u>Noon</u> <u>PM</u>	<u>Start</u> <u>Finish</u>	<u>Start</u> <u>Finish</u>	
	<u>Max.</u> <u>Min.</u>			

Remarks

Certified Correct

THE THOMPSON & LIGHTNER CO., INC.