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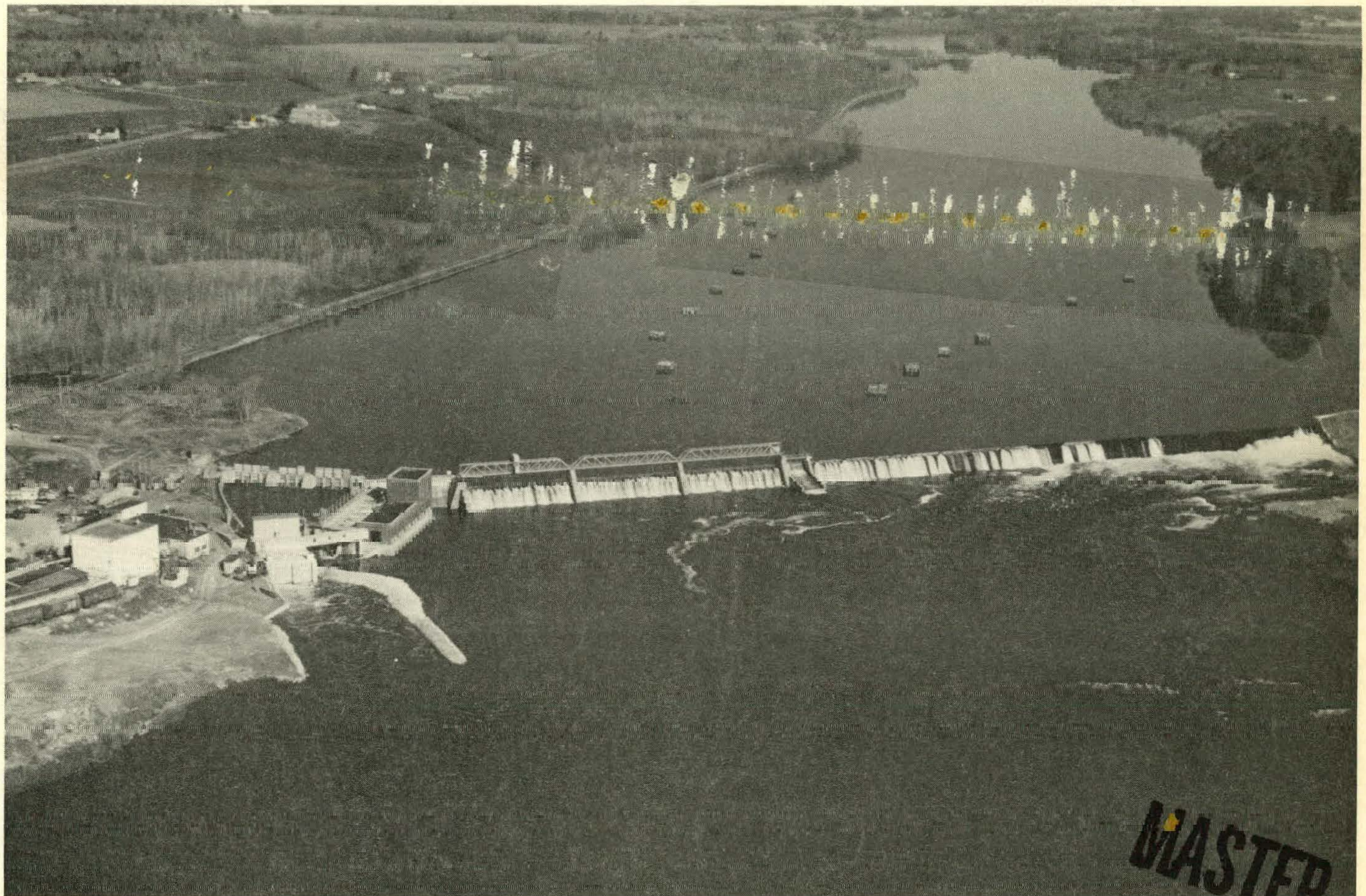
Small-Scale Hydroelectric Power Demonstration Project

Central Maine Power Company
Shawmut Redevelopment Project



MASTER

Final Technical and Construction Cost Report

Department of Energy, Idaho Operations Office

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SHAWMUT HYDROELECTRIC REDEVELOPMENT PROJECT

FINAL TECHNICAL AND CONSTRUCTION COST REPORT

BY

CENTRAL MAINE POWER COMPANY

AUGUSTA, MAINE

AUGUST 1982

PREPARED FOR THE

U. S. DEPARTMENT OF ENERGY

UNDER COOPERATIVE AGREEMENT NO. DE-FC07-80ID12126

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Introduction

This report describes the major steps undertaken by the Central Maine Power Company to redevelop an old existing lowhead hydroelectric station and, at the same time, demonstrate the commercial viability of such a venture.

The report addresses the process of site selection, preliminary conceptual design for determining economic viability, licensing and the regulatory process, final design, and project construction with the objective of presenting to the reader a technical and economical guide useful for a similar undertaking.

I. Background of Central Maine Power Company

Central Maine Power Company is an investor-owned, public electric utility company serving southern and central Maine. The Company is a member of the New England Power Pool and has provided electric service to Maine people and industry since 1899. Electric service is provided to 332 Maine communities in an 11,000 square mile area, about one third of the state's total area. The service area includes over 385,000 customers serving approximately 800,000 people.

System requirements are met by generation from hydro, oil-fired steam, internal combustion, nuclear plants, and through purchase agreements. The net system capability is 1,465 MW, of which 300 MW is available from 22 run of the river and peaking hydro plants. The system peak electrical demands are approximately 1,259 MW and are supplied by 21% hydro, 36% oil-fired steam, 35% nuclear, and 8% from other sources.

II. Existing Facilities

The Shawmut hydroelectric generating facility is located on the Kennebec River in the towns of Fairfield and Benton, Maine about 25 miles north of Augusta, the State Capital. The Kennebec is one of the largest rivers in the state with a drainage area of over 4,200 square miles at Shawmut. The river is highly developed with dams for both utility and industrial use and has a water storage capacity of over 1 million acre-feet.

The Shawmut site has had some form of development since the first saw mill was constructed in the 1830's. Numerous saw mills and grist mills occupied the site through the 1800's. In 1912, the Shawmut Manufacturing Company undertook redevelopment of the site to provide electrical and mechanical power for use by an adjacent pulp mill. The present dam, headworks, and powerhouse were constructed at that time and the old dam removed. Originally, four horizontal water turbines were installed, three to drive 750 KW electric generators and one to provide mechanical power for a pulp grinder. Between 1913 and 1921, two more turbine-generator units were added and the grinder turbine converted to drive a generator. The station, by this time, had an installed capacity of 4,650 KW.

Central Maine Power Company acquired the facilities in 1924 and added four feet of flashboards to the dam, increasing the total head from 19 feet to 23 feet. The additional head increased station output to over 41 million KWH annually. Additions and alterations have been made to the facility since that time. An important addition was made to the powerhouse forebay area when old timber cribwork was replaced with concrete; a separate intake section for a future vertical turbine-generator was constructed in the forebay. The intake section became the intake for the new facility described in this report.

III. Site Selection and Assessment

Since the oil embargo of the early 1970's, the Company has agressively investigated sources of energy which would reduce the dependence on foreign oil in an economically and environmentally acceptable manner. Although most of the viable hydroelectric sites have long since been developed, the Company began an aggressive program of reassessing existing hydro plants to determine by what means increased generation could be achieved.

Late in 1977, the DOE announced a grant program (Program Research and Development Announcement, PRDA) aimed at stimulating interest in developing low-head hydroelectric power plants at existing dams. Under the announcement provisions (called Program Opportunity Notice I, PONI), grants were available on a cost-sharing basis for conducting technical and economical feasibility studies at sites with potential power levels of 15 MW or less at existing dams with heads of 20 meters or less.

Central Maine Power, in conjunction with the Stone & Webster Engineering Corporation, Boston, Massachusetts, submitted a proposal to the DOE for a feasibility study at the existing Shawmut Hydro Station on the Kennebec River. The proposal was accepted in September of 1978.

The study performed by Stone & Webster Engineering Corp. focused on three options for increasing the generation at the Shawmut site. The first option would require the replacing of the old existing turbine-generators with larger, more efficient units; the second option proposed a new powerhouse on the east end of the existing dam; and the third option would take advantage of the existing intake structure for a future unit at the old powerhouse forebay on the west side of the river.

The first option was discarded after a preliminary assessment which indicated it was not economically viable. The second option would produce slightly more annual generation due to more available head and the site did not restrict construction. However, the east side location would require a more restrictive and expensive access and would not be as accessible to operating personnel. The third option, on the other hand, offered accessibility for personnel, use of an existing intake structure, and good accessibility to electric distribution, but available area for construction activities was limited, and some head loss would occur in the existing intake forebay.

As part of the feasiblity study, detailed preliminary cost estimates were prepared for options 2 and 3 and the relative economics compared. The cost evaluation is tabulated in Table 1 and Table 2. As a result of the economic comparison, Option 3 was selected as the best overall choice, both technically and economically. The completed study was submitted to the DOE in August 1979. Shortly after the study submittal, a second Program Opportunity Notice (PON II) was issued by the DOE. The PON II solicitation invited proposals for projects which would demonstrate the technical feasibility and the economic viability of small hydroelectric power plants at existing dams where feasibility assessments had been accomplished. This second PON offered participation by the DOE on a cost-sharing basis for the design,

- TABLE 1 -
SHAWMUT REDEVELOPMENT
PRELIMINARY COST ESTIMATE SUMMARY
(1979 $1,000's)

Item	West Side	East Side
Land	$ --	$ --
Powerhouse	492	796
Waterways	543	1,231
Turbine/Generator	1,535	2,277
Acc. Elec. Equipment	313	318
Aux. Plant Equipment	42	53
Roads	10	81
Substation	45	68
Transmission	2	34
Sales Tax, where applicable	18	42
DIRECT CONSTRUCTION COST	$3,000	$4,900
Omissions & Contingencies	390	600
Engineering & Supervision	650	1,000
Legal-Environmental Administration & Overheads	250	250
Interest (AFUDC)	200	310
GROSS PLANT INVESTMENT	$4,490	$7,060

Per unit costs were developed from the figures in Table 1. Table 2 contains the per unit economic analysis for the two Shawmut schemes.

- TABLE 2 -
SHAWMUT REDEVELOPMENT
ECONOMIC COMPARISON

	West Side	East Side
Hydro		
Rated Capacity (KW)	3,440	5,000
Average Annual Energy (MW)	18,000	21,000
Gross Investment ($1,000's)	4,490	7,060
Investment/Installed KW ($/KW)	1,305	1,412
Annual Cost ($1,000's)	898	1,412
Annual Energy Cost	49.9	67.2
Fossil Alternative		
Gross Plant Investment ($1,000's)	$ 798	$ 1,160
Annual Fixed Cost ($1,000's)	160	232
*Annual Fuel Cost ($1,000's)	936	1,092
TOTAL ANNUAL FOSSIL ($1,000's)	$ 1,096	$ 1,324
Comparison		
Annual Savings with Hydro ($1,000's)	198	(88)
Benefit/Cost Ratio, Hydro/Fossil	1.22	.94

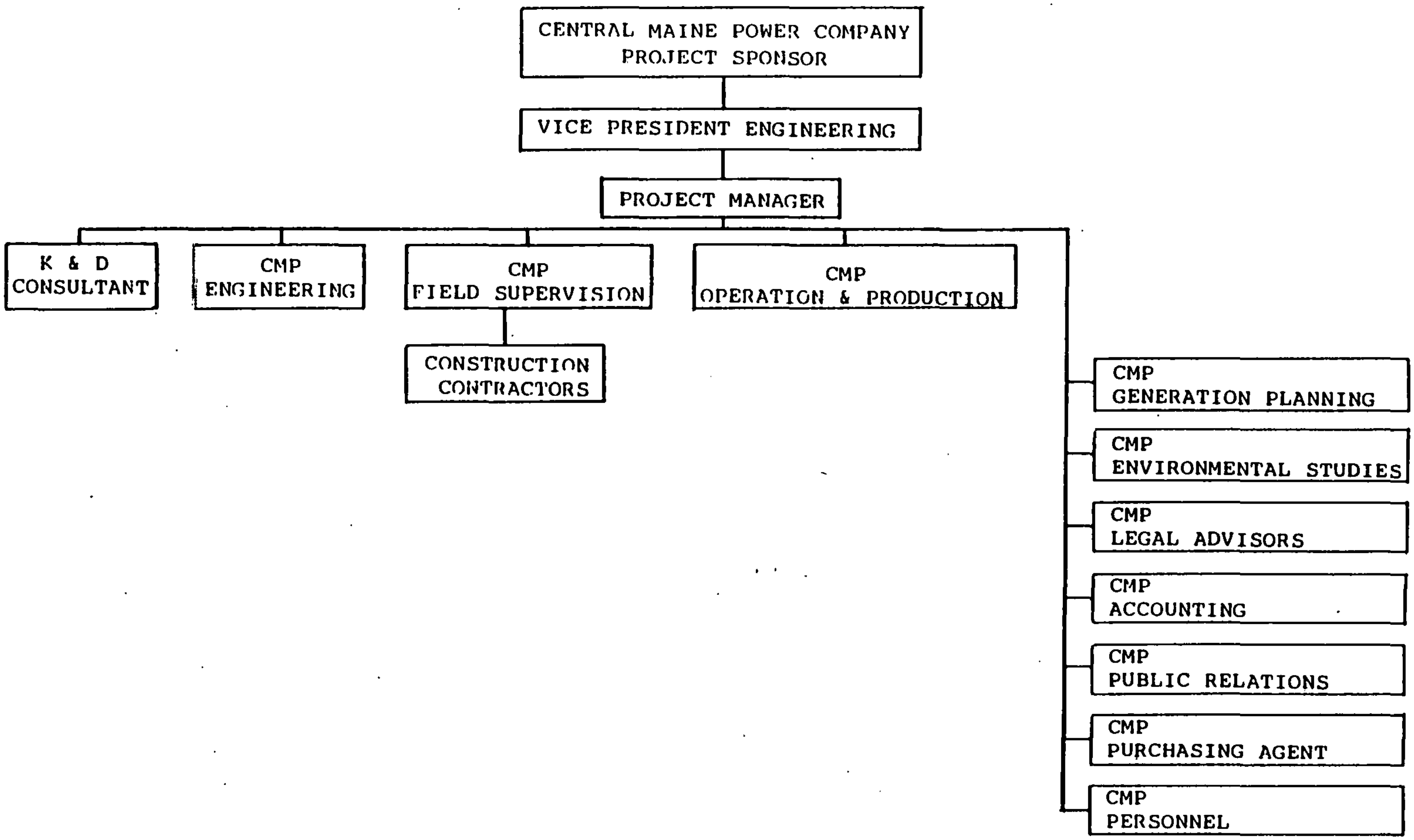
*Levelized cost (52 mills) over 50 years assuming 6% annual increases and a present day cost of 24 mills KWH.

construction, and operation of small hydro projects. Central Maine Power made application and received a grant for redeveloping the Shamwut site in June 1980. In return for the DOE participation, Central Maine Power Company will make available to the DOE all engineering, operational, economic and environmental data for evaluation and public distribution. This report includes all phases of the project development except the operational phase which will be reported separately after two years of operation.

V. Project Management

Central Maine Power Company acted as overall manager for the project. The detailed engineering design was contracted to Kleinschmidt & Dutting, Consulting Engineers, Pittsfield, Maine. The selection of Kleinschmidt & Dutting was based on previous design experience involving small scale tube-type turbine generator installations. The Engineering Department of Central Maine Power Company reviewed all design and specifications and purchased all major equipment. Central Maine Power Company also supervised the overall construction effort, furnished electrical workers, a start-up crew, and general engineering support.

The overall project organization is illustrated on Figure 1.



Organization Chart
Shawmut Redevelopment
Central Maine Power Company

Figure 1

V. Licensing and Regulatory Approvals

The licensing phase of the Shawmut Redevelopment started in the spring of 1979. This phase was to span a two-year period during which all necessary federal, state, and local approvals and licenses were obtained. The effort was undertaken by Central Maine Power Company with the aid of Kleinschmidt & Dutting. The subcontracted Architect-Engineer furnished the necessary preliminary engineering and conceptual design to support the licensing effort.

The following table summarizes the permits and licenses required for the project:

Authorization	Agency	Application Date	Approval Date
Certificate of Public Convenience & Necessity	Maine Public Utilities Commission	5/02/80	8/28/80
Project License	Federal Energy Regulatory Comm.	8/04/80	1/05/81
Stream Alteration Permit	Maine Fish & & Wildlife	7/24/80	8/29/80
Water Quality Certificate	Maine Dept. of Environmental Protection	5/02/80	5/21/81
Dredging Permit	U.S. Corps of Engineers	1/14/81	6/03/81
Building Permit	Town of Fairfield	3/31/81	3/31/81

With the exception of the Certificate of Public Convenience and Necessity from the Maine Public Utilities Commission, the time required from the start of preparing applications, to the date when applications were submitted to the various agencies, took about nine months. Several factors contributed to this comparatively short preparation time. In November of 1979, the Federal Energy Regulatory Commission issued revised regulations concerning applications for water power project licenses. The new regulation pertained specifically to major projects of greater than 1.5 MW which would utilize the water power potential of existing dams. The purpose of the new order was to simplify licensing procedures for projects eligible under the Public Utility Regulatory Policies Act (PURPA). The Shawmut Project qualified for this new short form of licensing. The time required to prepare the application for license and the approval by FERC took about eleven months, of which the actual approval process took only four months.

As an aid in initially contacting and informing the various federal, state, and local authorities of the Company's intentions to redevelop the Shawmut site, a brochure was produced which described the project in detail. The basis for the brochure information was the feasibility study produced under the PRDA solicitation by the DOE. The brochure proved to be a valuable method of informing the public at large, as well as the regulatory bodies.

VI. Project Design

Project design began with preliminary engineering to develop conceptual plans to support license applications in the spring of 1979. Detailed project engineering did not begin until the fall of 1979. Kleinschmidt & Dutting, were contracted for engineering services during the early project licensing stages and retained later for the final design stage.

The first steps towards developing detailed plans for construction were to make a detailed assessment of the design criteria and project schedule. A review of the space requirements, available river flows, head, and intake flow conditions revealed that larger tube turbines than the 2,500 MM units proposed in the feasibility study could be accommodated. The larger units would be 2,750 MM diameter turbines and would increase unit output from 1,720 KW to 2,045 KW. Coincident with optimizing runner size, an investigation was made of available gross head. The investigation revealed that an additional 1.6 feet of head could be gained by making a slight change in the direction of the tailrace discharge into the river. The increase in turbine size also more nearly matched the regulated river flow discharged from upriver hydro stations.

The project schedule proposed in the feasibility study had indicated the start of the design effort eighteen months before the start of construction and that the effort would essentially be completed before awarding a civil contract for the work. It was concluded that improvements in the schedule could be made contingent on several important factors, namely, shortening the design schedule, speeding up the license application submittal and approval, and obtaining major equipment earlier than originally planned.

The Architect-Engineer, Kleinschmidt & Dutting, reviewed the design schedule and advised that it was possible to shorten the schedule. Major equipment vendors assured Central Maine Power Company that improvements to the fabrication and shipping schedule could be met. The FERC advised Central Maine that the application approval process would be shortened to fit the new time frame. As a result of the schedule reassessment, the commercial power operation date was changed from October 15, 1982 to April 1, 1982. A major benefit was achieved by this change; the units would now be in operation to catch the spring run-off which starts in March and represents a period of major contribution to the gross annual generation.

The specifications for the turbine-generators were issued in September 1980 and bids received during October 1980.

Bids were requested from General Electric Company, Allis-Chalmers, Combustion Engineering, Inc., and James Leffel & Company. An order for the turbine-generator equipment was placed with Allis-Chalmers in November. The evaluation and selection of the turbine-generator package is discussed in detail in Section VII, "Selection and Description of Major Equipment."

Other engineering effort at this time consisted of a detailed hydraulic study of the existing intake structure which would be incorporated in the new design. The structure had been designed in 1941 for the future addition of a single 2,400 KW vertical turbine-generator. The intake center pier was offset from the overall intake centerline by two feet to accommodate the vertical unit. The hydraulic study indicated that a maldistribution of flow would not occur if the unequal openings were used for two tube turbine intakes as proposed. The study also assessed flow conditions through the old forebay gate openings, and results indicated that velocities and head losses were within acceptable limits.

A geotechnical investigation of the new powerhouse location and the existing intake concrete was made. The bedrock in the area is chlorite phyllite and found to have a competent bearing capacity. However, intense folding of the bedrock has left the metamorphic layers of sedimentary rock in a near vertical position, closely paralleling the longitudinal walls of the new structure. Because of the instability due to slabbing during the powerhouse excavation and exposed sides of the tailrace excavation, rockbolts were incorporated into the design. The rockbolts were installed by benching the ledge excavation at not over 15 foot intervals, installing rockbolts, and then stepping the excavation another interval. This was a time consuming process which delayed the start of concrete pouring by several weeks.

Facility design consists of a new powerhouse to house the two 2,750 MM turbines, generators, speed increasers and associated equipment, modifications and additions to the existing intake structure, a new tailrace with training wall, an enclosed access bridge from new to old power-house, and an addition to the existing substation.

The powerhouse is designed as a low profile, reinforced concrete structure, 70 feet long and 50 feet wide. A mezzanine floor above the main generator floor provides space for control boards and auxiliary electrical equipment. A walkway over the mezzanine floor provides access from the main powerhouse entrance to the enclosed access bridge to the old powerhouse. A stairway leads from the walkway down to the mezzanine level. Auxiliary-mechanical equipment consists of an all electric, single-girder overhead crane rated at 15 tons, sump pumps, roof ventilation equipment, speed increaser oil coolers (oil to air), and a 3 ton auxiliary hoist with monorail. The overhead crane can service all major turbine-generator equipment. If major equipment has to be moved in or out of the powerhouse, it can be accomplished through the roof hatch with the aid of a mobile crane. Smaller materials can be brought into the powerhouse through the main access door and handled with the 3 ton monorail hoist which can position loads on the mezzanine level for transfer by the overhead crane, if necessary.

The sump pumps handle turbine gland leakage and any other source of water. An oil detection system with alarm is installed in the sump pit. Discharge of the pumps goes to the city sewage system. The only plant discharge going to public waters is the in-flow to the turbine shaft seals, which is about 3 gpm total. The speed increaser oil coolers are wall mounted and fan cooled. The ventilating system is designed to dissipate equipment heat to the outdoors during warm months and transfer the heat to the old powerhouse, via the enclosed walkway, in the cold months. This utilization of waste heat is expected to greatly decrease heating costs of the old powerhouse when units are not operating.

The intake design includes new trash racks and support beams, a modified intake deck, emergency gates, and hydraulically operated control gates. The trash racks are designed with 3 1/2 inch clear openings to allow passage of small debris, but stop material which could become caught in the turbine runners. The racks are serviced by a trash rake with a hydraulically operated boom and rake. The rake is called the Berry Rake and is manufactured in Berlin, New Hampshire. Very good results have been achieved with the rake at other locations in removing old sunken logs and debris while the turbines are in operation.

Concrete was extended from the existing intake piers downstream to the powerhouse structure and a new concrete intake deck poured. More concrete was required for the intake section than originally planned due to the moving of the powerhouse downstream to accommodate safe ledge removal. Two intake gates are incorporated with each unit. The upstream gate is for emergency use or for dewatering a unit for inspection and maintenance. The gate is of two-piece steel construction with one section normally suspended by an electic hoist over the gate slot for each unit. When put into use, one gate is lowered and then the adjacent section moved over and lowered onto the first section. Only one gate services both units. Downstream of the emergency gate is a hydraulically controlled gate. The turbines are fixed blades without wicket gate control which require either a butterfly valve or gate to control flow for start-up or shutdown. Since the units will use the available river flows nearly 100% of the time, the units will either be at maximum flow or off line. The hydraulic gate was selected as the most economical method to fit these conditions of operation. The gates are steel with a concrete ballast to aid in rapid closing during an emergency trip. The hydraulic control system interfaces with other start-up features at the control boards.

The emergency gate, hoists, hydraulic gates, and hydraulic system are all housed in a weatherproof structure.

The tailrace was designed to take advantage of the ledge cut where possible. Rockbolts were installed to stabilize slabs of ledge and prevent overbreakage, spalling and sliding into the waterway. Where there was no ledge, side slopes were riprapped. In order to reduce the effect of the discharge from the old powerhouse on the new tailrace, a combined concrete and rock filled training wall was designed to separate the flows.

VII. Selection and Description of Major Equipment

General

The engineering assessments performed by Stone & Webster Engineering Corporation and Kleinschmidt & Dutting established the following basic specification criteria for each of the new Shawmut units:

Flow: 1,200 cfs
Head: 22.6 feet (net)
Turbine type: Tube
Runner Diameter: 2,750 mm
Fixed runner blades (stainless steel)

The flow of 1,200 cfs per unit, together with the flow being discharged by the old units, will utilize the regulated river flow approximately 70% of the time. This compares with a 45% utilization by the old units previously. The new units will operate at nearly 100% of the time with the old units being added as river flows permit, resulting in a net annual generation increase of 20,000,000 KWH.

The selection of axial-flow tube turbines was established when the site feasibility study was performed by Stone & Webster Engineering Corp. Previous studies by Central Maine had been based on a vertical unit, but the high equipment and civil costs, and power capacity, have always resulted in an unacceptable cost/benefit ratio. Tube units, on the other hand, offered significant savings in cost of equipment due to standardization, simplicity of design, space saving, and lower civil costs.

Other axial flow turbines were considered, including the STRAFO turbine and bulb turbine. In each case, the cost/ benefit ratio was unsatisfactory. The STRAFO turbine is better suited to slightly higher heads, and, although more compact, the savings in civil work did not offset the higher equipment cost. Bulb turbines are more suitable in larger sizes than required for Shawmut, and, as a result, costs similar to the STRAFO turbine would be expected.

The use of two tube units, instead of one, had several advantages. The forebay flow conditions dictated that 2,400 cfs was the maximum that could be considered without getting high head losses. Alterations to the existing forebay entrance gates to eliminate the problem were not economically practical at this time. Also, the use of two units takes advantage of the existing intake structure which had been constructed for a future unit. The selection of the 2,750 mm size turbines was the largest unit size which could be accommodated by the intake and have sufficient intake submergence.

Quotations for the two tube units were obtained from Allis Chalmers, Combustion Engineering, General Electric Co., and the Leffel Company and evaluated. The evaluations were based on overall quality, materials of fabrication, net unit output, component efficiency, delivery schedule, receipt of shop drawings, and total cost. As a result of the evaluation, an order was placed with Allis-Chalmers. The following is a description of the turbine-generator and other major electrical and mechanical equipment.

Turbine

The turbines are of the tube design as manufactured by Allis-Chalmers. The turbine runners are of the fixed, three-bladed design, 2,750 mm in diameter. The blades are of stainless steel and welded to a carbon steel hub with a hollow, carbon-steel shaft. The intake ring has only stay vanes and no wicket gates. The upstream end of the runner is supported by an oil bath lubricated, spherical roller bearing supported by the stay vanes in the intake ring. At the bearing and packing gland, the shaft is fitted with stainless steel sleeves.

The turbine has a maximum output of 2,146 KW at 22.6 ft. head (net). The guaranteed efficiency at this point is 91.1% (IEC).

Included with the turbine, in addition to the runner and intake ring, are the intake transition, draft tube elbow, and draft tube extension. The pieces were fabricated of steel plate and shipped to the site in sections. Final assembly was made at the project site.

Speed Increaser

The speed increasers are Dresser Model No. 3401 and were supplied as part of the Allis-Chalmers scope of supply. The units have welded carbon steel casings, precision helical gears, forced lubrication, 5.63 single reduction ratio and an AGMA suggested efficiency of 98%. The bearings have a minimum B-10 life of 100,000 hours. Thrust from the turbine is taken by the low speed bearing. Lubrication on start-up and shutdown is from an electric oil pump. Under normal operating conditions, lubrication is by a shaft mounted oil pump. Oil cooling is by forced air coolers.

Generators

The generators, each rated at 2,222 KVA, .9 p.f., 4,160 volt, 3 phase 60 hertz, were manufactured by Siemens-Allis, Inc. in Milwaukee, Wisconsin. They are eight-pole machines operating at 900 rpm with overspeed capability of 2,040 rpm. The construction is drip-proof, self-ventilated, with damper windings and two spherical roller bearings, oil bath lubricated.

Each generator is equipped with the following accessories:

1. Main lead terminal box containing main and neutral leads; four current transformers, Class C100, 400:5 amperes; surge capacitors; lightning arresters.
2. Six resistance temperature devices (RTDs) embedded in the stator windings.

3. Space heater, 1,500 watt, 120/240 volt.
4. Brushless exciter (described elsewhere).
5. Voltage regulator (described elsewhere).
6. Mechanical overspeed switch.
7. Electronic overspeed switch.
8. One RTD for each machine bearing.

The original generators quoted by Allis-Chalmers were to be units manufactured by Ideal Electric. Due to Central Maine Power Company's lack of familiarity with this vendor, plus a lower than available unit efficiency, Allis-Chalmers chose to substitute generators manufactured by Siemens-Allis. Central Maine Power found these units to be acceptable.

Exciter

The exciters supplied with the generators are of the brushless design with rectifier units. Each is rated 17 KW output at 30 VDC and is manufactured by Kurz and Root for Siemens-Allis.

Each exciter is essentially a brushless alternator with a stationary field and rotating three-phase armature, the output of which is rectified by integrally mounted diodes to provide the field power source for the main generator. The external voltage regulator (Basler, Model SR8F-3) senses the main generator output voltage and varies the field strength of the stationary exciter field to maintain the level required. A drive and mounting adapter is provided on the outboard end of the exciter for the mechanical speed sensing switch.

Unit Breakers

The unit breakers are located in a line-up of weatherproof metalclad switchgear in the station switchyard. Originally manufactured by Westinghouse in the 1950's for a unit substation, the switchgear was reconfigured by American Switchgear Corp. for use in the Shawmut Project. An economic evaluation of reconditioning the existing equipment, versus buying new switchgear, showed the former to be clearly less expensive to the Owner.

Ratings are 5 KV class, 1,200 amperes continuous, 150 MVA interrupting. Accessories included are:

1. Three sets of two potential transformers, 4,200 to 120 volt, connected open delta-open delta. One set is connected on the unit side of each breaker; the third set is on the bus.

2. Six sets of three current transformers, single ratio, 400:5 ampere.

3. One set of three 3 KV bus arresters.

4. A fused disconnect supply for a 150 KVA pad-mounted backup station service transformer.

Transformers

To convert the units output at 4,160 volts to CMP's subtransmission voltage of 34,500 volts, a step-up power transformer is used. Built by General Electric at their Rome, Georgia facility, the transformer is rated 3,750/4,200 KVA ($55^{o}/65^{o}C$ rise) self-cooled, 4,160 volt delta to 34,500 volt grounded wye. The step-up transformer is connected to an existing 34.5 KV bus through a gang-operated disconnect switch and a set of power fuses. The low voltage side of the transformer is connected by bare aluminum conductor to roof bushings on the adjacent metalclad switchgear. The step-up transformer, switchgear, and pad-mounted backup station service transformer are all within the fenced substation area, approximately 250 feet from the powerhouse.

Station Service

Two sources of 230 volt, 3 phase, 3 wire service are provided to the new powerhouse; the primary source from the old powerhouse station service bus and a secondary source transformed from the switchgear's 4,160 volt bus. These two sources come through an automatic transfer switch and KWH metering before feeding a 230 volt Motor Control Center in the new powerhouse. The two sources of station power assure that critical loads can be serviced during periods of equipment outage, such as failures or maintenance.

Main Generator Leads

The output of each generator is connected to its breaker via triplexed, 750 KCM, cross-linked polyethelene insulated, aluminum power cable. Routing of the cables is from generator terminal compartment to floor trench to wall-mounted ladder tray to concrete-encased underground duct to the metalclad switchgear. The generator neutral, formed in the generator terminal compartment, is connected to the neutral grounding resistor with a single 350 KCM aluminum cable insulated for 4,160 volt service.

Water Level Measurement

Electronic pressure transmitters are used to develop signals which display the following quantities: forebay water level, tailwater level, and differential water level across each of the two intake trash racks. Duplicate meters for these quantities are located in the new powerhouse and at the operator's location in the old powerhouse. Alarm modules will alert the operator through the station annunciator in the event of excessive trash rack differential level (indicative of a rack plugged with debris).

Gate Position Indication

Position of each unit's intake control gate is provided in the gatehouse by a moveable-staff, fixed-pointer arrangement. No indication is given at the control board.

Cable Tray and Conduit

Control cable and 600 volt class power cables are routed in the powerhouse by way of aluminum ladder-type cable tray and steel conduit. The tray was chosen for the flexibility offered during installation and in the future. Steel conduit was used for protection from physical damage to cables.

Control and Low Voltage Wiring

Control wiring utilizes cables built in three, five, and seven conductor, #14 AWG; 12C #12; and 4C #10 configurations, all copper. Insulation is cross-linked thermo-setting polyethelene, 30 mils thick, rated 600 volts. Cable jackets are of neoprene.

Low voltage power cables are utilized in sizes of three conductor, #12 AWG, 3C #10, 3C #6, and 3C #2. Insulation and jacketing are similar to that in the control cables.

Low-level instrumentation signals (i.e. RTD leads) use shielded triple conductors, arranged either as one triple or eight triples per cable.

Lighting

The ac lighting system in the powerhouse is fluorescent, using industrial type luminairies and eight-foot, high output, cool-white lamps.

The emergency lighting system consists of a Dualite emergency lighting unit with two remote heads.

Exit signs are self-illuminated with tritium light tubes, Betalight Model Safety 10.

Vibration Detectors

A vibration detector is mounted on the speed increaser of each unit. If the device detects excessive vibration, the occurrence is displayed to the operator via the station annunciator.

Fire Detection System

Ionization chamber type detectors mounted beneath the powerhouse roof monitor the area for smoke and/or fire. A control panel, normally powered by 120 VAC, but with battery backup, sends alarm signals to the station operator through the annunciator.

Station Annunciator

The annunciator for Units 7 and 8 was manufactured by Ronan and is mounted in the relay and control panel. Besides monitoring field contacts for abnormal conditions, it also accepts analog inputs (in this case from resistance temperature devices) and can provide alarm or trip outputs when set points are exceeded.

The following discrete events are monitored on each unit:

1. Auto Trip
2. Overspeed
3. 86G Lockout
4. Overvoltage
5. Loss of Control ac
6. Creep
7. Loss of Control dc
8. Vibration
9. Packing gland low coolant flow
10. Incomplete sequence
11. Nose cone bearing low oil level
12. Nose cone bearing high oil level
13. Speed increaser low oil flow

On each unit, the following analog quantities are monitored. Also shown are the alarm and tripping set points.

	Item	Alarm	Trip
1.	Turbine bearing high temp	25°C	30°C
2.	Turbine packing box high temp	30	35
3.	Speed increaser high speed bearing high temp	65	70
4.	Speed increaser low speed bearing high temp	65	70
5.	Generator coupling end bearing high temp	60	65
6.	Generator exciter end bearing high temp	60	65
7.	Generator stator winding high temp	120	125

The following discrete events common to both units are monitored:

1. Oil in station sump
2. Fire alarm
3. High water level in station sump
4. High ambient air temperature
5. Station service transformer trouble
6. Low pressure in gate hydraulic system
7. Low level in hydraulic system sump

Upon the occurrence of any of the above events, a bell is sounded in the old powerhouse (as well as in the new powerhouse) to attract the attention of the station operator to the annunciator.

Protection

Protection and control philosophy for Shawmut Units 7 and 8 was provided by Kleinschmidt and Dutting, Consulting Engineers, of Pittsfield, Maine. Detailed design, construction, and wiring of the relay and control panels was done by Central Maine Power Company in Augusta, Maine.

General Protection Scheme

There are three general methods of shutting down a machine: normal, protective, and emergency. In the normal shutdown mode, initiation first causes the unit control gate to move closed. As the unit starts to motor, the unit breaker will open upon sensing reverse power. In the event of a protective shutdown (through Device 94), the first action is to open the unit breaker while simultaneously starting to close the unit control gate. An emergency shutdown is similar to the protective shutdown except that, in order to restart, a lockout relay (Device 86) must first be hand reset after the trouble has been cleared.

Following is a listing of those parameters that initiate the three types of shutdown.

Protective Shutdown (Non-Lockout 94)

DEVICE NO.	DESCRIPTION	SOURCE	FUNCTIONS
12	Generator	Electro-Sensor	12 device trips the 94 at 110% overspeed
	Overspeed	MPS 6000	(990 RPM) which causes unit shutdown. An electronic detector, using field effect heads to determine RPM from a magnetic collar on the generator shaft, initiates the shutdown.
32	Reverse Power	West. CRN-1	On a stop command, the reverse power relay opens the unit breaker when the unit is unloaded to prevent overspeed of the generator. Acts as backup for generator differential relays.
46	Phase Unbalance	West. COQ	The negative sequence relay (COQ) detects 120 hz currents caused by a phase unbalance and causes unit shutdown. An $I_2{}^2T$ value of 40, recommended by the generator manufacturer, was used in calculations.
59X	Field	Basler Under-freq.overvolt. Mod. UFOV 260A	Basler UFOV 260A detects a field overvoltage condition of 130% and opens the field breaker. Upon loss of field voltage, the 59X drops out, causing unit shutdown.

*Unit shutdown refers to a shutdown caused by pick-up of the 94 relay. The 94 relay immediately opens the unit breaker and picks up the 5 relay. The 5 relay then drops out the master relays which removes the field and closes the gate (40-50 sec.). Immediately unloading the machine will normally cause overspeed and an emergency trip.

Normal Shutdown

38 TURBINE	Turbine High Temperature	RTD Nose Cone RTD Packing Box	The annunciator monitors an RTD in the runner nose bearing and one in the turbine shaft packing box. Both RTD's cause the annunciator to alarm at 85°F and initiate unit shutdown by the "5" relays at 95°F.
38 Increaser	Speed Increaser High Temperature	RTD High Speed Bearing, RTD Low Speed Bearing	The annunciator monitors an RTD in the high speed bearing and one in the low speed bearing. Both RTD's cause the annunciator to alarm at 150°F and initiate unit shutdown by the "5" relay at 160°F.
38 Generator	Generator High Temperature	RTD-Coupling Bearing, RTD-Exciter Bearing	The annunciator monitors an RTD in the coupling end bearing and one in the exciter end bearing. The coupling end RTD causes the annunciator to alarm at 145°F and initiate unit shutdown by the "5" relay at 150°F while the exciter end RTD alarms at 155°F and trips at 160°F.
39	Vibration	PMC/BETA Vibration Detectors	A vibration alarm is set in percent of trip value. Once the pick-up vibration level has been reached and maintained for 3 seconds, the "5" relay will pick-up causing unit shutdown.

Normal Shutdown

52CS	Breaker Control Switch	G.E. SB-1 Sw.	52CS opens and closes the unit breaker. If the unit breaker is opened with the machine lightly loaded (approx. 400 KW) a non-emergency, normal unit shutdown will occur. Over 400 KW will cause the unit to overspeed causing an emergency shutdown.
94	Unit Shutdown	West. MG-6	Unit shutdown initiated by the 94 is explained in the protective shutdown (94) section.

Unit shutdown initiated by the "5" relay drops out the master relays to close the gate, remove the field and open the unit breaker when a no-load condition is reached.

Emergency Shutdown (Lockout) (86G)

12	Generator Overspeed	Woodward Speed Switch	12 device trips 86G at 120% overspeed (1080 RPM) which causes emergency shutdown. This mechanical overspeed device is located on the end of the generator shaft and is backup for the electronic overspeed device.
27AC	Generator Overvoltage	G.E. IAV54E	Emergency shutdown (86G) for low (90%) or loss of 240 VAC unit control voltage. Tripping by 27 AC is inhibited when unit breaker is open by an "a" finger.
40	Loss of Field	West. CW	Directional power relay connected to initiate an emergency shutdown for var flow into the machine, which occurs with loss of field.

DEVICE NO.	DESCRIPTION	SOURCE	FUNCTIONS
49SD/X	Stator Thermal Shutdown	Stator RTD	Ronan series X12/X84 annunciator monitors one of six stator RTD's selected by a six position switch. When an overheating condition occurs, the annunciator energizes the 49SD/X to emergency shutdown the unit. Alarm occurs at 150°F and shutdown at 160°F.
51G	Generator Ground	West. CO-8	Inverse time overcurrent relay initiates emergency shutdown for any grounds detected out to and including the low side winding of the step-up transformer. Serves as backup for generator ground differential relay.
51V-2	Generator Overcurrent	West. COV-8	Voltage controlled inverse time overcurrent relay initiates emergency shutdown for phase faults from generator to step-up transformer. Some limited backup protection for substation feeders and generator is provided. Current unit is set for 50% of generator rating with the voltage element set for 75% rated voltage.
87U-1,2,3	Generator Phase Differential	West. CA	Emergency shutdown for generator phase faults with some limited ground fault protection. Ground protection is limited because of the high impedance grounding of the generators.

DEVICE NO.	DESCRIPTION	SOURCE	FUNCTIONS
87G	Generator Ground Differential	West. CWC	Directional current relay with the polarizing coil in the generator neutral to permit relay operation and emergency shutdown only for internal generator ground faults.
EMERGENCY STOP / GATE	Emergency Shutdown From Gatehouse	Pushbutton	Emergency switch is located outside gatehouse by the trash racks. Switch is spring loaded and initiates an emergency shutdown of generators 7 & 8. The switch is activated when the glass over the pushbutton is broken.
EMERGENCY STOP / LOCAL	Emergency Shutdown From Generator Panel	Pushbutton	Emergency switch is a spring return pushbutton located on the relay & control panel. This switch initiates an emergency shutdown of the unit.
EMERGENCY STOP / REMOTE	Emergency Shutdown From Old Station	Pushbutton	Emergency switch is a spring return pushbutton located on panel #14 in the old power-house. This switch initiates an emergency shutdown of the unit.
Fire Alarm		4 Pull Boxes & 8 Smoke Heat Sensors	4 pull boxes and 8 smoke/heat sensors are placed outside the powerhouse, inside the powerhouse, and inside the gate house to initiate an emergency trip when activated. In addition to an emergency trip, the vent fans are also shut off when a fire is sensed.

Emergency shutdown refers to shutdown caused by tripping of the 86G. 86G trips the unit breaker, opens the field, closes the gate (high speed 12 sec.), and drops out the master relays. The unit cannot be restarted until the 86G is reset.

The following tables list the protective and control devices used.

SHAWMUT DEVICE SETTINGS Unit 7

DEVICE NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTION
3	GE	HFA171	120 VAC	No Setting	Pnl 1 Tier 3	Checking Relay
4-1	GE	HFA171	120 VAC	No Setting	Pnl 1 Tier 4	Master Relay
4-2	GE	HFA171	120 VAC	No Setting	Pnl 1 Tier 5	Master Relay
4X	Agastat	70047	1-10 Min.	6 Min.	Rear Pnl 1	Hydraulic Unit Control
5	GE	HFA171	120 VAC	No Setting	Pnl 1 Tier 2	Checking Relay
12	Woodward	6905-295		1080 RPM	Generator Shaft	120%-Overspeed Trip
12	Electro Sensor	MSP-6000	0-2000 RPM	945RPM	North Wall	105%-Overspeed Alarm
12		MSP-6000	0-2000 RPM	990 RPM	North Wall	110%-Overspeed Trip
13	"	MSP-6000	0-2000 RPM	855 RPM	North Wall	95%-Full Speed
14-1	"	MSP-6000	0-2000 RPM	9 RPM	North Wall	1%-Creep
14X	GE	HGA11J70	120 VAC	No Setting	Rear Pnl 1	Start Pumps for Creep
14Z	Agastat	70041	1-10 Mins.	2 Mins.	Rear Pnl 1	Stop False Creep Alarm
20QS	Sq.D	LO-40	120 VAC	No Setting	Rear Pnl 1	Initiates Slow Sol.
20QSX	Sq.D	LO-40	120 VAC	No Setting	Rear Pnl 1	Picks up 20 QS @ 30" Gate
20WS	Sq.D	LO-40	120 VAC	No Setting	Rear Pnl 1	Water Sol. Valve
20WSX	Agastat	70041	1-10 Mins.	1 Min.	Rear Pnl 1	Prevent False H2O & Oil Alarm

Unit 7 Continued

DEVICE NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTION
20WSX1	Agastat	70041	1-10 Mins.	10 Mins.	Rear Pnl 1	Run Pump 10 Mins. After Shutdown
25	Basler	PRS210	.1-.5 sec 5°-40°	.15 sec.40°	North Wall	Auto-sync.
27AC/1	Porter Brumfield	KAP11AG	120 VAC	No Setting	Rear Pnl 1	Alarm 120 VAC Control Volt
27AC/3	GE	1AV-54E	110-280VAC	.9PU-216 VAC	Pnl 1 Tier 3	Trip Low System Voltage
27AC/3X	P.Brum.	KAP11AG	120 VAC	No Setting	Rear Pnl 1	Alarm 240VAC Control Volt
32	West.	CRN-1	13.4 KW	.023A @ 0° Lever 1	Pnl 1 Tier 3	Reverse Power
33GPX	Sq.D	L0-40	120 VAC	No Setting	Rear Pnl 1	Hydraulic Pump Control
38	Ronan	X12/X84	0-300°F	Alarm 85°F Trip 95°F	Pnl 2	Nose Cone
				Alarm 85°F Trip 95°F	Pnl 2	Packing Box
				Alarm 150°F Trip 160°F	Pnl 2	Speed Inc. HS Bearing
				Alarm 150°F Trip 160°F	Pnl 2	Speed Inc. LS Bearing
				Alarm 145°F Trip 150°F	Pnl 2	Gen. Coup. End Bearing

Unit 7 Continued

DEVICE NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTION
				Alarm 155°F Trip 160°F	Pnl 2	Gen. Exciter End Bearing
39	PMC/BETA	414BD	5-50 Mil 10-90%	20 Mil .50%	Speed Increas.	Vibration Detector
40	West.	CW	100-600 VAR	200 Sec.Var Lever 2	Pnl 1 Tier 3	Loss of Field
41	West.	SG	120 VAC	No Setting	Pnl 1 Tier 3	Field Application Relay
46	West.	COQ	3-5A	Tap 3.8 Lever 5	Pnl 1 Tier 3	Negative Sequence
48	Agastat	70041	0-10 Min.	6 Mins.	Rear Pnl 1	Incomplete Sequence
49SD	Ronan	X12/X84	0-300°F	Alarm 150°F Trip 160°F	Pnl 2	Stator Temperature
51G	West.	CO-8	.5-2.5A	Tap.5 Lever 1	Pnl 1 Tier 1	Neutral Overcurrent
51V-2	West.	COV-8	2-6A 80- 100 VAC	Tap 2 Lever 3 90 VAC	Pnl 1 Tier 1	Volt Control Overcurrent
59T	Basler	05391	240 VAC	No Setting	Pnl 1 Tier 5	Field Breaker
59X	GE	HGA111J19	240 VAC	No Setting	Rear Pnl 1	Overvoltage Trip&Alarm Aux
81U/59	Basler	UFOV260A	125-150%VAC	140VAC 53 hz	Rear Pnl 1	Underfrequency/Overvoltage Module
86G Lockout	Electro-Sw. Relay		LOR	125 VDC	None	Pnl 1 Tier 2

Unit 7 Continued

DEVICE NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTION
87G	West.	CWC	Upper .25-1 Low 1-4	Tap Product .25 Lever 1/2	Pnl 1 Tier 2	Gen. Gnd. Diff.
87U	West.	CA	.42-.47A	Factory Set	Pnl 1 Tier 2	Gen. Phase Diff.
90	Basler	SR8A	0-180VDC @ 10A	125 VDC	North Wall	Voltage Regulator
90C	Basler	MVC 108	0-220VDC 0-7A	Automatic	Pnl 1 Tier 5	Manual Voltage Control Module
94	West.	MG-6	125 VDC	No Setting	Pnl 1 Tier 1	Trip Aux.
GP	Cuttler Hammer	E50SB	Mech.Pos.	30" Gate	Gatehouse	Energize Field

SHAWMUT DEVICE SETTINGS Unit 8

DEVICE NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTIONS
3	GE	HFA171	120 VAC	No Setting	Pnl 3 Tier 3	Checking Relay
4-1	GE	HFA171	120 VAC	No Setting	Pnl 3 Tier 2	Master Relay
4-2	GE	HFA171	120 VAC	No Setting	Pnl 3 Tier 1	Master Relay
4X	Agastat	70047	1-10 Min.	6 Min.	Rear Pnl 3	Hydraulic Unit Control
5	GE	HFA171	120 VAC	No Setting	Pnl 3 Tier 4	Checking Relay
12	Woodward	6905-295		1080 RPM	Generator Shaft	120%-Overspeed Trip
12	Electro Sensor	MSP-6000	0-2000 RPM	945RPM	North Wall	105%-Overspeed Alarm
		MSP-6000	0-2000 RPM	990 RPM	North Wall	110%-Overspeed Trip
13	"	MSP-6000	0-2000 RPM	855 RPM	North Wall	95%-Full Speed
14-1	"	MSP-6000	0-2000 RPM	9 RPM	North Wall	1%-Creep
14X	GE	HGA11J70	120 VAC	No Setting	Rear Pnl 3	Start Pumps for Creep
14Z	Agastat	70041	1-10 Mins.	2 Mins.	Rear Pnl 3	Stop False Creep Alarm
20QS	Sq.D	L0-40	120 VAC	No Setting	Rear Pnl 3	Initiates Slow Sol.
20QSX	Sq.D	L0-40	120 VAC	No Setting	Rear Pnl 3	Picks up 20 QS @ 30" Gate
20WS	Sq.D	L0-40	120 VAC	No Setting	Rear Pnl 3	Water Sol. Valve
20WSX	Agastat	70041	1-10 Mins.	1 Min.	Rear Pnl 3	Prevent False H2O & Oil

Unit 8 Continued

DEVICE NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTIONS
20WSX1	Agastat	70041	1-10 Mins.	10 Mins.	Rear Pnl 3	Run Pump 10 Mins. After Shutdown
25	Basler	PRS210	.1-.5 sec 5°-40°	.15 sec.40°	North Wall	Auto-sync.
27AC/1	Porter Brumfield	KAP11AG	120 VAC	No Setting	Rear Pnl 3	Alarm 120 VAC Control Volt
27AC/3	GE	1AV-54E	110-280VAC	.9PU-216 VAC	Pnl 3 Tier 3	Trip Low System Voltage
27AC/3X	Por.Brum.	KAP11AG	120 VAC	No Setting	Rear Pnl 3	Alarm 240VAC Control Volt
32	West.	CRN-1	13.4 KW	.023A @ 0° Lever 1	Pnl 3 Tier 3	Reverse Power
33GPX	Sq.D	L0-40	120 VAC	No Setting	Rear Pnl 3	Hydrualic Pump Control
38	Ronan	X12/X84	0-300°F	Alarm 85°F Trip 95°F	Pnl 2	Nose Cone
				Alarm 85°F Trip 95°F	Pnl 2	Packing Box
				Alarm 150°F Trip 160°F	Pnl 2	Speed inc. HS Bearing
				Alarm 150°F Trip 160°F	Pnl 2	Speed inc. LS Bearing
				Alarm 145°F Trip 150°F	Pnl 2	Gen. Coup. End Bearing

Unit 8 Continued

DEVICE NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTION
				Alarm 155°F Trip 160°F	Pnl 2	Gen. Exciter End Bearings
39	PMC/BETA	414BD	5-50 Mil 10-90%	20 Mill 50%	Speed Increas.	Vibration Detector
40	West.	CW	100-600 VAR	200 Sec. Var Lever 2	Pnl 3 Tier 3	Loss of Field
41	West.	SG	120 VAC	No Setting	Pnl 3 Tier 3	Field Application
46	West.	COQ	3-5A	Tap 3.8 Lever 5	Pnl 3 Tier 3	Relay Negative Sequence
48	Agastat	70041	0-10 Min.	6 Mins.	Rear Pnl 3	Incomplete Sequence
49SD	Ronan	X12/X84	0-300°F	Alarm 150°F Trip 160°F	Pnl 2	Stator Temperature
51G	West.	CO-8	.5-2.5A	Tap.5 Lever 1	Pnl 3 Tier 5	Neutral Overcurrent
51V-2	West.	COV-8	2-6A 80-100 VAC	Tap 2 Lever 3 90 VAC	Pnl 3 Tier 5	Volt Control Over-current
59T	Basler	05391	240 VAC	No Setting	Pnl 3 Tier 1	Field Breaker
59X	GE	HGA111J19	240 VAC	No Setting	Rear Pnl 3	Overvoltage Trip & Alarm Aux.
81U/59	Basler	UFOV260A	125-150%VAC	140VAC 53 hz	Rear Pnl 3	Underfrequency/ Overvoltage Module
86G	Electro-Sw.	LOR	125 VDC	None	Pnl 3 Tier 4	Lockout Relay

Unit 8 Continued

DEV.NO.	MFG.	MODEL NO.	RANGE	SETTING	LOCATION	FUNCTION
87G	West.	CWC	Upper .25-1 Low 1-4	Top Product .25 Lever 1/2	Pnl 3 Tier 4	Gen. Gnd. Diff.
87U	West.	CA	.42-.47A	Factory Set	Pnl 3 Tier 4	Gen. Phase Diff.
90	Basler	SR8A	0-180VDC @ 10A	125 VDC	North Wall	Voltage Regulator
90C	Basler	MVC 108	0-220VDC 0-7A	Automatic	Pnl 3 Tier 1	Manual Voltage Control Module
94	West.	MG-6	125 VDC	No Setting	Pnl 3 Tier 5	Trip Aux.
GP	Cuttler Hammer	E50SB	Mech.Pos.	30" Gate	Gatehcuse	Energize Field

Intake Control Gates

The new units will be on a first-to-run basis at the facility, i.e. they will be base loaded up to 100% of the time and the old turbine-generators will be stepped on as river flows permit. Based on this concept of operation, the extra cost of installing butterfly valves over the cost of controlled, car-wheeled gates for start-up, shutdown, and emergency use could not be warranted. The control gates are of steel construction and loaded with concrete ballast. The ballast was added to give an emergency drop time of 12 seconds. The lifting device is a hydraulically operated six-inch cylinder operating at 2,200 psi oil pressure.

The hydraulic system is capable of raising the gate at a slow speed to allow filling of the unit intake and draft tube, and bring the unit to synchronization speed for putting on line. After synchronous speed of the generator (900 rpm) is achieved, the system raises the gate at a fast speed to the full-open position.

The design of the gates and hydraulic system was the responsibility of Kleinschmidt & Dutting. The control method is not new--several other installations designed by Kleinschmidt & Dutting have had satisfactory applications.

Emergency Intake Gate

The emergency intake gate will isolate one unit in case of an emergency and if the control gate fails to function or to seal. The gate is located upstream of the control gate.

The gate is of two-piece steel construction. The two piece concept was selected due to the advantage of smaller hoist load, lower headroom requirements, and smaller enclosure. The lifting structure has an overhead monorail system with two ten-ton hoists, each suspending one half of the gate. In the event a gate has to be lowered in either gate slot, the gate section over the slot is lowered first and the other section transported over the slot and lowered into position on top of the first section. The gates are of the car-wheel design fitted with rubber J- seals.

Draft Tube Gate

The draft tube gate will isolate one unit at a time from tailwater for the purposes of dewatering for inspection or maintenance. The runner centerlines are +1.0 feet above normal tailwater, necessitating the dewatering.

The gate is a one-piece, sliding type gate fitted with rubber J- seals. The gate and gate guides are fitted with wedging devices which will wedge the bottom of the gate for seal contact. The gate will normally be stored by dogging in the top part of one of the gate slots. Lowering into position will be done by a mobile crane when required.

<u>Powerhouse Bridge Crane</u>

The powerhouse crane is a 15 ton, single girder, all electric, overhead bridge crane. Only one crane manufacturer could meet all the space limitations specified, Boston Tram Rail Co., Inc., Holbrook, Massachusetts. The crane load was determined by the weight of the generator which weighed approximately 15 tons.

The crane has a span of 45 feet to service both units. The hoist has a two-speed control of 7.8/2.3 fpm to permit the necessary control during equipment handling.

The trolley and bridge have single-speed control of 26 fpm and 40 fpm respectively. Power is supplied to the crane by a festooned flat cable on a pipe rack. The hoist is fitted with a 6 part chain. Chain was selected as a preference over cable due to lack of stretch while making machine settings. The crane performed very well during the erection of the turbine-generator.

Emergency Gate Hoists

Hoists to handle the two-piece emergency intake gate were purchased from American Chain and Cable Co. The electric hoists are 10 ton with single speed (1.3 fpm), 46 feet lift, chain fitted, and hand geared trolley. The hoists are conventional monorail mounted units, except for the long lift chain which was considered more desirable for water submergence.

Rack Rake

The hydraulically operated rack rake consists of a rake, telescoping boom, and hydraulic power system mounted on a traveling gantry. The rake will be used to remove debris which has accumulated on the intake trash racks while the generating units are in operation. The rake is capable of boom extension and retraction, boom movement away and towards the racks, rake unloading to the gantry platform, and traveling the length of the intake of units #7 and #8 for servicing both sets of intake racks and trash disposal.

The boom length was designed to a length greater than required for the present location to accommodate a future location of the unit to the forebay intake at such time as the old powerhouse units are retired and the station repowered.

The rake was custom built by L. H. Berry, Inc., Conway, New Hampshire.

VIII. Project Construction

Construction drawings and specifications for the Shawmut Redevelopment Project were issued in early May, and a contract was awarded to Cianbro Corporation, Pittsfield, Maine, on May 27, 1981.

Site clearing mobilization started immediately, and construction of the earth cofferdam began June 3rd upon acquiring the dredging permit from the U.S. Corps of Engineers.

The excavation of 13,000 yards of earth and 5,000 yards of ledge began the week of June 8th and continued through mid-August.

One notable aspect of the excavation was the manner of ledge removal. The vertically bedded chlorite phyllite ledge was pre-split to ensure a relatively smooth face--as this face was to be the outside form for the powerhouse walls. A particle velocity limitation of 2" per second was used during blasting to protect the adjacent structures. This proved to be no problem since small charges were sufficient to break the ledge into relatively small pieces. The excavated ledge proved to be extremely useful for barrier walls, cofferdams, and roadway. When used in the training wall core, the material maintained a 15" head differential.

During the excavation process, approximately 1,600 linear feet of rock bolts were used to stabilize the exposed rock faces. This procedure involved the drilling, grouting and tensioning of steel rods. These rods were positioned so that any loose or fractured faces of ledge were safely anchored, thereby preventing them from falling into the excavation.

The Dywiday rock bolting system was used and proved very satisfactory. One major advantage of this particular rock bolting system is that the bolts can be ordered to stock lengths and field cut as needed. Any bolts that do not take (due to a soft spot in ledge, etc.) can be re-used elsewhere or re-installed at a different depth. The percentage of bolt failures under test was very low, making for a safe, economical, and reliable bolting system.

While the excavation was proceeding, assembly of the steel draft tube liner sections began and continued through the week of August 10th. The steel draft tube liner consisted of four sections: the intake transition, intake ring, draft tube elbow, and draft tube extension.

Each of these sections (with the exception of the intake ring) consisted of four individual parts. Each section had been pre-assembled at the factory and fitted with tabs and bolts to aid in field assembly for field welding.

We found it very beneficial to pre-assemble and align these components prior to field welding. For example, the intake ring (1 piece) was bolted to the draft tube elbow section (4 pieces). An alignment wire was then established through the center of the three critical areas to assure that proper alignment tolerance was maintained. (The three critical areas being the machined upstream bearing lip, the runner throat, and the shaft packing box flange). Once assured that proper tolerances were obtained, the individual parts were welded to form a section. Later, as the excavation was completed, these pre-welded draft tube sections were set into place and the individual sections welded together to complete the draft tube liner assembly.

Another critical aspect of the draft tube installation is the final alignment. Optical instruments were used in conjunction with special targets at the three critical diameters. The individual sections were thus set in final position and the alignment monitored during each successive stage of concrete embedment.

Approximately 3,700 yards of 4,000 psi concrete was placed during the course of the project from July 28, 1981 to February 4, 1982. Since most of the critical powerhouse concrete was placed during the winter months, it was extremely important to follow proper cold weather practices for concrete. These involved using heated mix water, insulating and heating formwork both before and after placing concrete, and carefully monitoring the concrete temperature.

The Maine winter of 1981-1982, with its above average snowfall and below average temperature, only served to complicate the already critical scheduling of the concrete work. Another hindrance to the progress of the concrete work was the dependency of the powerhouse wall construction upon the completion of the draft tube embedment. This created a construction bottleneck in the most critical phase of the project. In the future, the design will be modified, making the various structural concrete components of the powerhouse as independent as possible from the draft tube embedment.

The concrete powerhouse shell was complete when the last section of cast-in-place concrete roof was placed on January 29, 1982.

Along with the above mentioned difficulties in maintaining the concrete schedule, fall floods also left their mark on the schedule. On September 24th and again on October 24th, the construction cofferdam had to be intentionally flooded to prevent an uncontrolled breeching by the rising waters of the Kennebec River. An average loss of 3-5 days per occurrence resulted.

Central Maine Power Company's electrical crew began the installation of systems and components in early January 1982. At the same time, the Cianbro Corporation's mechanical crew began the assembly and installation of the mechanical equipment.

Through the efforts of both crews, the necessary mechanical and electrical systems were completed and ready for testing on schedule.

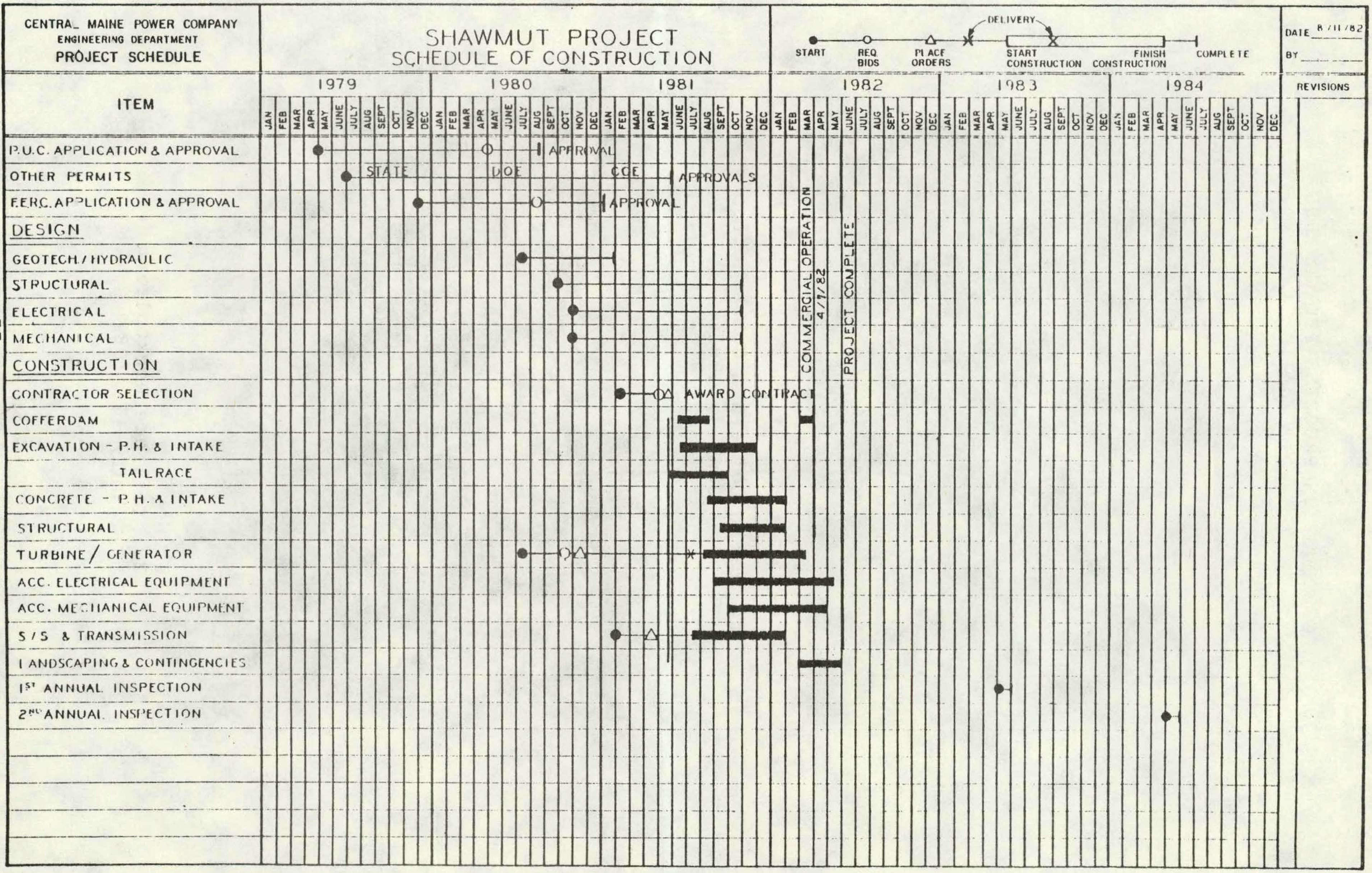
Testing and trouble shooting occupied most of March, resulting in Unit #7 being operational on March 17, 1982 and Unit #8 operational on March 24, 1982. Although both units were declared commercial on April 1, 1982, system debugging and testing continued for several more weeks.

Once the units were generating electricity, emphasis shifted to the construction and installation of the secondary systems, such as heating and ventilating, emergency lighting, and fire alarm. This work, along with the powerhouse painting, security fence installation, and yard grading and paving, was completed in time for the June 3rd project dedication ceremony.

The actual schedule of construction is shown on Figure II.

The following construction progress pictures illustrate the stages of progress from the beginning of civil work in June 1981 with the construction of the tailwater cofferdam to the final project completion of the project at the end of April 1982.

FIGURE II

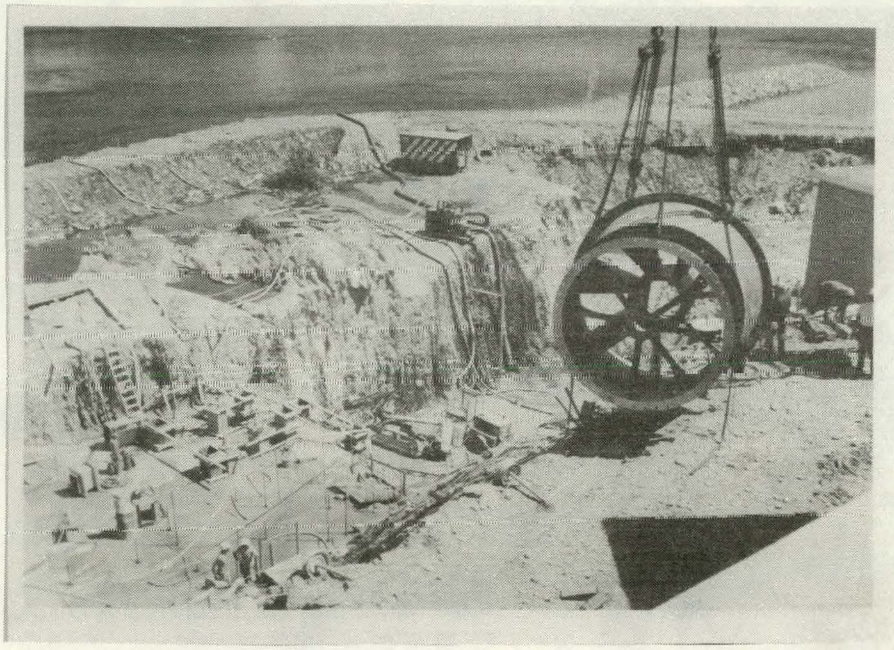


CENTRAL MAINE POWER COMPANY
ENGINEERING DEPARTMENT
PROJECT SCHEDULE
SHAWMUT PROJECT
SCHEDULE OF CONSTRUCTION
START
REQ BIDS
PLACE ORDERS
DELIVERY
START CONSTRUCTION
FINISH CONSTRUCTION
COMPLETE
DATE 8/11/82
BY
REVISIONS
ITEM
1979
1980
1981
1982
1983
1984
JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV DEC
P.U.C. APPLICATION & APPROVAL
APPROVAL
OTHER PERMITS
STATE
DOE
COE
APPROVALS
F.E.R.C. APPLICATION & APPROVAL
APPROVAL
DESIGN
GEOTECH./HYDRAULIC
STRUCTURAL
ELECTRICAL
MECHANICAL
CONSTRUCTION
CONTRACTOR SELECTION
AWARD CONTRACT
COFFERDAM
EXCAVATION - P.H. & INTAKE
TAILRACE
CONCRETE - P.H. & INTAKE
STRUCTURAL
TURBINE / GENERATOR
ACC. ELECTRICAL EQUIPMENT
ACC. MECHANICAL EQUIPMENT
S/S & TRANSMISSION
LANDSCAPING & CONTINGENCIES
1ST ANNUAL INSPECTION
2ND ANNUAL INSPECTION
COMMERCIAL OPERATION 4/1/82
PROJECT COMPLETE

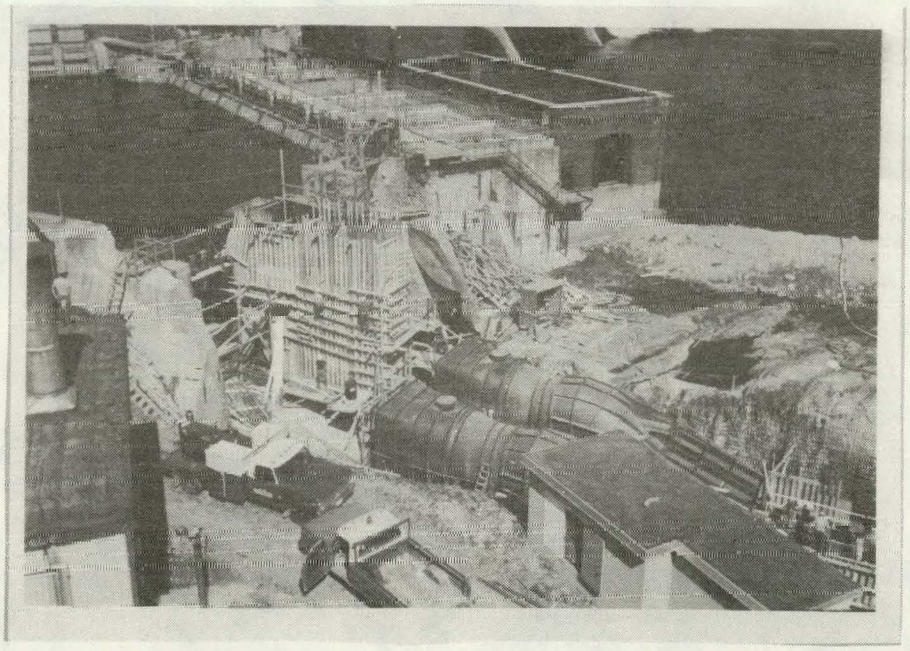
CONSTRUCTION PROGRESS PHOTOGRAPHS

1. Earth Cofferdam Construction
June 4, 1981

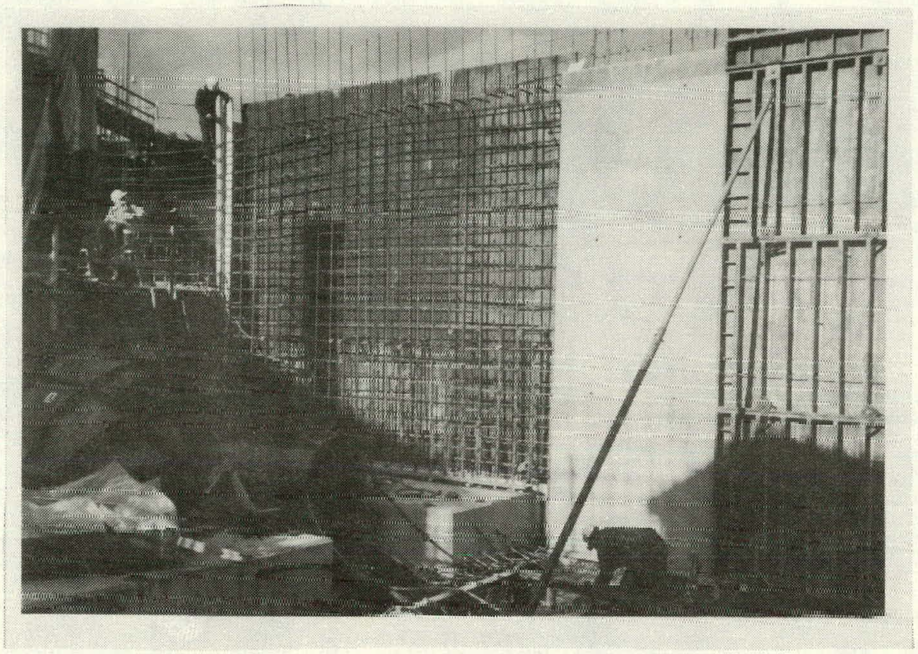
2. Tailrace Rockbolting
July 17, 1981



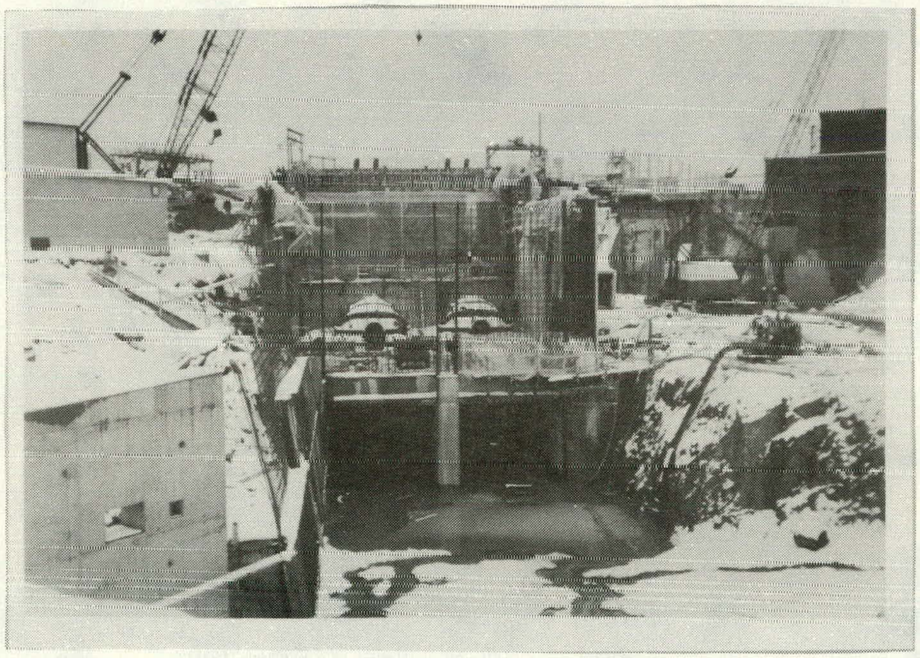
3. Placing Unit #7 Fixed Vane Assembly
August 20, 1981



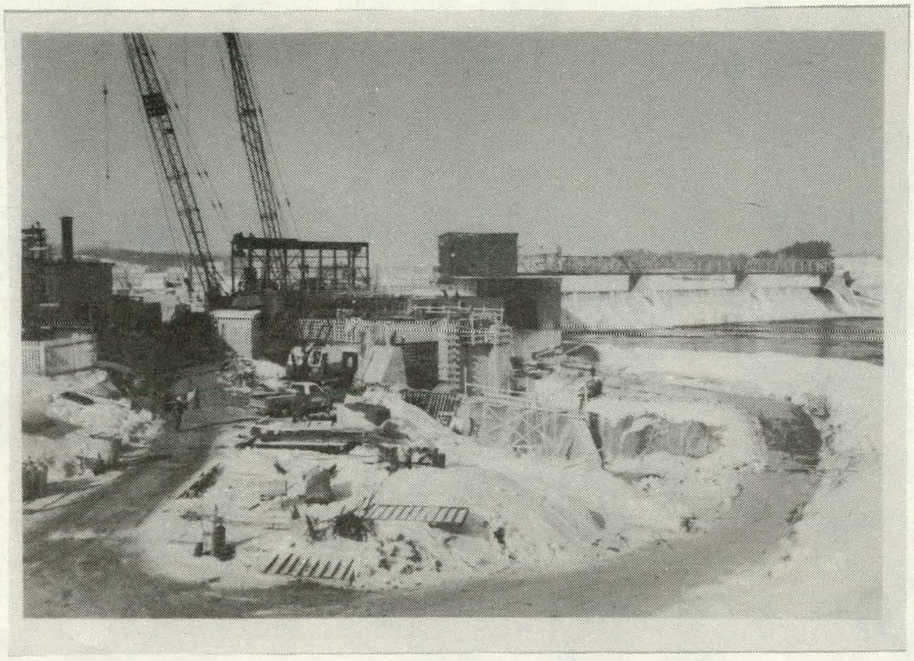
4. Draft Tube Liner Assemblies in Position
September 16,1981



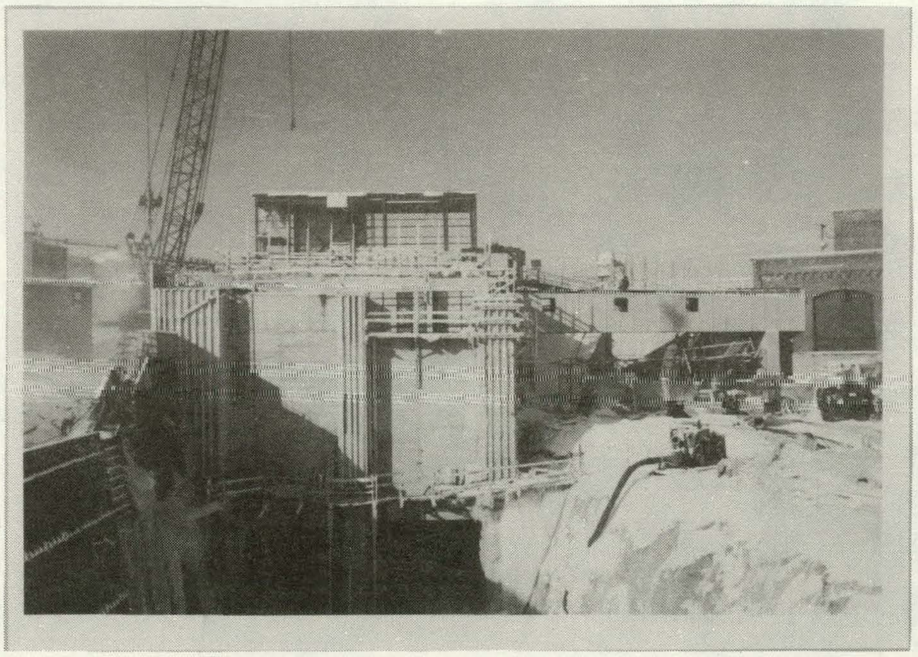
5. East Powerhouse Wall
November 23, 1981



6. Powerhouse
December 16,1981

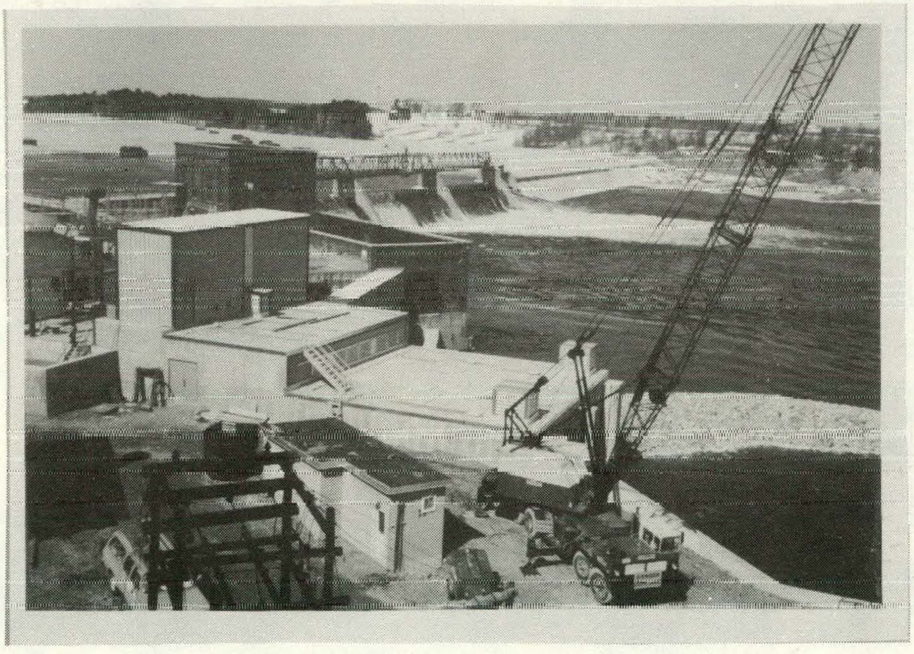


7. Powerhouse and Tailrace
January 25, 1982



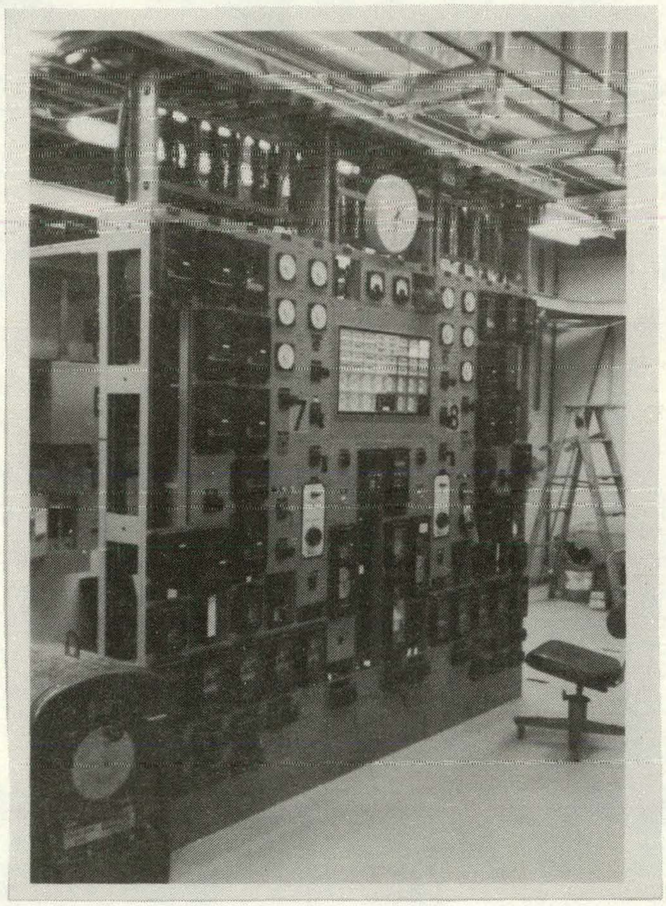
8. Powerhouse and Access Bridge
January 25, 1982

9. Unit #7 Runner and Shaft Assembly
January 25, 1982

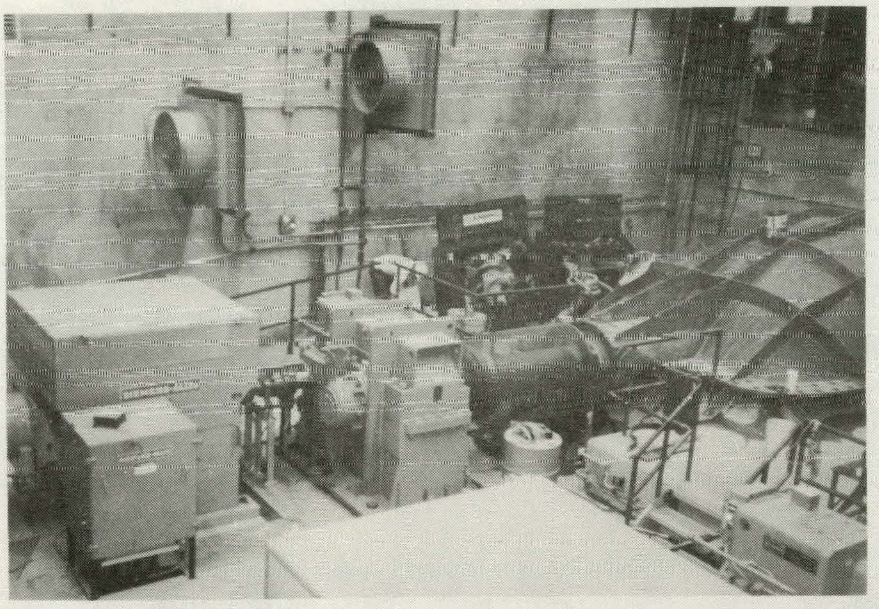


10. Powerhouse
March 24, 1982

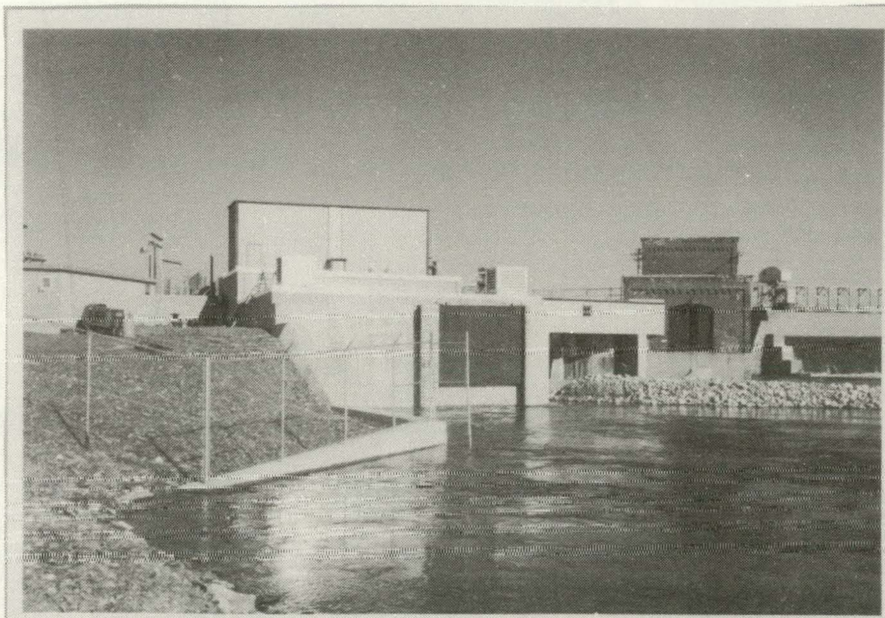
No. 11 Hydraulic Rack Rake



No. 12 Control Panel



13. Unit #8 Equipment Layout
March 24, 1982



14. Completed Project
April 29, 1982

IX. Testing and Start-Up

The testing and start-up phase for the first turbine-generator unit and associated equipment was initiated on March 1, 1982 with the preparation of equipment, instrumentation and control check-off lists, and testing procedures. Check-off lists covered approximately forty basic systems, which included about three-hundred component check points. The first unit was operationally tested on March 17, 1982 and the second unit on March 24, 1982.

Problems encountered during this phase consisted of wiring errors, incorrect equipment installation, misapplication of equipment, equipment failures, and incorrect design. The wiring errors were concentrated primarily in used and reconfigured switchgear and, to a lesser degree, in the main control panels. Incorrect installation of equipment occurred in the control gate hydraulic system where: a solenoid valve was installed backwards; piezometer tubing was brought to the wall-mounted test rack in a mixed array; the oil fill line to the upstream runner bearing was pulled through a plastic conduit with obstructions requiring the oil to be pumped to the bearing instead of gravity filling; and other lesser problems.

Misapplication of equipment occurred with the installation of an electronic oil level detecting device in the runner nose bearing. The instrument utilizes a prism which becomes coated with splashed oil, giving false high-level alarms. A shield was installed to protect the detector from the splashing oil and appears to be operating satisfactorily. Another improper equipment application or design problem has occurred in the water supply to the turbine shaft packing gland. The water is pumped from the forebay through very fine strainers to meet the micron requirements of the turbine manufacturer. Due to the fairly high debris content of the river water during high flows, the strainers become plugged rapidly--requiring very frequent cleaning. The problem is being assessed at this time to see if strainers with a coarser mesh can be used.

Failed equipment consisted primarily of two minor items; the vibration detectors on the speed increaser and the station sump oil detector. Both were returned to the manufacturer for repair or replacement.

Incorrect design has been responsible for the most serious operational problems. The areas of major concern are the design of the hydraulic control system for the control gates and the runner and stay vane design of the turbines. The control gate hydraulic system was designed to start-up and shutdown the units in lieu of the use of wicket gates to control water admission to the runner. The system was designed with two-speed control to be achieved by two positive displacement hydraulic pumps supplying the gate lift cylinder. In actual operation, it was found that the slow speed gate lift accelerated the units faster than the automatic synchronizer could perform. This condition introduced greater slip frequency and larger out-of-phase angle than tolerable on the distribution system. The problem was aggravated by higher gate friction than anticipated, which required increasing the system pressure. Several modifications were made to the system to gain the proper gate speed control with varying degrees of success. The units appear to have two points of speed dip when accelerating. The higher speed dip occurs at about 870 rpm (synchronous speed: 900 rpm). After passing this point, acceleration is rapid. The speed switch used to apply field to the generator sensed speed from the turbine shaft. The speed change would cause the speed switch to open and close several times prior to achieving speed-no-load. A modification was made whereby the field is applied by a position switch on the control gate. Since head variations would normally only delay the control gate high speed operation by a short-time, and start-ups are expected to be infrequent, this approach should be satisfactory. An evaluation is being done on the hydraulic system which will be reflected in the design of a two tube turbine installation being undertaken at Brunswick on the Androscoggin River.

An efficiency test was performed on both units by Aquatec, Inc. of Vermont. A draft report of the results indicated that the units are using a higher water flow than expected, which contributes to a much lower unit efficiency than guaranteed. The turbine vendor proposed two modifications, one would involve extending the trailing edge of the turbine blades, which would in effect reduce the vent opening as well as reduce the unit area power loading on the blades. The change should help reduce the flow to within the intended limits of design and reduce or eliminate cavitation taking place at the top quadrant of the runner. After this modification is completed on the first unit, an index test will be run to verify results. If results are as predicted, the second modification will be undertaken, which will consist of cutting the inlet stay vanes and changing their orientation angle. The present vane angle is 70°; the modification would change the angle to 60°, with a net result of decreasing flow and raising the efficiency at the guaranteed point. After the modifications are complete, another full efficiency test will be conducted by Aquatec, Inc. Assuming results are satisfactory, work will start immediately on the second unit. All costs of work, material, and tests will be born by the turbine manufacturer.

The original design for control power consisted of obtaining an alternating current supply from the station service system. This approach would eliminate the need of a new storage battery system or a long supply cable from the storage battery in the existing powerhouse. The ac system incorporated stored energy (capacitor) trip devices for the breaker trip circuit and the lockout relays. Numerous failures occurred from burned-out components or unexplained fail-to-trip incidences. Because of the lack of dependability, the circuits were rewired to trip on dc power from the existing batteries in the old station and the capacitor trip devices were reserved for backup. It was suspected that high voltage spikes from the capacitive trip devices were responsible for causing several electronic card failures in the annunciators, possibly due to induction into the circuits.

It has been common practice in the past to group or parallel alarm circuits for economy and by importance of the particular individual points being monitored. During the start-up, this arrangement made it very difficult to trace unit trip causes. The new approach will be to annunciate all unit trip contacts.

The control panels had insufficient human engineering applied in the design layout of panel switches and instruments. The units will normally operate unattended, but during start-up, testing, and maintenance, an improved panel layout could inhibit possible operating errors.

Noise from the rotating equipment has been of some concern. Most of the noise eminating from the turbine, generator, and speed increaser is in the low frequency range. Noise from the oil to air fan coolers for the speed increasers is higher frequency and objectionable. A study was performed to ascertain the extent of the problem. Recommendations included changing the fan oil coolers to a cooling tower type and also placing sound absorbing blankets on the removable draft tube cover. No firm decision has been reached to date.

In overall summary, the testing and start-up progressed satisfactorily and the commercial operation date of April 1, 1982 was met. However, the correction of many deficiencies have been made since that date, and the final correction of the hydraulic design of the control gates and turbine modification remains to be completed and assessed.

X. Operation

General Method of Starting

The Shawmut units are started, synchronized to the line, and loaded automatically via controls incorporated in the control and relay panels. In response to a start command, the unit control gate opens at slow speed to a speed-no-load-minus position, then creeps slowly upward (increased opening). As synchronous speed is approached, a gate position switch initiates application of the unit field (at approximately 95 percent of synchronous speed). Thereafter, an automatic synchronizing relay monitors machine and system speeds and initiates unit breaker closure at the appropriate speed and phase angle. Once the unit is connected to the system, the control gate is opened fully at fast speed. If the auto sync relay fails to achieve synchronism, the gate will go closed either from unit overspeed or timeout of the incomplete sequence circuit. The operator then initiates a re-start.

Detailed Starting Procedure

A. Pre-start checks:
1. Power to gate operator hydraulic pumps 1 and 2.
2. Power to speed increaser lube oil pump.
3. Power to oil cooler fans 1 and 2.
4. Power to powerhouse intake vent fans.
5. Power to control circuits and voltage regulator.
6. Turbine nose cone bearing oil level.
7. Speed increaser oil level.
8. Generator guide bearing oil level.
9. Generator guide/thrust bearing oil level.
10. Turbine shaft packing gland water supply.

11. Check the following control/relay panel devices.
    a. Generator lockout (86G) reset.
    b. Generator control mode (43G) in local.
    c. Generator breaker (KG) open.
    d. Synchronizing control switch on.
    e. Voltage control mode automatic.
    f. System voltages proper magnitude (3 phase).
    g. All relay targets cleared.

B. Starting Procedure
   1. Manually initiate starting sequence via 1CS.
   2. Observe rotation of turbine shaft.
   3. Observe field energization on field volt meter.
   4. Observe generator phase voltage on generator volt meter.
   5. Observe unit approaching synchronism on synchroscope.
   6. Observe indication of generator breaker closing.
   7. Observe generator output rising and, finally, indication of fully open gate.

C. Post Start Checks
   1. Turbine packing gland water pressure and flow.
   2. Speed increaser oil pressure and level.
   3. Transfer of speed increaser oil pump from electric to mechanical prime mover.

Remote Control Station

The foregoing description of unit controls describes devices in the powerhouse for Units 7 and 8. In addition, a small control panel is provided for station operators near their booth in the old powerhouse for Units 1 through 6. Through this panel, the remote operator has indication of unit kilowatts, vars, amperes, and generator breaker position. He also has a start, normal stop, or emergency stop command capacity.

XI. Project Costs

At the time this report was written, there remained estimated expenditures in the amount of $143,600 to complete the Shawmut Project, bringing the plant gross capital investment to $5,561,350. The estimated project cost submitted with the proposal to DOE in June 1980 was $5,796,000, of which $5,716,000 represented investment in plant. The balance of $80,000 represents operation and maintenance costs for two years following commercial operation. Based on civil contract costs, revised construction schedules, and major equipment purchases, the capital cost estimate was revised to $5,216,000 in May 1981 and the project budgeted for this amount, plus $80,000 for operation and maintenance over the two years following commercial operation.

Although the actual gross plant cost overran the project budget by only 7.5%, specific accounts should have some explanation of the variances which occurred.

331 Structures & Improvements

A major variance occurred in the cost of the powerhouse concrete and reinforcing, amounting to over $100,000. The lack of detail in estimating of quantities was the main contributor to the overrun.

Other extra costs were incurred in underestimating the miscellaneous steel work, such as railings, hatches, etc., which amounted to $20,000. Holes made in the draft tube liners to aid in placing concrete and then rewelded accounted for $11,000. The completed, in place, cost of the access bridge to the old powerhouse cost an additional $20,000. Special construction joints were added to the powerhouse structure at a cost of $13,000. Yard grading, paving, and erecting a security fence added another $24,000. The above mentioned items account for approximately 50% of the $491,365 variance. The remaining 50% was distributed over many items and represented 5% or less of the estimated amounts for specific subaccounts.

332 Reservoirs, Dams, and Waterways

All items of work in this account compared well with the construction budget with the exception of the additional cost for replacing riprap on the cut-off wall near the powerhouse and the cost of replacing the rack support beams in the intake. A small sluice gate, which discharges adjacent to the powerhouse, washed away part of the rap rap used on the cut-off wall near the powerhouse and was replaced by heavier rock. An initial inspection of the rack support beams suggested they were not severely deteriorated, but on closer examination, a decision was made to replace them with new beams. The total additional cost of this effort alone was $66,000.

333 Waterwheels, Turbines, and Generators

The major cause of overrun by $136,470 was due to the extensive cost of debugging and modifying the intake control gate hydraulic system and other control features. The extra costs for this work alone accounted for over $87,000. As mentioned in the design section of this report, the hydraulic system required considerable redesign in the field.

334 Accessory Electrical Equipment

A major modification to the electrical duct runs between the new and old powerhouses accounts for the major part of the overrun in this account. The original design called for the conduit runs to be installed in the enclosed bridge connecting the two powerhouses. After reviewing future plans for replacing the existing turbine-generators in the old powerhouse, which would require removing the bridge during construction, the conduit runs were relocated to a concrete encased duct bank constructed on ledge between the two buildings. A considerable quantity of fill concrete was necessary to accomplish this task. Extra conduit was also installed in the duct run to take care of the future construction.

Additional costs were also incurred from modifications to the station service system. The new units and old units have separate station service transformers with interconnections for redundancy. During construction, it was found that much of the old station service equipment was unserviceable and had to be replaced.

375 Overheads and Expenses

Part of the variance in this account occurred primarily in the consulting engineering and Central Maine Power engineering cost. Extra costs were incurred from design modifications, the debugging and testing of equipment, and, to some degree, underestimating field supervisory engineering.

Escalation was greatly overestimated in the DOE proposal due to a higher escalation rate assumed over a longer time frame than used in preparing the budget estimate. At the time the budget estimate was made in May 1981, the value of the major equipment and civil contract were known, and the escalation rate was applied primarily to the construction period. The summary of costs indicates that the escalation, together with the contingency account, have been distributed to other direct and indirect costs, as required. The estimated cost of operation and maintenance for two years after commercial operation is not included as part of the gross plant investment, but is shown on the cost summary for comparison with the proposal made to the DOE.

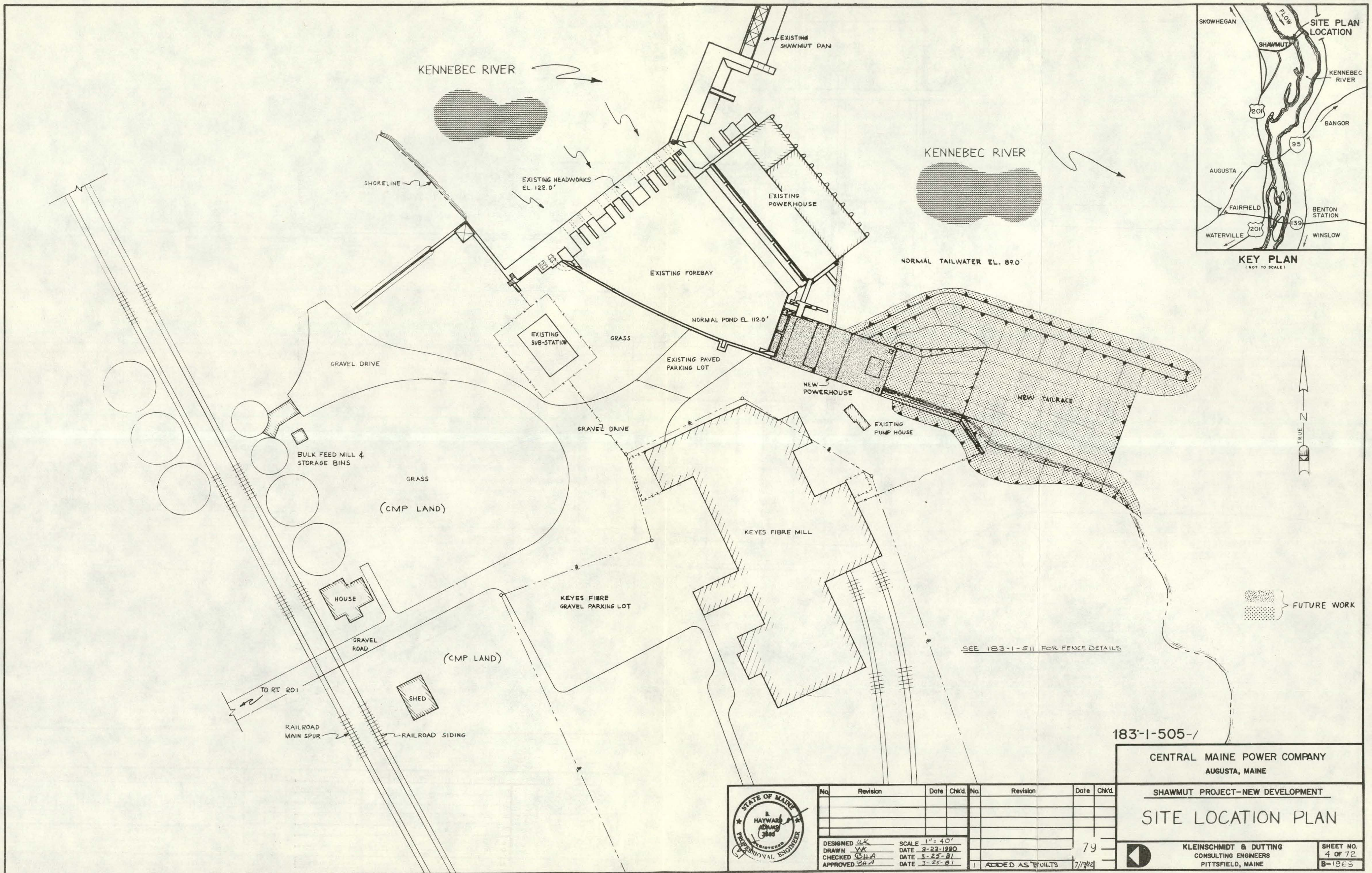
Table III shows a detailed comparison of project costs by FERC accounts.

Financing

The construction costs were funded utilizing unsecured short-term borrowings. At appropriate intervals, such short-term debt will be permanently funded with a mixture of mortgage bonds, preferred, and common stock.

CENTRAL MAINE POWER COMPANY
SHAWMUT REDEVELOPMENT PROJECT
COST SUMMARY AS OF JUNE 30, 1982
TABLE III

FERC PLANT CONST. ACCT. DESCRIPTION	DOE PROPOSAL EST. COST	BUDGETED COST 5/31/80	EXPENDED TO DATE	ESTIMATED COST TO COMPLETE	TOTAL COST	EXPENDED MORE/(LESS) THAN BUDGETED
331 Structures & Improvements	$ 503,000	$ 581,000	$1,067,365	$ 5,000	$1,072,365	$ 491,365
332 Reservoirs,Dams & Waterways	550,000	946,000	963,370	24,000	987,370	41,370
333 Waterwheels,Turbines & Gens.	1,535,000	1,427,000	1,542,470	21,000	1,563,470	136,470
334 Accessory Elec. Equipment	313,000	208,000	377,679	10,000	387,679	179,679
335 Power Plant Equipment	42,000	107,000	50,449	10,000	60,449	(46,551)
336 Roads & Bridges	10,000	25,000	-0-	18,000	18,000	(7,000)
353 Station(Switchyard) Equip.	45,000	125,000	149,019	-0-	149,019	24,019
355 Poles & Fixtures	-0-	2,500	-0-	-0-	-0-	(2,500)
356 Overhead Conductors & Devices	2,000	2,500	-0-	-0-	-0-	(2,500)
Subtotal	$3,000,000	$3,424,000	$4,150,352	$ 88,000	$4,238,352	$ 814,352
375 Overheads & Expenses						
Infor. Dissemination	$ 60,000	$ 60,000	$ 32,268	$ 28,600	$ 60,868	$ 868
K&D & CMP Co. Engr. FERC Applications & Environ.	650,000	590,000	872,512	12,000	884,512	294,512
Gen. Exp., Overhead & Admin. Services Including Legal	250,000	129,400	198,102	15,000	213,102	83,702
AFUDC	419,000	347,600	244,516	-0-	244,516	(103,084)
Subtotal Specific Const.Costs	$4,379,000	$4,551,000	$5,497,750	$ 143,600	$5,641,350	$1,090,350
Contingency	390,000	400,000	These Funds Have Been	Distributed		-0-
Escalation	947,000	265,000	To The Above	Accounts As Needed		-0-
Gross Plant Investment	$5,716,000	$5,216,000	$5,497,750	$ 143,600	$5,641,350	$ 425,350
O & M (2 years)	80,000	80,000	-0-	80,000	80,000	-0-
TOTAL	$5,796,000	$5,296,000	$5,497,750	$ 223,600	$5,721,350	$ 425,350
D.O.E. Funding	($850,000)		($850,000)	$662,000	($188,000)	($850,000)



183-1-505-1

CENTRAL MAINE POWER COMPANY
AUGUSTA, MAINE

SHAWMUT PROJECT–NEW DEVELOPMENT

SITE LOCATION PLAN

KLEINSCHMIDT & DUTTING
CONSULTING ENGINEERS
PITTSFIELD, MAINE

SHEET NO. 4 OF 72
B-1963

STATE OF MAINE — B. HAYWARD ADAMS 3865 — REGISTERED PROFESSIONAL ENGINEER

No.	Revision	Date	Chk'd.

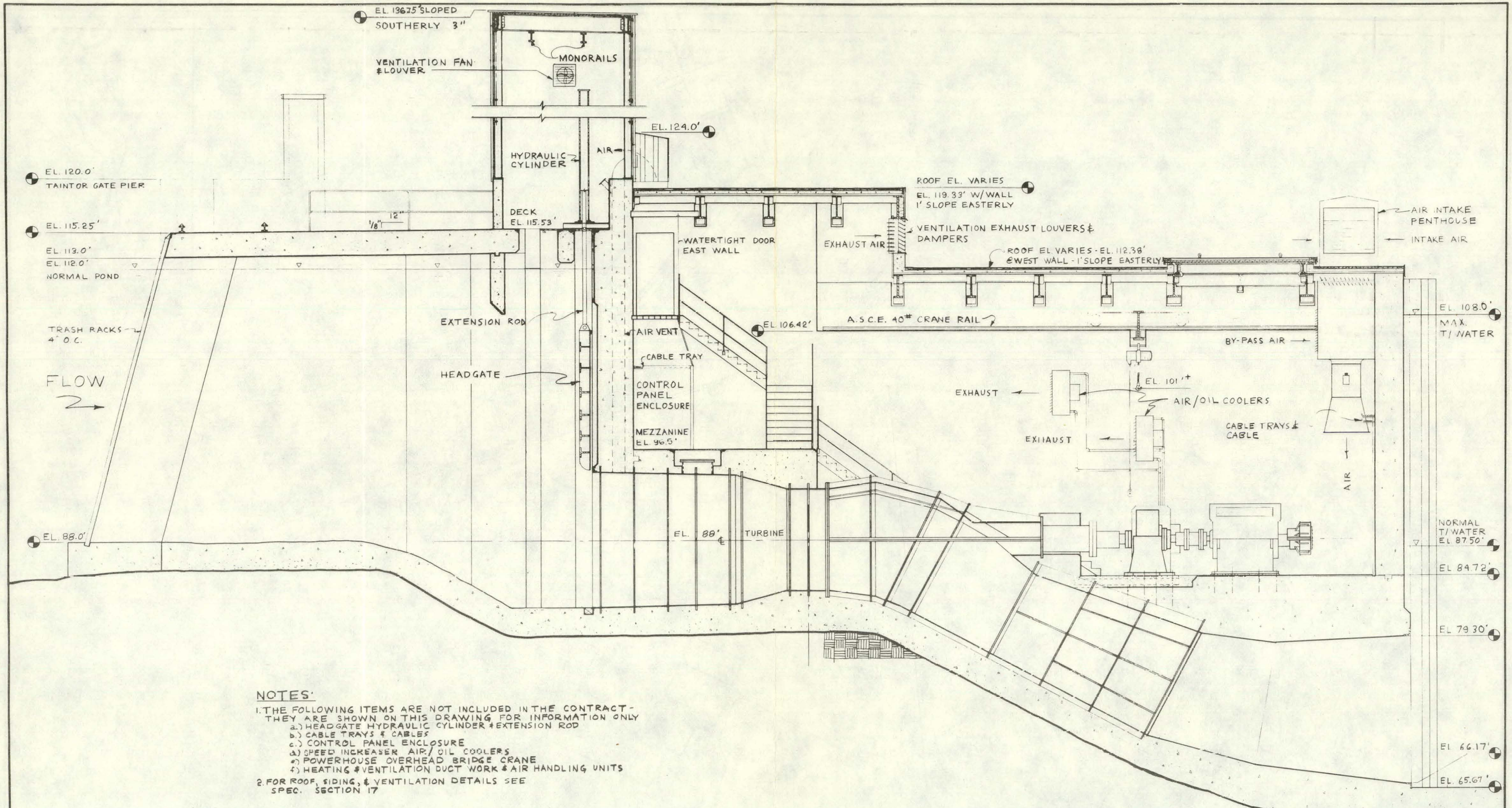
No.	Revision	Date	Chk'd.
1	ADDED AS BUILTS	7/19/82	

79

DESIGNED UK — SCALE 1" = 40'
DRAWN VK — DATE 9-23-1980
CHECKED BHA — DATE 3-25-81
APPROVED BHA — DATE 3-25-81

K&D No. SD-1

MICROFILMED ___ ___ ___



NOTES:

1. THE FOLLOWING ITEMS ARE NOT INCLUDED IN THE CONTRACT - THEY ARE SHOWN ON THIS DRAWING FOR INFORMATION ONLY
   a.) HEADGATE HYDRAULIC CYLINDER & EXTENSION ROD
   b.) CABLE TRAYS & CABLES
   c.) CONTROL PANEL ENCLOSURE
   d.) SPEED INCREASER AIR/OIL COOLERS
   e.) POWERHOUSE OVERHEAD BRIDGE CRANE
   f.) HEATING & VENTILATION DUCT WORK & AIR HANDLING UNITS
2. FOR ROOF, SIDING, & VENTILATION DETAILS SEE SPEC. SECTION 17

183-42-504-1

CENTRAL MAINE POWER COMPANY
AUGUSTA, MAINE

SHAWMUT PROJECT-NEW DEVELOPMENT

LONGITUDINAL SECTION

STATE OF MAINE — B. HAYWARD ADAMS 3863 — REGISTERED PROFESSIONAL ENGINEER

No.	Revision	Date	Chk'd.	No.	Revision	Date	Chk'd.
				1	ADDED AS BUILT	6/7/82	

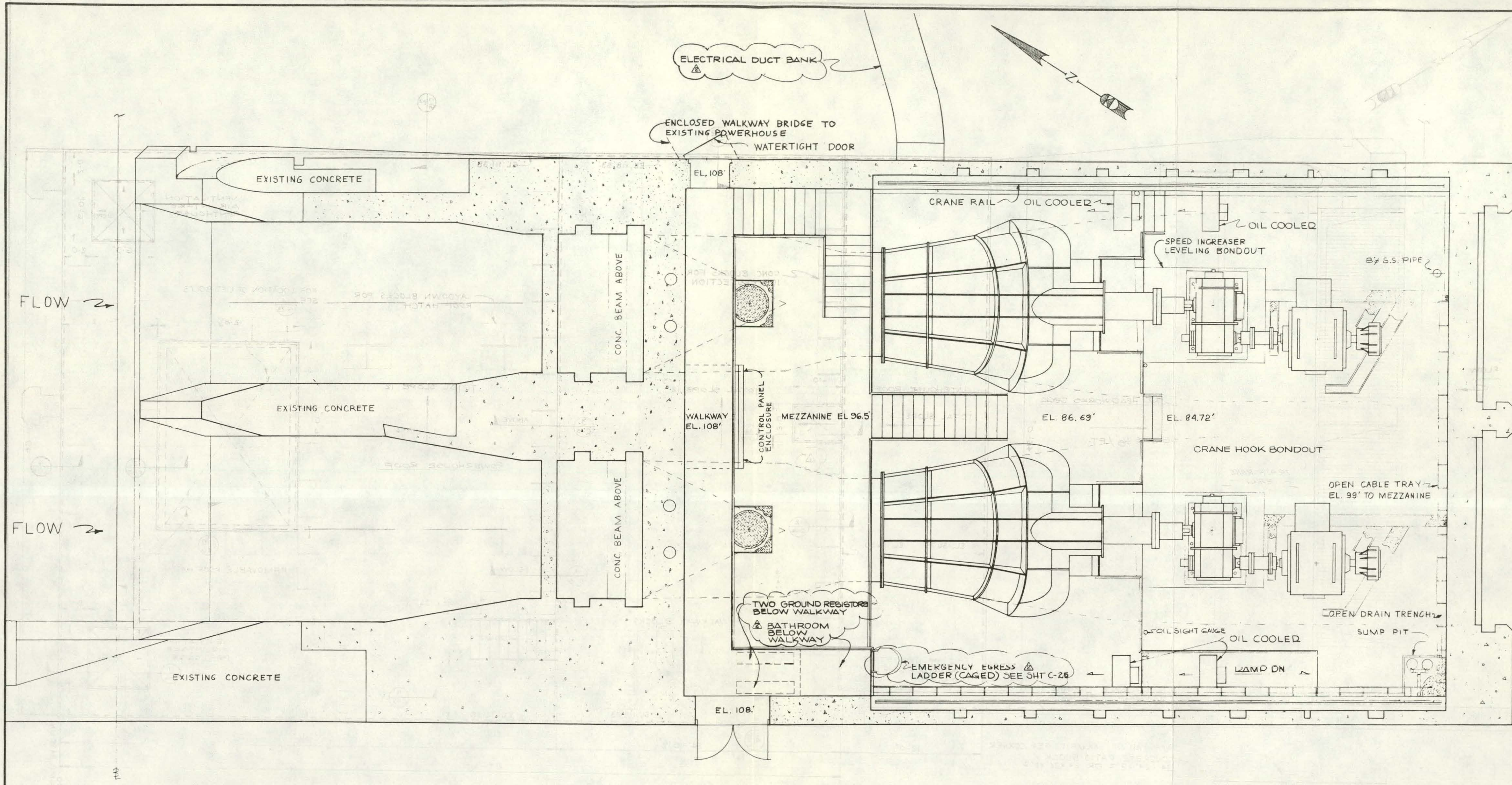
DESIGNED WK — SCALE 1/4" = 1'-0"
DRAWN WK — DATE 1/27/81
CHECKED BHA — DATE 3/25/81
APPROVED BHA — DATE 6-5-81

KLEINSCHMIDT & DUTTING
CONSULTING ENGINEERS
PITTSFIELD, MAINE

SHEET NO. 13 OF 72
B-2139

K & D No. C-1

MICROFILMED ___ ___ ___



⚠ SEE DWG. S-11 FOR BONDOUTS

183-42-505-1

No.	Revision	Date	Chk'd.	No.	Revision	Date	Chk'd.
2	BATH., ELECT. BANK ADDED-LAD. MOVE	8-30-81					
1	ELECT. BONDOUT REMOVE	8-3-81	BHA				
				1	ADDED AS BUILT	6/15/82	

STATE OF MAINE — B. HAYWARD ADAMS — 3983 — REGISTERED PROFESSIONAL ENGINEER

DESIGNED IJK — SCALE 1/4" = 1'-0"
DRAWN — DATE 12-31-80
CHECKED BHA — DATE 3-25-81
APPROVED BHA — DATE 6-4-81

81

CENTRAL MAINE POWER COMPANY
AUGUSTA, MAINE

SHAWMUT PROJECT-NEW DEVELOPMENT

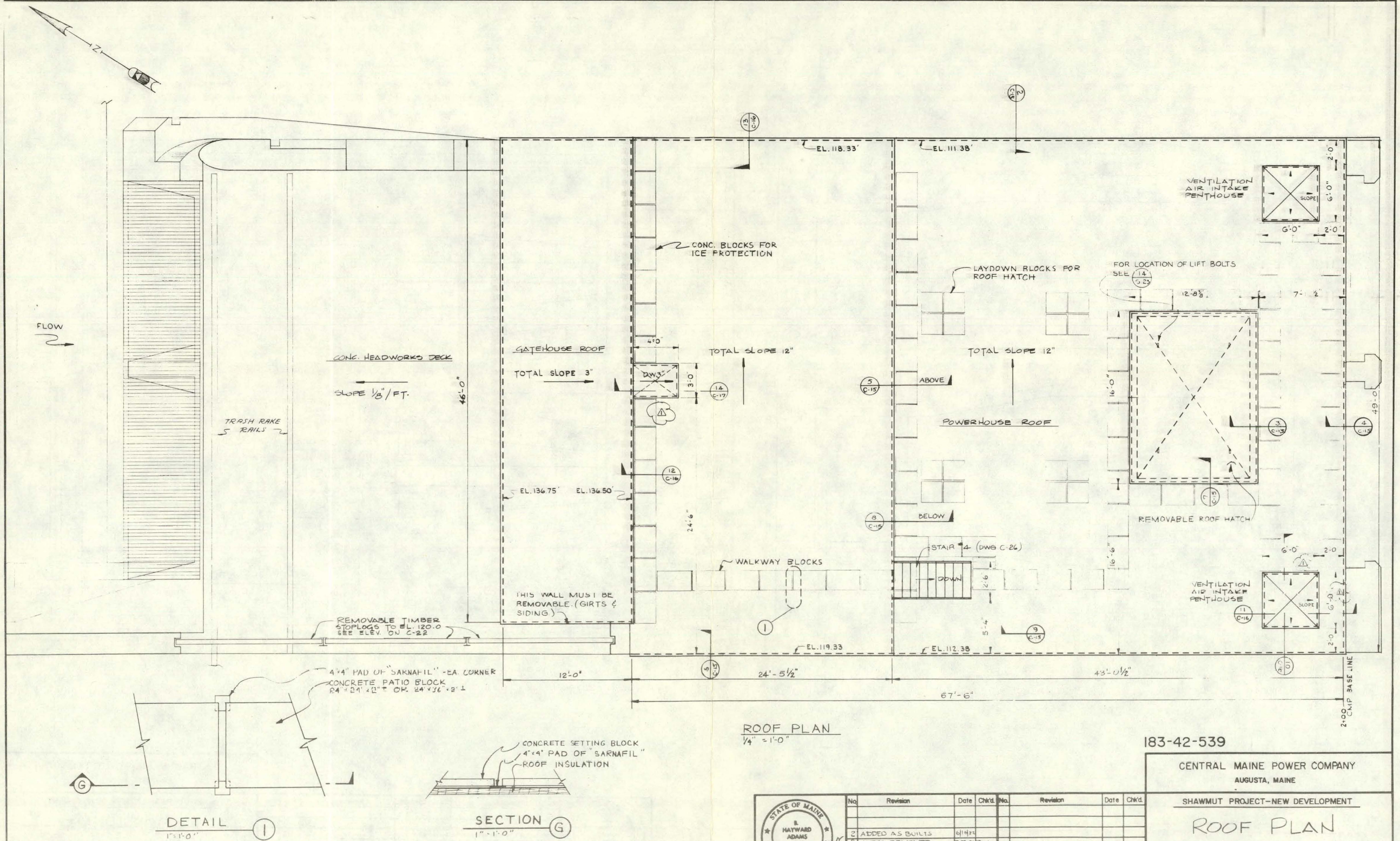
FLOOR PLAN
@ ELEV. 109'

KLEINSCHMIDT & DUTTING
CONSULTING ENGINEERS
PITTSFIELD, MAINE

SHEET NO. 14 OF 72
B-2140

K&D No. C-2

MICROFILMED ___ ___ ___



183-42-539

CENTRAL MAINE POWER COMPANY
AUGUSTA, MAINE

SHAWMUT PROJECT–NEW DEVELOPMENT

ROOF PLAN

No.	Revision	Date	Chk'd.
2	ADDED AS BUILTS	6/14/82	
1	NOTES REMOVED	9-29-81	T.J.W.

STATE OF MAINE — B. HAYWARD ADAMS 3883 — PROFESSIONAL ENGINEER

DESIGNED HX — SCALE AS NOTED
DRAWN — DATE 1-14-81
CHECKED DWE — DATE 5-6-81
APPROVED BHA — DATE 6-8-81

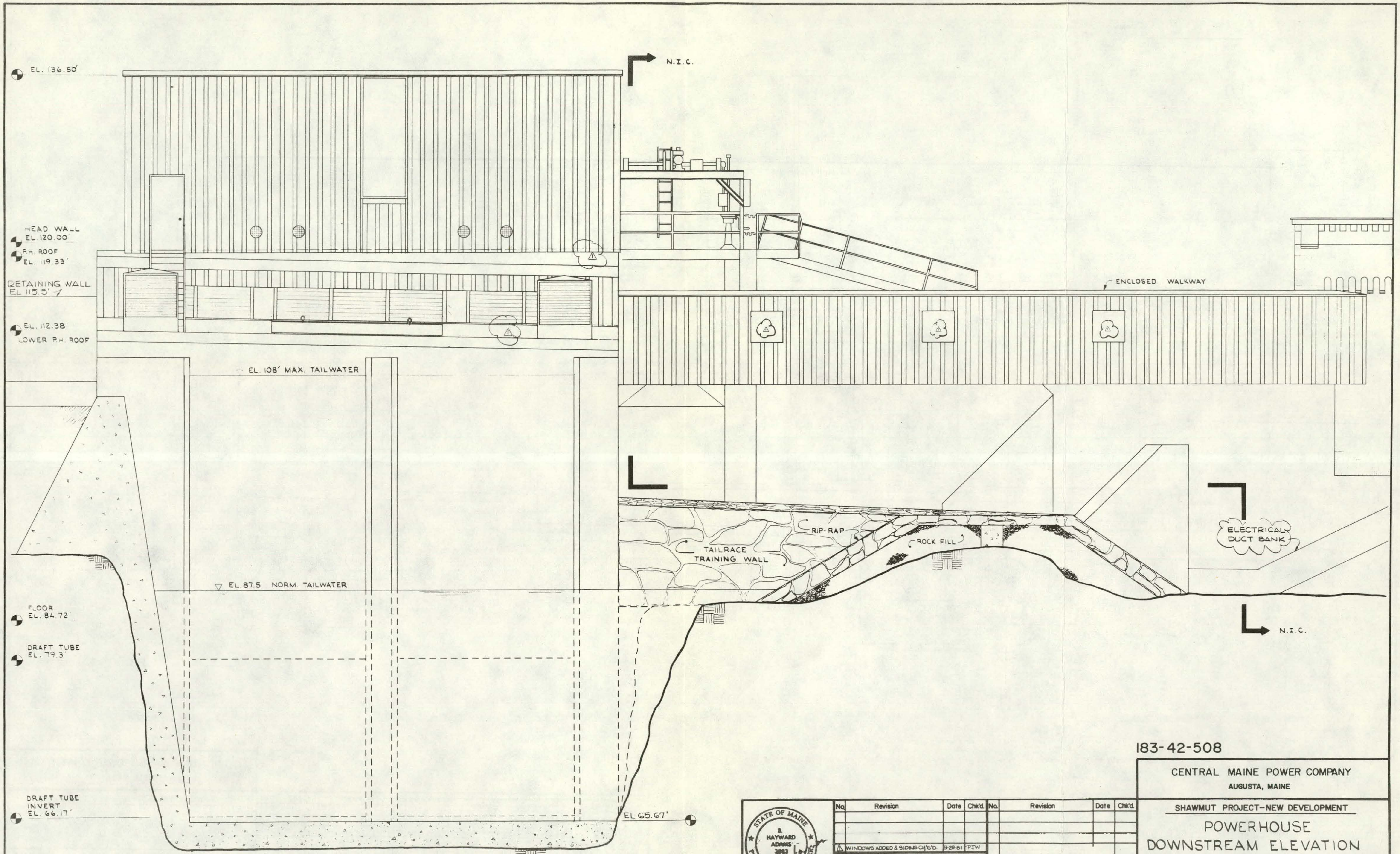
KLEINSCHMIDT & DUTTING
CONSULTING ENGINEERS
PITTSFIELD, MAINE

SHEET NO. 25 OF 72
B-2194

MICROFILMED

K&D C-14

82



183-42-508

CENTRAL MAINE POWER COMPANY
AUGUSTA, MAINE

STATE OF MAINE · B. HAYWARD ADAMS · 3883 · REGISTERED PROFESSIONAL ENGINEER

No.	Revision	Date	Chk'd.	No.	Revision	Date	Chk'd.
△	WINDOWS ADDED & SIDING CH'G'D.	9-29-81	PJW				

DESIGNED W.K — SCALE 1/4" = 1'-0"
DRAWN D. QUA — DATE 2-9-81
CHECKED BHA — DATE 3-25-81
APPROVED BHA — DATE 6-8-81

83

SHAWMUT PROJECT–NEW DEVELOPMENT

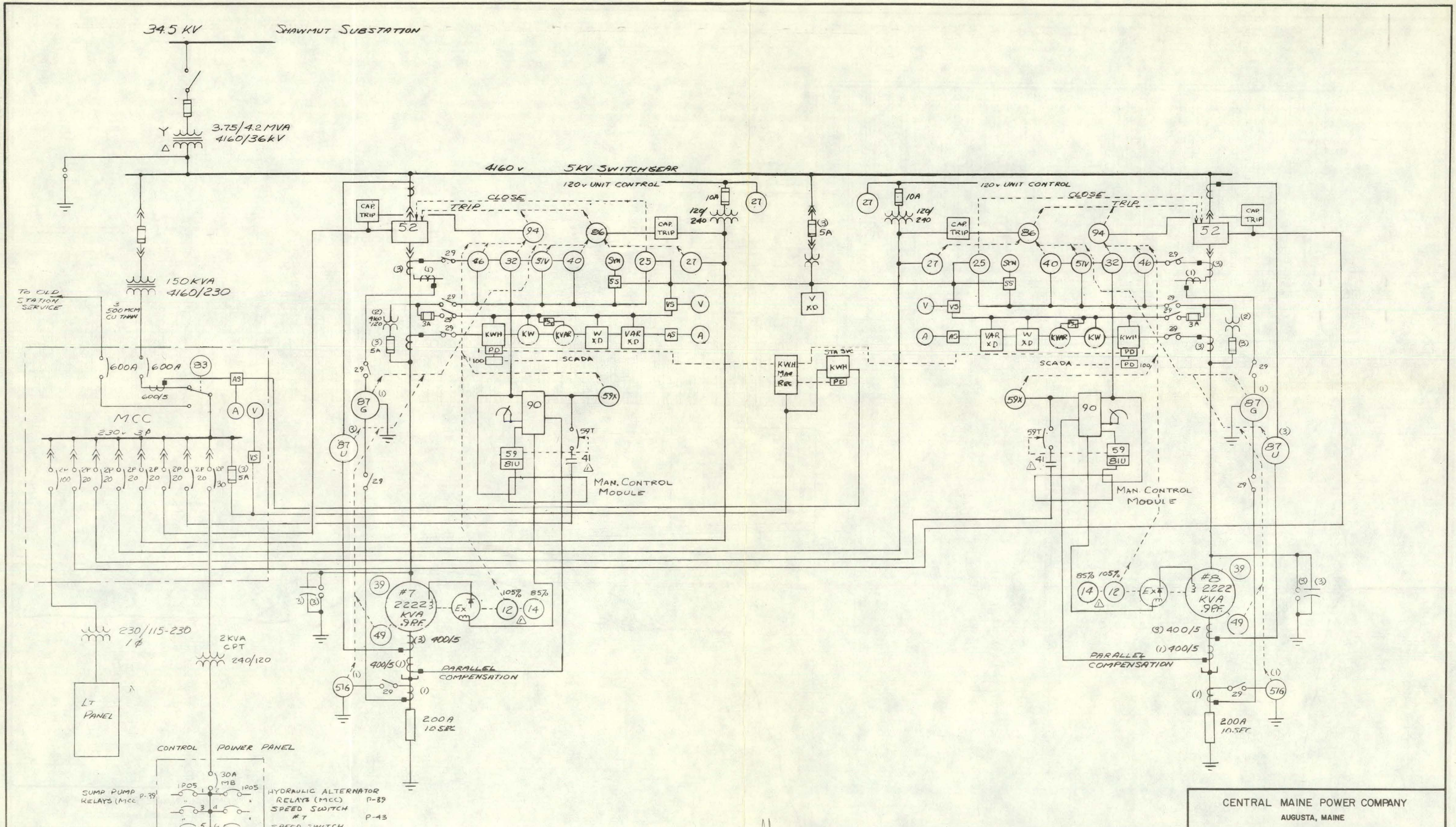
POWERHOUSE DOWNSTREAM ELEVATION

KLEINSCHMIDT & DUTTING
CONSULTING ENGINEERS
PITTSFIELD, MAINE

SHEET NO. 17 OF 72
B-2136

K&D C-5

MICROFILMED



No.	Revision	Date	Chk'd.
2	29s, PD3, PST's & CP ADDED		OHS
1	FUNCTION & VOLTAGE CHANGE		OHS
	REDRAWN	2/13/81	

DESIGNED OHS — SCALE —
DRAWN OHS — DATE 2-18-81
CHECKED — DATE 9-21-81
APPROVED RAA — DATE 9-21-81

CENTRAL MAINE POWER COMPANY
AUGUSTA, MAINE

SHAWMUT PROJECT–NEW DEVELOPMENT

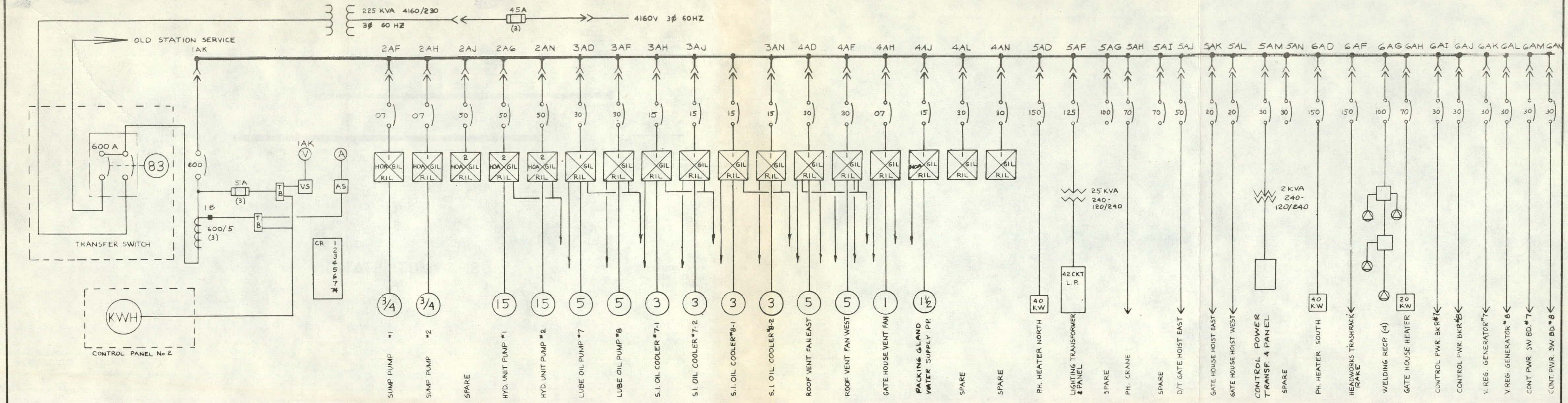
ONE LINE DIAGRAM
UNITS #7 & #8

KLEINSCHMIDT & DUTTING
CONSULTING ENGINEERS
PITTSFIELD, MAINE

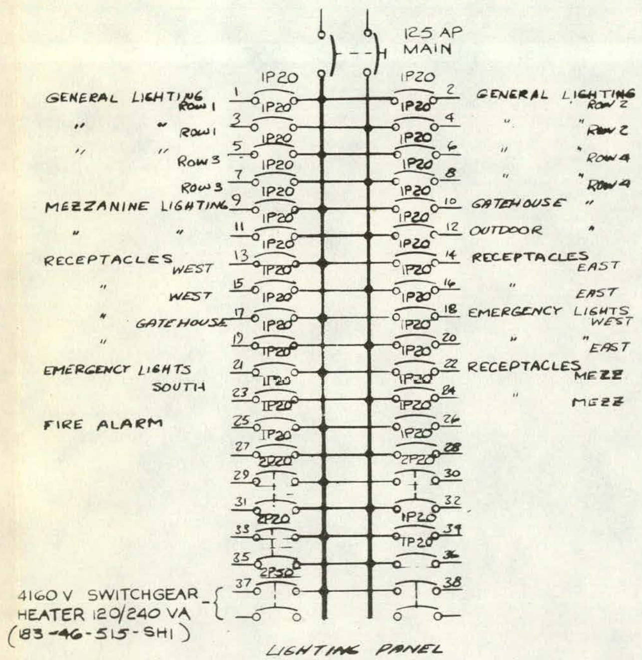
E-1.0

183-46-305

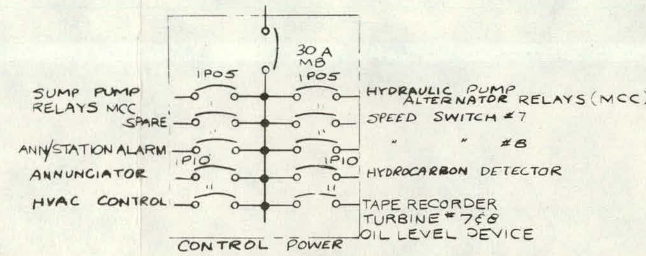
MICROFILMED



1	2	3	4	5	6
MAIN BREAKER 240 V 600A	SPARE 2AD	LUBE OIL PUMP #7 3P 30 AMP 3AD 1	ROOF VENT FAN EAST 3P 30 AMP 4AD 1	POWERHOUSE HEATER NORTH 5AD 150A	POWERHOUSE HEATER SOUTH 6AD 150A
	SUMP PUMP #1 3P 07AMP 2AF 1	LUBE OIL PUMP #8 3P 30 AMP 3AF 1	ROOF VENT FAN WEST 3P 30AMP 4AF 1	LIGHTING TRANSFORMER 5AF 125A	HEADWORKS TRASH RACK RAKE 6AF 150A
METERING VM VM	SUMP PUMP #2 3P 07AMP 2AH 1	S.I. OIL COOLER FAN #7-1 3P 15 AMP 3AH 1	GATEHOUSE VENT FAN 3P 07AMP 4AH 1	SPARE 3P 100 AMP (5AG) POWERHOUSE CRANE, 3P 70AMP (5AH)	WELDING RECP. 3P 100 AMP (6AG) GATEHOUSE HEATER (6AH) 3P 70AMP
1AK	SPARE 3P 50 AMP 2AJ 2	S.I. OIL COOLER FAN #7-2 3P 15AMP 3AJ 1	PACKING GLAND WATER SUPPLY PUMP 3P 15AMP 4AJ 1	SPARE 3P 70 AMP (5AI) DRAFT TUBE GATE HOIST; 3POLE, (5AJ) 50 AMP	CONTROL POWER KG7 3P30AMP (6AI) CONTROL POWER KG8 3P30AMP (6AJ)
CONTROL RELAYS	HYD. UNIT PUMP #1 3P 50AMP 2AL 2	S.I. OIL COOLER FAN #8-1 3P 15AMP 3AL 1	SPARE 3P 30 AMP 4AL 1	GATEHOUSE HOIST EAST; 3P 20AMP (5AK) GATEHOIST HOIST WEST; 3P20AMP (5AL)	VOLTAGE REG. GEN #7 (6AK) 2P 30AMP VOLTAGE REG. GEN #8 (6AL) 2P 30AMP
1AN	HYD. UNIT PUMP #2 3P 50AMP 2AN 2	S.I. OIL COOLER FAN #8-2 3P 15AMP 3AN 1	SPARE 3P 30AMP 4AN 1	CONTROL POWER PANEL TRANS (5AM) 3P30AMP SPARE 3POLE 30AMP (5AN)	CONTROL POWER SWITCHBOARD #7 (6AM) 2P 30AMP CONTROL POWER SWITCHBOARD #8 (6AN) 2P 30AMP



LIGHTING PANEL DETAIL



CONTROL POWER PANEL DETAIL

No.	Revision	Date	Chk'd.	No.	Revision	Date	Chk'd.
2	FIELD ADDITIONS	7-23-82	MLE				
1	AS BUILT	2-24-82	OHS				

DESIGNED OHS SCALE NONE
DRAWN UK DATE 8-6-81
CHECKED OHS DATE 12-7-81
APPROVED [illegible] DATE 12/18/81

85

CENTRAL MAINE POWER COMPANY
AUGUSTA, MAINE

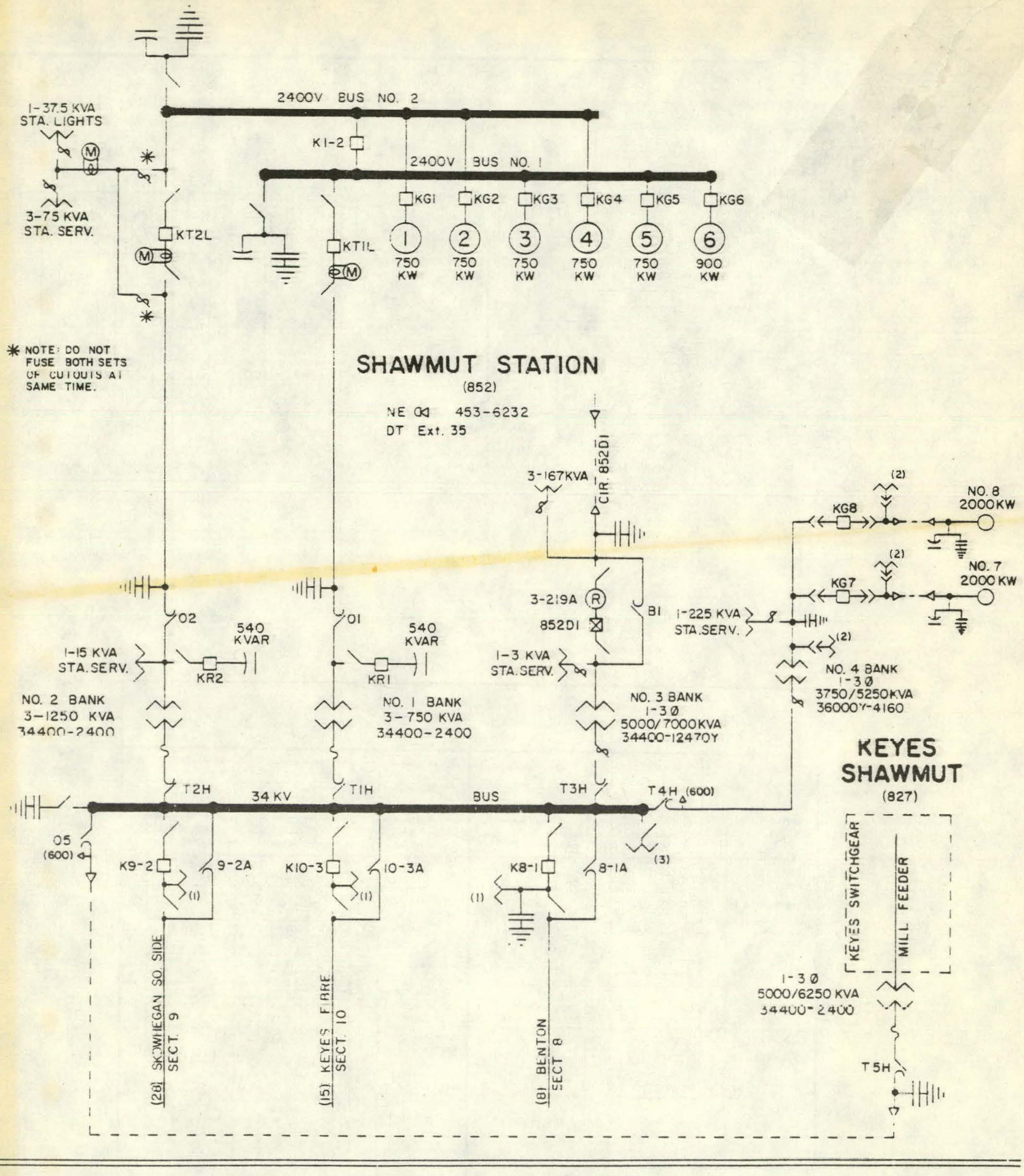
SHAWMUT PROJECT–NEW DEVELOPMENT

MOTOR CONTROL CENTER ONE LINE DIAGRAM & LAYOUT

KLEINSCHMIDT & DUTTING
CONSULTING ENGINEERS
PITTSFIELD, MAINE

E-6.0
183-46-502

MICROFILMED ___ ___ ___



6/17/82

KEYES-SHAWMUT
SHAWMUT STATION

N 27