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Small-Scale Hydroelectric Power
Demonstration Project

NEW YORK STATE ELECTRIC & GAS CORPORATION

UPPER MECHANICVILLE HYDROELECTRIC REDEVELOPMENT PROJECT

PROJECT DESIGN CRITERIA MANUAL

Department of Energy, Idaho Operations Office

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BY

ACRES AMERICAN INCORPORATED

FOR

NEW YORK STATE ELECTRIC AND GAS CORPORATION
BINGHAMTON, NEW YORK

DECEMBER 1980

PREPARED FOR THE
U. S. DEPARTMENT OF ENERGY
UNDER CONTRACT DE-FC07-80ID12117

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NEW YORK STATE ELECTRIC & GAS CORPORATION

**UPPER MECHANICVILLE HYDROELECTRIC
REDEVELOPMENT PROJECT**

Acres Report No. P5390.11.13

PROJECT DESIGN CRITERIA MANUAL

DECEMBER, 1980

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INTRODUCTION AND SUMMARY

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INTRODUCTION AND SUMMARY

The design criteria presented in this manual are to be used as the bases for the detailed design for the Upper Mechanicville Hydroelectric Redevelopment Project. The manual refers to codes and standards which are to be used in the design of the project. Design approaches not covered by existing codes and standards are also given for all phases of the project.

The manual is divided into six sections; civil design, hydraulic design, geotechnical design, electrical systems, mechanical systems, and major equipment.

Section 1, Civil Design, outlines the standards to which the powerhouse and associated civil structures are to be designed. The loadings on the powerhouse are defined, and detailed wherever possible; material quality and allowable strengths are stated; and loading conditions, limiting criteria and boundary conditions for stability analysis are summarized.

Section 2, Hydraulic Design, summarizes the flow conditions for design of the intake and tailrace. Probable flood levels and discharges are presented and low flow conditions are defined.

Section 3, Geotechnical Design, presents the methods to be employed to analyze the stability of slopes and the earth pressures on structures. The design of the cofferdams is outlined.

Section 4, Electrical Systems, outlines the applicable safety standards and presents a basis for the selection of station equipment. Industry standards and NYSEG standards are referenced to the equipment design. Service conditions are defined as they apply at the powerhouse. Design procedures are outlined and sequenced. Voltages and equipment ratings are presented and protection systems are given. Requirements for lighting, electrical equipment installation and station services are included. Generator control, metering and relaying requirements and design considerations are outlined. Basis for selection of raceway systems and wire and cable systems is given.

Section 5, Mechanical Systems, presents the primary systems for the powerhouse services including station service water, fire protection, compressed air, waste handling and heating and ventilating. The design requirements, system details and list of major equipment are presented in the criteria.

Section 6, Major Equipment, outlines the basic requirements for the major equipment including turbines, generators, gates, trashracks and powerhouse crane.

These design criteria are to be used as a guide for design. When changes become necessary, these shall be documented by the engineer responsible for the design. This documentation shall be sent to the Project Engineer and Project Manager for submission to the Client for reference. The documentation shall specify the reason for the change and shall be routed to all Departmental Coordinators.

SECTION 1

CIVIL DESIGN

SECTION 1 - CIVIL DESIGN

1.1 - General

This section sets forth general criteria for the design of the powerhouse and associated structures.

1.2 - Codes and Standards

The following codes and standards shall govern the design of the powerhouse and appurtenant works. In the event of a conflict among codes or with any of the information presented in this document, the most stringent requirement shall be used.

- New York State Building Construction Code, latest edition (NYSBCC)
- New York State Energy Conservation Construction Code, January, 1979 (NYSECCC)
- International Conference of Building Officials "Uniform Building Code", 1979 (UBC)
- American National Standards Institute, "Building Code Requirements for Minimum Loads in Buildings and Other Structures" (ANSI A58.1 - 1972) (ANSI)
- American Institute of Steel Construction "Specification for the Design, Fabrication and Erection of Structural Steel", 8th Edition (AISC)
- American Concrete Institute "Building Code Requirements for Reinforced Concrete" (ACI 318-77) (ACI)
- American Society for Testing and Materials Standards (ASTM)
- American Welding Society, D-1.1 "Structural Welding Code" (AWS)
- Factory Mutual Engineering Corporation (FM)
- Occupational Safety and Health Administration Standards (OSHA)
- American Association of State Highway and Transportation Officials, "Standard Specification for Highway Bridges", 1977 (AASHTO)
- New York State Department of Transportation "Standard Specifications, Construction and Materials" (NYSDOT)

The applicable revision of a code or standard shall be the revision in effect at the time design is started.

1.3 - Design Factors

1.3.1 - Elevations and Water Levels (NGS Datum)

(a) Headwater

- Normal water level with flashboards El. 69.1
- Maximum high water level (200-year
return period) El. 78.6
- Minimum operating low water level El. 66.6
- Freeboard to intake deck at normal water
level 13.9 ft

(b) Tailwater

- Normal water level El. 49.3
- Water level corresponding to maximum high
headwater El. 64.0
- Minimum low water level El. 47.1

1.3.2 - Unit Weights

(a) Concrete

- Structural concrete 150 lb/ft³
- Mass concrete (as defined in ACI 207) 145 lb/ft³

(b) Steel 490 lb/ft³

(c) Water 62.5 lb/ft³

(d) Compacted Fill and Backfill

Typical design values; actual values will depend on specific material characteristics:

- Granular - moist 135 lb/ft³
 - saturated 143 lb/ft³
 - submerged 81 lb/ft³
- Ordinary soil - moist 130 lb/ft³
 - saturated 134 lb/ft³
 - submerged 71 lb/ft³
- Rockfill - moist 130 lb/ft³
 - saturated 140 lb/ft³
 - submerged 78 lb/ft³

(e) Rock 170 lb/ft³

1.3.3 - Foundation Bedrock

See Section 3 - Geotechnical Design

1.3.4 - Angle of Internal Friction

These are typical design values which will depend on the specific soil characteristics:

- (a) Granular material 30°-38°
- (b) Ordinary soil 15°-20°
- (c) Rockfill 38°

1.3.5 - Coefficient of Friction

- (a) Concrete on concrete 0.80
- (b) Concrete on rock (based on $\phi = 35^\circ$) 0.70

1.3.6 - Cohesion (c)

- (b) Concrete to solid rock to be furnished later
- (c) Concrete to fractured rock to be furnished later

1.4 - Design Loads

Design loads shall be in accordance with American National Standards Institute ANSI A-58.1, New York State Building Construction Code, and as defined herein.

1.4.1 - Dead Load

The dead load shall be taken as the weight of the structure and all permanently installed machinery.

1.4.2 - Live Loads

Live loads shall include snow, wind, imposed floor loadings, operation of machinery (static and dynamic), load rejection, and all temporary loads imposed during construction.

1.4.3 - Snow Loads

Snow loading will be determined from the values given in the New York State Building Code for the Upper Mechanicville area. The snow load may be increased in accordance with the recommendations of ANSI A58.1, Section 7 for areas where snow may drift and accumulate such as at differential roof levels.

Snow load 50 lb/ft²

1.4.4 - Wind Loads

The annual extreme wind speed is 75 miles per hour (50-year recurrence), at a height of 30 feet above the ground surface. Distribution and application shall be in accordance with the American National Standards Institute ANSI A58.1, and the New York State Building Code.

- (a) Roof 20 lb/ft² (suction)
- (b) Walls- windward side 17 lb/ft²
 - leeward side 13 lb/ft²
- (c) Siding and girt design 21 lb/ft²

1.4.5 - Crane Loads

- (a) Bridge weight 220,000 lbs.
- (b) Trolley weight 70,000
- (c) Maximum capacity 100/25 tons
- (d) Lateral force (at top of rail) 12.5% of lifted load
and trolley weight
on each rail, or
25% on one rail
- (e) Longitudinal force (at top of rail) 12.5% of maximum wheel
loads
- (f) Vertical impact 25% of live load
- (g) Maximum wheel load 90,000 lb.

1.4.6 - Imposed Floor Loadings

- (a) Communication room and battery room 200 lb/ft²
- (b) Stairways, corridors and washrooms 100 lb/ft²
- (c) Main generator floor El. 67.0:
 - Live load on erection area 1000 lb/ft² uniform
load or 100 kips
concentrated load
placed in designated
laydown areas or
AASHTO Bridge
Loading
 - Live load between units 500 lb/ft²
 - Other areas (El 69.0) 500 lb/ft² and
reaction from super-
structure columns
- (d) Floors at Elevation 85.0, all areas 500 lb/ft²
- (e) Floors at Elevation 50.13, all areas 500 lb/ft²
- (f) Floors at Elevation 34.15, all areas 500 lb/ft²
- (g) On generator cover 120 lb/ft²

1.4.7 - Equipment Loads

(a) Turbine Component Weights

- Turbine shaft	16,000 lb
- Turbine runner	112,000 lb
- Outer head cover	54,300 lb
- Inner head cover	53,000 lb
- Stay ring assembly	109,000 lb
- One wicket gate	2,550 lb
- Discharge ring including bottom ring	47,000 lb
- Draft tube liner	21,800 lb
- Pit liner	23,500 lb
- One complete turbine	615,000 lb
- Maximum weight to be handled by Powerhouse crane (runner/shaft/head cover)	181,000 lb
- Maximum hydraulic downthrust	267,000 lb
- Maximum hydraulic upthrust	132,000 lb

(b) Generators

- One half stator section	48,000 lb
- Complete stator (wound)	115,000 lb
- Lower bracket	61,000 lb
- Upper bracket	Later
- Rotor spider	53,000 lb
- Rotor rim	91,000 lb
- Complete rotor	206,000 lb
- Shaft and thrust bearing	28,500 lb
- One complete generator	402,000 lb
- Maximum weight to be handled by Powerhouse Crane (rotor with rim)	180,000 lb
- Stator Sole plate loads (8 stator sole plates)	
- Vertical - Due to weight of parts	17,500 lb
- Tangential - At rated conditions	6,700 lb
- At short-circuit condition	23,500 lb
- Radial - At rated conditions	2,400 lb
- Lower bracket sole plates (4 bearing housing sole plates)	
- Vertical - At rated conditions	171,250 lb
- During transient conditions	190,525 lb
- Radial - At rated conditions	4,875 lb

(c) Trashracks and Gates

Weights of the trashrack, draft tube gates and intake bulkhead gates to be furnished later.

1.4.8 - Earthquake Loads

- (a) All structures shall be designed with due consideration given to forces imposed by earthquakes for the powerhouse located in a Seismic Risk Zone 2.
- (b) For the purposes of stability analysis the force due to earthquake shall be taken as 0.10 times the sum of the total vertical dead load and fixed live load.
- (c) Earthquake forces shall be considered to act on the structure in the following manner:
 - On the superstructure, structural members or systems in accordance with the provisions of the Uniform Building Code (UBC) Section 2313(d). A minimal lateral seismic force (V) assumed to act in any direction shall be:

$$V = ZIKSCW$$

Where:

Z = numerical coefficient dependent upon the location of the building as determined by the UBC United States map of seismic risk. For this site in Zone 2, Z is equal to 3/8.

I = occupancy importance factor as specified in Table No. 23-K, page 148 of the UBC. I is equal to 1.0.

K = numerical coefficient dependent upon the type of structural system used. K is equal to 1.33 for the steel structure and concrete substructure.

C = numerical coefficient equal to:

$$C = \frac{1}{15(T)^{1/2}}, \text{ but not greater than } 0.12;$$

where T is the fundamental period of vibration of the structure, in seconds. For this structure having a single degree of freedom, the value of T shall be determined by the formula given below: (page 369, Concrete Engineering Handbook by M. Fintel)

$$T = 2\pi(M/k)^{1/2} \text{ sec.}$$

where k = stiffness of the structure in kips/inch in the direction being analyzed and M is the mass at the roof level in kips-sec²/in, which shall include the roof truss, roofing, snow, unloaded crane and crane runaway.

In the absence of properly substantiated technical data for the proposed structure, T may be determined from the equation given below:

$$T = \frac{0.05h_n}{D}$$

Where:

h_n = height of the structure above the base of the foundation

D = dimension (ft) of building in the direction parallel to the applied forces.

S = numerical coefficient defined in Section 2312(d) of the UBC, equal to 1.5 if there is no sufficient geotechnical data to evaluate the characteristic site period (Ts).

W = total dead load and applicable equipment load, and 50 percent of live load.

1.4.9 - Hydrostatic Pressure

- (a) Water shall be assumed to act on the upstream and downstream faces of the powerhouse in accordance with the principles of hydrostatics except in the case of earthquake loading in which case it shall be in accordance with Subsection 1.4.11.
- (b) Full consideration shall be given to residual hydrostatic pressures behind retaining structures resulting from rapid drawdown of water surfaces.

1.4.10 - Hydrostatic Uplift

Hydrostatic uplift forces shall be calculated in the following manner:

The hydraulic gradient shall be assumed to vary linearly from headwater at the upstream face to tailwater at the downstream face. Normal uplift pressure at any location shall be equal to the vertical distance from this gradient to the face of the structure at that location. This uplift condition will also apply for the extreme uplift, where drains are provided but are inaccessible for monitoring, and assumed to be ineffective in reducing the uplift.

1.4.11 - Lateral Water Pressure During Earthquake

- (a) An increase in hydrostatic pressure (P_e) at a depth h feet below water surface will be computed according to the formula:

$$P_e = C a w h$$

Where:

P_e = pressure normal to the face

C = A dimensionless pressure coefficient

$$= \frac{C_m}{2} \left[\frac{y}{h} \left(2 - \frac{y}{h} \right) + \frac{y}{h} \left(2 - \frac{y}{h} \right)^{1/2} \right]$$

$$a = \frac{\text{horizontal earthquake acceleration}}{\text{acceleration due to gravity}} = 0.1$$

(Zanger, C.N. "Hydro Dynamic Pressures on Dam due to Horizontal Earthquake Effects", Bureau of Reclamation Special Assignments Section, Report No. 21, 1950.

w = unit weight of water, pounds per cubic foot

h = total depth of water at section being studied, in feet

y = the vertical distance from the water surface to the elevation in question, in feet

C_m = maximum value of C for a given constant slope determined from "Design of Gravity Dams" by U.S. Department of the Interior, Bureau of Reclamation, 1976 Figure 4.18.

(b) The horizontal force above any elevation is:

$$V_e = 0.726 P_e y$$

and the moment is

$$M_e = 0.299 P_e y^2$$

1.4.12 - Ice Loads

The following horizontal ice load shall be considered to act at mid-depth of an 18-inch thick ice cover at water surface:

- On the structure 6.50 kips/lin ft.
- Impact load due to ice flow 10.8 kips/lin ft.
- Impact load due to ice flow for the design of
guide vane (Section 2.5) 130k

1.4.13 - Thermal Loads

The thermal loading will be those loads, forces and effects due to contraction or expansion resulting from temperature changes, shrinkage, moisture changes, and creep in component materials, or combinations thereof. The effects of differential settlement shall also be considered with thermal loads:

- (a) Average winter air temperature 23.5°F
- Maximum air temperature 106°F
- Minimum air temperature -22.5°F
- (b) Coefficient of thermal expansion:
 - Steel 6.5×10^{-6} in/in
per °F
 - Concrete 5.5×10^{-6} in/in
per °F.

1.4.14 - Vehicle Loading

Vehicle loading will be H-20 loading as a minimum and will be increased where appropriate.

1.4.15 - Earth Pressures

Earth pressures are assumed to act on the powerhouse and retaining walls according to the Rankine Theory of earth pressures as outlined in Section 3, Geotechnical Design.

1.4.16 - Earthquake Forces on Retaining Structure

Structures subjected to lateral earth pressures shall be designed for earthquake in accordance with the following recommendations:

- The static lateral earth pressures shall be increased to account for the dynamic effect of the earthquake by the following values:

$$E_{ae}^m = \frac{1}{2} (K_{ae}^m - K_a) \gamma_{sat} H^2 \text{ for saturated soils or dry soils}$$

$$E_{ae}^s = \frac{1}{2} (K_{ae}^s - K_{ae}^m) \gamma_{sub} h^2 \text{ for submerged soils}$$

where:

- H = height from saturation line to base of structure
- h = height from water line to base of structure
- γ_{sat} = unit weight of saturated soil or dry soil
- γ_{sub} = unit weight of submerged soil
- K_a = static earth pressure coefficient
- K_{ae}^m = dynamic active earth-pressure coefficient for saturated soil or dry soils
- K_{ae}^s = dynamic active earth-pressure coefficient for submerged soil.

$$K_{ae}^m = \frac{(1 \pm k_v) \cos^2 (\phi - \theta - \delta)}{\cos \theta \cos \delta^2 \cos (\delta + \varphi + \theta) \left[1 + \sqrt{\frac{\sin (\phi + \varphi) \sin (\phi - \beta - \theta)}{\cos (\delta + \varphi + \theta) \cos (\delta - \beta)}} \right]^2}$$

- where: ϕ = angle of internal friction of soil
- φ = angle of friction between structure and soil
- δ = angle of batter of the wall with respect to vertical
- β = angle of the sloping backfill with respect to horizontal

$$\theta = \tan^{-1} \frac{k_h}{1 \pm k_v}$$

$$\theta = \tan^{-1} \frac{k_h}{1 \pm k_v} \cdot \frac{\gamma_{sat}}{\gamma_{sat} - \gamma_w}$$

- γ_w = unit weight of water
- k_h = horizontal seismic coefficient
- k_v = vertical seismic coefficient

For the submerged portion of the soil, K_{ae}^S shall be calculated by replacing θ with θ' in the formula for K_{ae} .

The dynamic forces E_{ae}^m and E_{ae}^s act $2/3 H$ and $2/3 h$ above the base respectively.

The hydrostatic force on front of the structures shall be reduced by an amount equal to:

$$\frac{7}{12} h^2 r_w k_h$$

acting at a distance of $0.41h$ above the base

Reference: "Seismic Design of Retaining Walls and Cellular Cofferdams" by Satayananda Chakrabarti, Alan D. Husak, Paul P. Christiano and David E. Troxell ASCE Conference on Earthquake Engineering, 1978, Vol 1, page 325.

1.5 - Stability Analysis

1.5.1 - Description

- (a) The stability analysis design shall demonstrate by means of adequate safety factors, the ability of the structure to resist overturning, sliding and floatation, and that allowable foundation bearing values are not exceeded.
- (b) The analysis shall show for the various load cases the individual exterior loadings, the assumed area of the base, the magnitude and distribution of the normal and shearing force at the foundation level, and the location and direction of the resultant.

1.5.2 - Stability Criteria

(a) Overturning

The factor of safety against overturning is the ratio of the moments about the toe of the structure of the resisting effective force to that of the overturning total force.

$$F.S. = \frac{M_r}{M_o}$$

- In normal case the resultant of the algebraic sum of the forces should remain within the middle third of the base.
- In extreme case, the resultant should lie within the base of the structure considered.

(b) Sliding

Sliding along a horizontal or gently sloping plane is resisted by friction plus shear due to any cohesion between the potential sliding surfaces. The factor of safety is the ratio of this total resisting force to the driving force from the net unbalanced headwater (plus silt load or earthquake load on the structure if any), and is determined by the following "shear - friction" formula:

$$F.S. = \frac{(V-U) \tan \phi + cA}{P_w}$$

Where, for a horizontal potential failure plane:

V = total vertical force due to weight of concrete substructure including water as applicable

U = total vertical uplift force acting over 100 percent of base area

ϕ = angle of friction along plane

c = unit cohesion along plane

A = base area of potential sliding plane

P_w = horizontal thrust of headwater, plus silt, ice or earthquake load and tailwater

(c) Flotation

The factor of safety against flotation is the ratio of the maximum vertical load (W) to the maximum uplift forces (U) due to hydrostatic pressure under the base.

$$F.S. = \frac{W}{U}$$

1.5.3 - Factors of Safety

Factors of safety are the ratio of the resisting forces to the forces tending to cause movement. The minimum factors of safety for stability are as follows:

	<u>Factors of Safety</u>		<u>Associated Structure</u>
	<u>Normal</u>	<u>Unusual/ Extreme</u>	
- Minimum sliding (no shear friction)	2.0-1.75	1.5-1.3	1.5 (2.0)**
- Minimum sliding (with shear friction)	4.0 (3.5)*	2.5 (2.0)*	-
- Minimum overturning	1.2	1.1	1.5
- Minimum flotation	1.2	1.1	-

* Based on laboratory results (minimum)

** With mechanical anchorage

Reference: U.S. Bureau of Reclamation, Design Standards No. 9, 1972.

1.5.4 - Load Combinations

(a) Normal Loading Combination

Normal design headwater elevation with appropriate dead loads, uplift, silt, ice and tailwater. If temperature effects are applicable, use minimum usual temperatures. Earthquake is not considered.

(b) Unusual and Extreme Loading Combination

- Maximum design headwater elevation with appropriate dead loads, silt, minimum usual temperature, tailwater, plus full uplift. Earthquake is not considered.
- Normal design headwater elevation with appropriate dead loads, silt, full uplift, usual minimum temperature effects, if applicable, tailwater, plus the effects of the maximum credible earthquake.

1.5.5 - Load Cases

The following load cases shall be considered for stability:

(a) Construction Phase

- Case 1 - Concrete in place, site dewatered
- Case 2 - Concrete in place, maximum headwater and no tailwater
- Case 3 - Concrete in place, maximum headwater and tailwater
- Case 4 - Concrete in place, normal headwater, tailwater and earthquake

(b) Operating Phase

- Case 5 - Two units in operation.

(c) Repair Phase

- Case 6 - One unit in operation, second unit dewatered with equipment removed to service area.

Above load cases (b) and (c) will be calculated for conditions of normal and extreme loading combinations.

1.6 - Structural Design Data

1.6.1 - Reinforced Concrete

(a) Design Basis

Reinforced concrete design shall be in accordance with the ACI "Building Code Requirements for Reinforced Concrete" (ACI 318-77), Appendix B - Alternate Design Method, and appropriate ACI and PCA standards.

(b) Stress Increase for Combined Loadings

Allowable stresses may be increased for particular combinations of loads in accordance with Subsection 1.6.4.

(c) Concrete Strength

The minimum 28-day compressive strength of concrete shall be as follows:

- Structural concrete $f'_c = 4000$ psi
- Mass concrete $f'_c = 3000$ psi
- Secondary concrete $f'_c = 5000$ psi

(d) Reinforcement

Reinforcing bars (#4 through #11) shall conform to ASTM A615 "Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement", Grade 60.

Yield stress (f_y) 60,000 psi

(e) Temperature and Shrinkage Reinforcement

Temperature and shrinkage reinforcement will be generally in accordance with the American Concrete Institute Standard 318-77, except that those requirements will be modified for thick members where reinforcement will be designed according to the cracking theory. For surfaces in contact with flowing water, the minimum temperature and shrinkage reinforcement shall be #8 bars at 12 inches each way.

Shrinkage stresses will be reduced as far as practicable by careful selection of the location of joints and the order of concrete placements.

(f) Concrete Protection for Reinforcement

The minimum concrete cover for reinforcement shall generally be in accordance with ACI 318-77 except as modified following:

- Concrete in waterpassages 4 inch cover
- Concrete poured against rock or ground, or
in contact with still water 4 inch cover
- Concrete slabs 1 inch cover
- All other locations 2 inch cover

(f) Seals

PVC waterstop seals will be used in all water-retaining structures as follows:

- Contraction joints, where required;
- Vertical construction joints communicating with dry interior spaces;
- Horizontal construction joints communicating with dry interior spaces where the concrete thickness is less than 10 feet.

1.6.2 - Structural Steel

(a) Design Basis

Structural steel design shall be in accordance with the American Institute of Steel Construction "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings", 8th edition.

(b) Stress Increase for Combined Loadings

Allowable stresses may be increased for particular combinations of loads in accordance with Subsection 1.6.4.

(c) Materials

Structural steel shapes and plates ASTM A-36
Bolts, nuts and washers ASTM A-325

(d) Connections

Generally shop connections shall be welded; field connections shall be bolted.

All bolted connections shall be friction type.

(e) Welding

All welding shall be in accordance with the American Welding Society Standard - AWS D1.1, as modified by the AISC Specifications.

Electrodes shall be type E70-XX in accordance with AWS Standard - A5.20.

(f) Corrosion Allowance

The thickness of all structural steel sections which have been dimensioned to carry maximum allowable stresses shall be increased 1/16 inch where the sections are exposed to weather or are in contact with water. Except for fillers, webs of rolled sections and fully embedded plates, no structural steel shall be less than 5/16-inch thick.

1.6.3 - Miscellaneous Metalwork

(a) Design

Miscellaneous metalwork includes handrails, embedded plates, hatch frames and covers and other metal parts where partial or no structural analysis is required. Such design as may be necessary shall be in accordance with AISC Specifications.

(b) Materials

The minimum thickness of all shapes and plates shall be 1/4 inch. Wherever possible, eyebolts, frames, ladders, anchor bars, bolts, etc. shall be standard items. Handrails will be Schedule 40 pipe. Miscellaneous metalwork will be hot dipped galvanized.

1.6.4 - Combined Loadings

Where stresses due to wind, snow, ice, construction or other unusual forces are combined with those due to dead, water or normal live loads, the sum of the stresses shall not exceed the allowable stresses given in 1.6.1 or 1.6.2 by more than the following percentages:

<u>Combined Loading</u>	<u>Allowable Percent Increase of Normal Unit Stresses</u>
Dead plus (live or wind or earthquake or thermal) ..	0
Dead plus live and (wind or earthquake or thermal) ..	33-1/3
Dead plus thermal and (wind or earthquake)	33-1/3

1.7 - Substructure Design

1.7.1 - Floor Loadings

Imposed loads for the various floor areas shall be in accordance with Section 1.4.

1.7.2 - Intake

(a) Intake Base Slab

The following loads and forces are considered:

- Seepage water pressure at horizontal construction joints
- Reactions from piers
- Shrinkage

(b) Intake Piers and Sidewalks

The piers will be assumed to act as beams fixed at both ends. The following loads and forces are considered:

- Reactions from the powerhouse deck slabs as well as machinery and superstructure loads;
- Unbalanced horizontal water pressure resulting from closure of intake bulkhead gate and draft tube gates for one unit and dewatering while full head is maintained in the second unit (center pier only);
- Hydrostatic and saturated earth pressures on outer piers while unit is dewatered;
- Shrinkage;
- Protection of pier nose in area of water level fluctuation.

(c) Intake Roof

The following loads and forces are considered:

- Reactions due to water pressure and ice pressure on piers;
- Wall downstream of the bulkhead gate will be designed for full headwater pressure.

(d) Road Deck and Hatch Covers

- The hatch covers shall be concrete-filled sheet frames. These corners shall be fabricated entirely in steel.
- All covers for the bulkhead gate shaft shall be provided with perimeter seals (neoprene).
- Design for the most severe of the following loading conditions:
 - H20 - S16 Highway loading
 - Flatbed transporting a bulkhead gate section
 - Mobile crane lifting a bulkhead gate section.

1.7.3 - Slab Upstream, Turbine Generator Enclosure Walls and Foundations

- (a) Floor slab upstream of the turbine will be designed for uplift pressures from the water passages to the extreme maximum headwater level plus pressure rise on unit load rejection.
- (b) Generator enclosure walls will be designed as cantilevers supporting adjacent slabs and beams. Allowance shall be made for a horizontal force on the sliding joint equal to $0.45 \times$ vertical reaction from beam/slab arrangement. At the beam locations assume the force spreads at an angle of 45° each side down to foundation level.

The generator foundations shall be designed for all dead and live loads from the enclosure walls and for the appropriate loads from the generator and turbine.

These loads will include the following:

- 120 lb/ft² on the generator cover;
- Weight of stator and tangential forces due to short circuit conditions and magnetic unbalance;
- Maximum vertical loads at bearing bracket soleplates (including turbine shaft and runner and maximum hydraulic thrust), maximum radial force due to short circuit condition and braking forces in the tangential direction.

1.7.4 - Powerhouse Semi-spiral Case

(a) Load Cases

The basic loads and forces considered will be dead loads, internal and external water pressures, turbine and generator weights and concrete shrinkage. These are critically combined to form the following load cases:

- Unit shutdown with reservoir pressure inside the semi-spiral case;
- Unit operational with reservoir pressure inside the semi-spiral case and full hydraulic thrust;
- Unit shutdown and semi-spiral case dewatered;
- Shutdown of unit with 30 percent internal pressure rise.
- Pressure rise (assuming no cushioning on governor) 50 percent at baffle vane decreasing linearly to 0 percent at infront of intake.

Allowable stresses in reinforcing steel shall be reduced to 20,000 psi for all cases except shutdown with internal pressure rise.

(b) Invert

- Shear from walls resisted as axial (or radial) forces in invert slab;
- Tie-back forces (connection between powerhouse and intake);
- Reactions from lower cone.

(c) Lower Cone

- Hydrostatic forces;
- Loads transmitted by stay ring

(d) Walls

- Hydrostatic pressure on wall;
- Axial forces due to hydrostatic pressure acting on the scroll case roof, less self-weight of roof;
- Tie-back forces between intake and powerhouse

(e) Upper Cone

- Weight of stator on upper bracket. Weights of generator rotating parts, turbine runner and shaft with net thrust on lower bracket;
- Hydrostatic forces;
- Reactions from frame analyses of wall sections.

(f) Roof

- Shears from wall resisted as axial (or radial) forces in roof;
- Tie-back forces;
- Reactions from upper cone

1.7.5 - Draft Tube and Gallery Floors Above Draft Tube

Floor slabs in the access gallery above the draft tube will be designed to withstand uplift pressures equivalent to maximum headwater level.

It will be assumed that the draft tube structure acts as a rigid system and that loadings are distributed according to the stiffness of the area on which a particular loading acts. The stresses in the concrete shall be established by means of rigid frame, rigid arch and two-way arch theories.

The design will include the following load conditions:

(a) Construction Stage

All dead loads accrued from the semi-spiral case, generator pit, tailrace deck, superstructure and all mechanical and electrical parts of the turbine, semi-spiral case and generator, and including reaction from the superstructure caused by wind loads and from operation of powerhouse crane, but excluding earthquake loads and internal or external water pressure.

(b) Operating Stage

All dead and live loads accrued from semi-spiral case, generator foundation, service area and galleries, superstructure (including crane and wind or snow loads) and all mechanical and electrical parts of the turbine semi-spiral case, generator, hydraulic thrust and variation between internal and external water pressure and maximum bearing pressure from headworks/powerhouse stability calculations.

(c) Repair Stage

All dead and live loads as outlined in condition (a), combined with full external hydrostatic pressure from tailwater.

1.7.6 - Sump Area

The drainage and dewatering sump shall be located so as to effectively drain the draft tubes. The sump will be designed for conditions with full hydrostatic head in the sump and with the sump completely dewatered.

The dead and live load design parameters for the sump area shall be the same as those listed in Section 1.4.

1.8 - Superstructure Design

1.8.1 - General

The powerhouse main frames will consist of columns fixed or pinned at the bases and roof beams (or trusses) pinned at the top of the columns. Lateral loads in the longitudinal direction will be resisted by bracing provided between bays. Lateral loads in the plane of the frames will be transmitted to the end frames by a horizontal truss system provided at roof level.

1.8.2 - Loadings

Load design parameters shall be as presented in Section 1.4.

1.9 - Architectural

1.9.1 - Codes and Standards

The building envelope will conform to the New York State Energy Conservation Construction Code (January 1, 1979) E 402.3 and to the Factory Mutual Engineering Corporation for Class 1 type construction. All design shall meet the requirements of the New York State Building Code.

1.9.2 - Design Basis for Energy Conservation

- (a) The combined thermal transmittance (U_o) for the gross area of the exterior building envelope shall be based on the following values as specified for the Mechanicville, New York area (7000 degree days):

- Maximum " U_o " walls26
- Maximum " U_o " roof/ceiling07
- Minimum " R " slab edge - unheated slab 5.5

- (b) Design shall be in accordance with the New York State Energy Conservation Construction Code for "Building Design by Component Approach". The equation

$$U_o = \frac{U_w A_w + U_g A_g + U_d A_d + \dots}{A_o}$$

will be used to determine acceptable combinations of subsystems and thermal properties to meet this requirement,

where:

U_o = the average or combined thermal transmittance of the gross exterior wall or floor or roof/ceiling assembly area (except slabs on grade) in BTU/hr/sq.ft./°F

A_o = the gross exterior wall, floor or roof/ceiling assembly area in sq. ft.

U_w = the thermal transmittance of the components of the opaque wall, floor or roof/ceiling assembly area. The U_w of any assembly will be the average value for the composite construction and assembly including structural members such as studs, joists, etc.

A_w = opaque wall, floor or roof/ceiling assembly area

U_g = the thermal transmittance of the glazing (window or skylight) area. The U_g of glazing will be the average value of the window or skylight frames and glazing area

A_g = glazing area (will be assumed to be the area of the finished opening)

U_d = the thermal transmittance of the door or similar opening

A_d = door area (will be assumed to be the area of the finished opening)

NOTE: Where more than one type of wall, window, door, roof/ceiling and skylight is used, the U and A terms for those items shall be expanded into subelements as:

$$U_{w1} A_{w1} + U_{w2} A_{w2} + U_{w3} A_{w3} + \text{etc.}$$

1.9.3 - Building Systems and Components

(a) Building Siding

The siding will be determined by the requirements placed upon the structure and its integration with the site. The types of materials used will be evaluated in terms of the following characteristics:

- (1) Insulative Values
- (2) Fire Resistance
- (3) Long-Term Durability
- (4) Visual Appearance
- (5) Cost Effectiveness

The materials chosen will offer an interior and exterior finish which is durable and long-term maintenance free.

(b) Roofing

The roofing and installation will conform to Factory Mutual Engineering Company Class 1 construction requirements. The minimum slope to roof drains will be 1/4 inch per foot.

Roofing shall incorporate a base layer of 3/4 inch fiber board over decking followed by a fire retardant barrier, a four-ply built-up asphalt roof with insulation as required and gravel topping.

(c) Doors

All exterior man-doors will be insulated metal doors with metal frames. Doors may be provided with windows. Vertical slat observation windows will not exceed 100 square inches and will be glazed with wire glass.

Truck access doors will be insulated metal roll-up type.

Windows, if used, will not create security problems, or be located so as not to be exposed to possible damage.

1.9.4 - Interior Spaces

- (a) Offices: Personnel enclosures will be sound rated to provide effective noise isolation rated to have an STC value of not less than 42. The enclosures will include a door with lock, fluorescent lighting and ventilation with air conditioning capabilities.

- (b) Washroom: A washroom will be provided for the use of the maintenance crew. The waste system for the facility will discharge into a holding tank. The tank will require pumping at approximately four week intervals.

Janitor's service sink will be included in the washroom.

SECTION 2

HYDRAULIC DESIGN

SECTION 2 - HYDRAULIC DESIGN

2.1 - Flows

The following data are based on the results of the USGS WATSTORE Program for the Hudson River at Mechanicville.

Long term average flow	8,000 ft ³ /sec
Maximum project design flood (200 yr return period)	113,500 ft ³ /sec
Maximum construction design flood (20 yr return period) ..	66,450 ft ³ /sec

2.2 - Headwater and Tailwater Levels and Freeboard

Rating curves have been developed for both the headwater and tailwater levels based on average daily flows and daily staff gage readings. For the case of flashboards in place on the dam, a rating curve was derived by applying the equation for a sharp crested weir. The relationship between water levels and flow duration is shown in Figure 2.1.

Operating Levels (NGS datum)

Normal headwater	El. 69.1
Normal minimum headwater level	El. 66.6
Normal maximum headwater level	El. 73.2
Normal tailwater level (8,000 ft ³ /sec)	El. 49.3
Minimum tailwater level	El. 47.1

Flood Levels (NGS datum)

Maximum project design headwater level	El. 78.6
Maximum project design tailwater level	El. 64.0
Maximum construction design headwater level	El. 76.0
Maximum construction design tailwater level	El. 59.2

Freeboard

Allowance for waves	3.0 ft
Allowance for surge due to rapid gate closure	2.5 ft

References 1 and 2 were used in calculating wave heights. The fetch was considered to be one mile and the wind velocity was based on the fastest mile recorded at the Albany Airport.

2.3 - Reservoir Area and Storage

Area	260 acres
Active storage	640 acre-ft

2.4 - Special Considerations

Upstream of the powerhouse location, the distribution of flow to the intake channel is not uniform. Downstream, the Champlain Barge Canal navigation channel may be subjected to adverse crossflows due to the discharge from the tailrace. A physical hydraulic model study has been undertaken to investigate these problems and develop remedial measures.

Preliminary results from the upstream model tests, indicate that flow redirection structures will be required to provide an acceptable flow distribution in the intake channel. In addition, three cells of the upstream construction cofferdam on the east side of the intake channel will have to remain in place after completion of the project. The locations and shape of these structures are shown in Figures 2.2 and 2.3.

These criteria will be supplemented by final data from the model testing program as they become available.

2.5 - Forces

Hydrostatic 62.4 lb/ft of depth

Hydrodynamic force on redirection structures
(normal to long axis) 83 kips

Ice Pressures

Thermal

Powerhouse 6.5 kips/lin ft
Redirection structures Not considered

Dynamic

Powerhouse 324 kips
Redirection structures 130 kips
Cofferdam cells 130 kips

Ice force calculations were based upon the method described by Michel in Reference 4.

2.6 - Design References

1. U.S. Army Corps of Engineers, Engineering Technical Letter No. 1110-2-8, Computation of Freeboard Allowances for Waves in Reservoirs, Aug. 1966.
2. Standard Handbook for Civil Engineers, F.S. Merritt (ed.), McGraw Hill, 2nd Edition.
3. Engineering Hydraulics, H. Rouse (ed.), Wiley, 1950.

4. U.S. Army Corps of Engineers, CRREL Monograph III - B16, Ice Pressures on Engineering Structures, 1970.
5. Design of Small Dams, U.S. Bureau of Reclamation, 1974.
6. Hydraulic Design Criteria, U.S. Army Corps of Engineers, Vols. 1 and 2
7. U.S. Army Corps of Engineers, Engineering Manual EM 1110-2-1409, Backwater Curves in River Channels.
8. Handbook of Applied Hydraulics, C.V. Davis and K.E. Sorensen(eds.), McGraw Hill, 3rd Edition.
9. Hydroelectric Handbook, W.P. Creager, 1950.

UPPER MECHANICVILLE
HEADWATER - TAILWATER - DURATION CURVES

UPPER MECHANICVILLE
PLAN VIEW OF INTAKE

S 14

UPPER MECHANICVILLE
VANE SCHEMATICS

SECTION 3

GEOTECHNICAL DESIGN

SECTION 3 - GEOTECHNICAL DESIGN

3.1 - General

This section gives geotechnical design criteria for the powerhouse and associated structures.

3.2 - Foundation Bedrock Characteristics

Rock type Grey to black slightly metamorphosed shale with occasional intercalations of sandstone.

Rock structure The strike orientation of the bedrock varies from N15° E to N 25° E with dip of 45° to 60°E. The area is folded and cut by joint patterns with localized intensive faulting.

Thickness..... More than 100 ft

Rock Quality Designation .. Average 75%
(RQD) Minimum 0%
Maximum 100%

In-situ permeability Less than 10^{-7} cm/sec

Dry unit weight 170 lb/ft³ (average)

Rock compressive strength . 2,890 lb/in² (average).
Laboratory unconfined uniaxial compression tests.

Angle of shearing 33° for shale on shale along undulating
resistance ($\phi + i$) bedding planes*
35° for concrete on shale

Young's Modulus of
Elasticity 0.3×10^6 to 0.8×10^6 lb/in² based on
average rock strength values.

3.3 - Bearing Capacity

The average maximum design loading on the bedrock under the powerhouse will be approximately 3.5 tons/ft². This loading is less than the average allowable bearing pressure for the shale at the site of 4 tons/ft² recommended in Acres Geotechnical Investigation Report No. P5390.11.12. This value of 4 tons/ft² was established on the basis of a tolerable differential settlement in the powerhouse foundation of 0.25 in; using conservative deformation properties of the rock.

* The angle of shearing resistance can be as low as 22.5° along presheared or slickensided planes or mylonitic fillings. The existence of such features will be investigated by mapping during excavation.

For structures other than the powerhouse, the allowable bearing pressure may be increased.

3.4 - Cofferdam Design

3.4.1 - Upstream Cofferdam

The upstream cofferdam will be a cellular sheet pile structure founded on rock. The stability of the cofferdam will be analyzed in accordance with the U.S. Steel Sheet Piling Design Manual (July 1975) and the Foundation Engineering Handbook (1975). Fill material for the cells will be a free draining gravelly sand. The cofferdam will be analyzed for five extreme hydraulic conditions.

- (a) 20-year recurrence flood condition which gives the maximum anticipated water level, (Elevation 76.0) for this structure.
- (b) Water level at Elevation 68.0 and a thermally expanding ice load of 6.5 kips/lin ft.
- (c) 130 kips impact load for ice with the water level at Elevation 71.0.
- (d) Maximum expected water level (Elevation 76.0) and no drainage of the cell. This condition will only be considered to check for piling interlock failure.
- (e) Seismic forces with the water level at Elevation 69.1. This condition will be considered for those cells to remain permanently, see Section 3.6.7 for procedures.

<u>Design Condition</u>	<u>Minimum Factor of Safety</u>
Maximum Water Level	1.25
Thermal Expanding Ice Loading	1.00
Impact Ice Loading	1.00
No Cell Drainage	2.00
Earthquake Loading	1.00

3.4.2 - Downstream Cofferdam

The downstream cofferdam will be an earthfill structure. It will be sealed at its contacts with bedrock as required to reduce seepage into the excavations. They will be designed for both end-of-construction and long-term stability as follows:

<u>Design Condition</u>	<u>Minimum Factor of Safety</u>	<u>Remarks</u>
End-of-Construction	1.3	Upstream and downstream slopes
Steady seepage with maximum water level	1.5	Downstream slope only
Earthquake for both conditions above	1.0	Upstream and downstream slopes.

- Based on U.S. Army Corps of Engineers (1970).

Slope stability analyses will be done using a Janbu slope stability computer program.

3.5 - Rock Slope Stability

Excavation slopes will be generally near vertical and less than 70 feet. Because of the rock condition, slope failure through intact rock is not considered to be a problem. Therefore, the design and analysis of rock slopes will be based on the spatial orientation of discontinuities and the shear resistance available along these discontinuities. A procedure using the limiting equilibrium analysis will be followed as described below:

- Define the shape of the potential failure surface along which sliding is postulated.
- Calculate the shear stresses along the potential failure surface.
- Evaluate the available shearing resistance along the potential failure surface.
- Use the values obtained above to calculate the safety factor of the slope.

Factors of safety in simplified terms for different conditions will be calculated as follows:

- Potential failure block acted on by its own weight and sliding down a plane:

$$\text{Factor of Safety} = \frac{\tan (\emptyset + i)}{\tan \emptyset}$$

- Potential failure block acted on by its own weight and by pore water pressure along the planar failure surface:

$$\text{Factor of Safety} = \frac{(N-U) \tan (\emptyset + i)}{S}$$

Where:

- i = Angle of surface undulations
- $\emptyset$ = Angle of shearing resistance along discontinuities
- $\emptyset$ = Angle of prevalent dip of discontinuities
- N = Normal force on the failure plane
- U = Uplift (pore water pressure)
- S = Shear force down the failure plane (driving forces).

- Three-dimensional wedge stability by joint orientation using stereographic methods.

Support systems will be designed on the basis of the stability analysis results and the rock conditions.

3.6 - Lateral Loading

The lateral loading on a retaining structure due to soil backfill is dependent upon the following factors:

- Physical characteristics of the soil
- Degree of compaction
- Location of the water table
- Rigidity of the retaining structure
- Foundation deformation

3.6.1 - Cohesionless Soils

These soils are considered to be granular backfill material with little or no cohesion. For a cohesionless backfill the material will have the following pressure coefficients.

Coefficient of active earth pressure $k_a = \tan^2 (45 - \phi'/2)$

Coefficient of passive earth pressure.... $k_p = \tan^2(45 + \phi'/2)$

Coefficient of at-rest earth pressure ... $k_0 = 1 - \sin \phi'$

Where ϕ' is the angle of internal friction of the backfill material.

Calculations of lateral earth pressures will be based on these coefficients.

3.6.2 - Cohesive Soils

These soils consist of fine grained material with predominately silt- and clay-size particles. They are considered unsuitable for use as backfill immediately adjacent to retaining structures.

3.6.3 - Effect of Water Table

For soils below the water table, the buoyant weight of the soil plus the full pressure of the water will be used in calculating the lateral pressure on the retaining structure.

3.6.4 - Effect of Surcharge Loads

Concentrated loads will be treated separately using the Boussinesq solution for lateral loads or similar elastic solutions (Soil Engineering, Spangler & Handy, 1973). The influence of construction loads will be treated in a similar manner.

Surcharge loads for design will be as follows:

Normal conditions.....300 lb/ft²

Construction300 lb/ft² plus concentrated construction crane loading.

The stresses caused by construction loads should not exceed basic allowable stresses by more than 33 percent. The specifications will limit the magnitude and proximity of construction loads to retaining walls.

3.6.5 - Location of Lateral Earth Pressures

The location of resultant lateral earth pressures will be determined by the geometry of the horizontal forces acting on the structure.

3.6.6 - Selection of Lateral Pressures for Structural Design

Where it appears that the deformation of a retaining structure due to rotation, member deflection, or foundation yielding, will not exceed 0.005 H, the at-rest lateral pressures will be used.

At-rest lateral pressures will be used in the case of a gravity wall or similar structure on a rock foundation.

3.6.7 - Lateral Pressures due to Earthquake

The design of the earth retaining structures for lateral pressures due to earthquake will be checked in accordance with the procedures given in "Design of Earth Retaining Structures for Dynamic loads" by H.B. Seed & R.V. Whitman(1970) or by the procedures outlined in Section 1.4.16.

3.7 - Seepage

3.7.1 - Seepage Potential

Seepage can potentially occur whenever a differential water pressure head is present.

Seepage can occur:

- (a) Through a pervious material
- (b) Through a fractured or jointed material
- (c) Along construction joints
- (d) Along contact surfaces

3.7.2 - Seepage Control

The permeability of the foundation material has been determined to be less than 10^{-7} cm/sec, so seepage should be minimal. The powerhouse will be designed for full uplift pressures.

If, during excavation, rock conditions dictate the need, a grout curtain will be added to the design.

Piezometers will be provided for monitoring the uplift pressure under the structure.

3.7.3 - Dewatering

Cofferdams will be constructed to allow all excavation to proceed in the dry.

The cofferdams will be located and designed with due consideration given to the seepage potential through any existing or placed material which may allow high inflows into the dewatered area.

Seepage and rain water within the excavation will be collected and pumped out.

3.7.4 - Drains

Drains may be used as an effective means of reducing pressures caused by differential water heads. Pressure relief drains therefore may be included to reduce uplift pressures under the powerhouse.

Permanent drain holes will be considered 100 percent effective only if they are placed so as to be accessible for observation and cleaning.

A sump will be provided for the dewatering of the turbine semi-spiral case and draft tubes.

REFERENCES

- Seed, H.B. and Whitman, R.V. "Design of Earth Retaining Structures for Dynamic Loads", ASCE Specialty Conference, Lateral Stresses in the Ground and Design of Earth Retaining Structures, 1970.
- Spangler, M.G. and Handy, R.L. Soil Engineering, 3rd Edition, Harper & Row Publishing Co., New York, 1973
- United States Army, Office of the Chief of Engineers, Engineering and Design of Earth and Rock-Fill Dams, EM 1110-2-1902, Washington, D.C., 1970.
- United States Steel, Steel Sheet Piling Design Manual, United States Steel Corporation, Pittsburgh, Pennsylvania, 1975.
- Winterkorn, H.F. and Fang, H-Y, Foundation Engineering Handbook, Van Nostrand Reinhold Co., New York, 1975

SECTION 4

ELECTRICAL SYSTEMS

SECTION 4 - ELECTRICAL SYSTEMS

4.1 - Introduction

4.1.1 - General

This section outlines the criteria to be used in the design of the electrical equipment and service systems. The following systems and equipment are covered:

- Single Line Diagram
- Generators and Exciters
- Generator Control, Metering & Relaying
- Transformer Yard
- Station Service Systems
- Lightning and Overvoltage Protection
- System and Equipment Grounding
- Lighting Design
- Electric Wire, Cable and Hardware
- Raceways

4.1.2 - Codes and Standards

The design of the electrical systems will be based on the following codes:

- ANSI C1 - National Electrical Code, NFPA No. 70
- ANSI C2 - National Electrical Safety Code, National Bureau of Standards H-81
- ANSI C5.1 - Lightning Protection Code, NFPA No. 78
- OSHA - Occupational Safety & Health Act

The latest revisions of applicable standards of the following organizations apply generally to the electrical work for the project:

- ANSI - American National Standards Institute
- IEEE - Institute of Electrical & Electronics Engineers
- NEMA - National Electrical Manufacturer's Association
- NFPA - National Fire Protection Association
- UL - Underwriters Laboratories Incorporated
- ASTM - American Society for Testing and Materials
- IPCEA - Insulated Power Cable Engineers Association

- IEC - International Electro-Technical Commission
- ISA - Instrument Society of America
- NYSEG - New York State Electric & Gas

4.1.3 - Basic Design Criteria

This section outlines the service conditions and the basic design criteria for the electrical systems.

4.1.3.1 - Service Conditions

a) <u>Ambient Temperature</u>	Indoors	Outdoors
Maximum	40°C (104°F)	37°C (98.6°F)
Minimum	10°C (50°F)	-35°C (-30°F)
b) <u>Relative Humidity</u>	Indoors	Outdoors
Maximum	90%	100%
Minimum	0%	50%
c) <u>Cooling Water Temperature</u>		
Maximum	30°C (86°F)	
Minimum	0°C (32°F)	

4.1.3.2 - Miscellaneous Design Considerations

a) Sound Levels

Sound levels for electrical equipment will meet or exceed appropriate standards (e.g. NEMA, OSHA, etc.) and will not exceed 85 dB at 1 meter.

b) Moisture and Condensation Control

Thermostatically controlled small enclosure heaters will be provided for electrical panels where moisture and condensation could have a deleterious effect on the equipment.

c) Air-borne Contamination

Use of gasketed enclosures will be made for electrical panels where air borne dust could affect the reliability of the equipment. Since there are no manufacturing processes nearby, aerosol contamination is not expected to be a significant consideration.

d) Hazardous Area Designations

No area within the project is considered hazardous as defined by NEC.

e) Clearances

Electrical clearances will be based on good engineering practice and generally will be in accordance with the NESC.

4.2 - Single Line Diagram

The single line diagram prepared by Acres for initial design is shown on Drawing No. C-10402. This diagram is intended to illustrate only the general arrangement of the primary electrical equipment and protective relaying. The arrangement is based on units connected to a step-up transformer with switching on the high voltage side. The salient features of this scheme are as follows:

- The generator stator neutral will be high impedance grounded through a single phase grounding transformer;
- The generators will be connected to a common bus through generator circuit breakers and then to a step-up transformer.
- The generator bus connection to the step-up transformer will be by a non-segregated bus duct.
- The station services and the unit auxiliaries will normally be supplied from a station service transformer connected to the generator bus. Alternate source of power for station services will be derived from the existing 4.8 kV NYSEG feeder.

4.3 - Generators & Exciters

Two synchronous generators each rated at 8400 kva @0.95 pf, 4160V, 3Ø coupled to vertical adjustable blade propeller turbines will be provided.

The generators will be capable of 115% load operation and will be air cooled.

Each generator will have its own inverting type excitation system and automatic voltage regulation system.

The excitation system will consist of an excitation transformer, solid state rectifier/thyristor, D.C. field switch with associated discharge resistor, etc.

The automatic voltage regulation system will consist of solid state operational amplifiers and other control components to maintain generator voltage within 80% to 110%. It will also be capable of manual operation.

The details of the above equipment are given in Specification UM-1.

4.4 - Generator Control, Metering & Relaying

4.4.1 - General

The generator control, metering and protective relaying of both units, station auxiliary system and switchyard equipment will be combined on a sectionalized walk-in type duplex switchboard (CM&R panel). The front stationary panels will contain the control and metering devices while the rear panels will be dedicated for protective relays. The panel layout design will take into consideration NYSEG's requirements for 34.5 kv line protection and controls.

4.4.2 - Generator Control

The controls will be designed for the following modes of operations:

a) Unit Start

- i) Local (manual) start, manual synchronize
- ii) Local (manual) start, auto synchronize
- iii) Remote (auto) start, auto synchronize

b) Unit Shutdown

- i) Manual normal and emergency shutdowns
- ii) Remote normal shutdown
- iii) Emergency shutdown initiated by protective relays

4.4.2.1 - Unit Start Logic

Upon initiation of start signal, the unit start controls go through the following four phases:

- a) Check the status of the station to ensure that the unit can be started, initiate incomplete sequence timing;
- b) Start the necessary station auxiliaries;
- c) Open the wicket gates and bring the unit to synchronous speed;
- d) Synchronize: De-energize incomplete sequence timer.

a) Checking the Status of the Station

This includes, depending upon the type of the unit, the following:

- Governor oil pressure "normal"
- Generator & turbine bearings temperature "normal"
- Brakes in "off" position
- All protective relays de-energized and reset
- Voltage regulator in "on" position
- Water level in water passage
- Any other permissive or interlock in normal condition
- Initiate incomplete sequence timing

b) Starting the Station Auxiliaries

- Start oil lift, cooling water and/or lube oil pumps (or check their pressure/flow normal)
- If governor oil pressure ok, energize governor solenoid
- Close field breaker. Alternatively, the field breaker may be closed after the exciter voltage relay has picked up.

c) Open the Wicket Gates

The governor solenoid will gradually open the wicket gates to speed-no-load position. This will cause:

- The unit to start and run at approximately synchronous speed,
- At about 95% speed, oil lift pump will be disconnected,
- At about 95% speed, field breaker will have closed if not already done so,
- Initiate the synchronizer circuit

d) Synchronizing the Unit

Manual Synchronizing (Local)

In this mode, the operator will synchronize the unit to the system by closing the generator breaker:

- When unit and system voltages and frequencies are matched, and
- At the instant when phase displacement is zero degrees electrical.

To assist the operator in manual synchronization, running bus and incoming bus voltage, incoming generator frequency meter, synchronizing lamps and a synchroscope will be provided. During manual synchronization, the generator voltage and frequency will be adjusted using the same controls as used for VAR and W.

Automatic Synchronization (Local or remote)

In this mode, the synchronization will be automatic utilizing voltage, frequency and phase matching relays.

There is no provision for automatic dead bus synchronization.

Incomplete Sequence Timer

In the manual synchronization mode, the incomplete sequence timer is de-energized as soon as the unit has attained say 10% speed.

In the automatic synchronizing mode, the incomplete sequence timer is de-energized as soon as the unit is synchronized to the system.

If the timer remains energized for a pre-set delay, it initiates a shutdown through master stop relay.

4.4.2.2 - Unit Stop Logic

Local (Manual) or Remote Normal Shutdown

In this mode, the unit is brought to a standstill under governor control by gradually closing the wicket gates. As the wicket gates start closing, the following operations take place:

- Unit starts unloading to 0 MW
- At no load position, the generator circuit breaker is tripped followed by field switch trip
- The governor proceeds to close the wicket gates
- At about 70% speed, oil lift pump is activated to maintain oil pressure in the generator thrust bearing.
- At about 40% speed, the braking system is energized.
- When unit has come to rest, all unit auxiliary systems are shut down.

Local (Manual) or Protective Relay Emergency Shutdown

In this mode, the unit is brought to a standstill by simultaneously tripping the generator AC breaker and the field switch, energizing master stop relay(s). The governor solenoid closes and locks the gates. The generator brakes are applied and all auxiliaries are shutdown.

4.4.2.3 - Unit restart after shutdown

If the unit shutdown was caused by a lock-out relay operation (86N or 86E, fault condition) or emergency push button, the unit cannot be re-started until the relays are manually reset.

However, the unit can be restarted locally or remotely if the unit shutdown was caused by Normal shutdown signal initiated either locally or remotely.

4.4.3 - Metering, Telemetering and Remote Control

4.4.3.1 - Local Metering

Metering at the control, metering and relaying (CM&R) panel will be provided as follows:

For each unit: Generator voltage
 Generator current (3 ammeters)
 MVar
 MW
 Power factor
 Watt hour

For Synchronizing: Synchroscope
 Starting bus frequency meter
 Running bus voltmeter
 Starting bus voltmeter

4.4.3.2 - Telemetry and Remote Control

For the purpose of remote control and telemetry, provision will be made to connect following inputs/outputs to NYSEG's SCADA Remote Terminal unit:

SCADA Point List:

A. Status Input Points - Closed contact for closed breaker switch, alarm condition, auto status or on condition.

1. 52-SST
2. 52 G-1
3. 52 G-2
4. Low battery voltage
5. Battery ground
6. Loss of DC (relay)
7. Supervisory cut-off (closed contact for any cut-off switch)
8. Local/Remote (internal point)
9. Unit 1 - On/Off
10. Unit 2 - On/Off
11. Unit 1 - Automatic/Manual
12. Unit 2 - Automatic/Manual
13. Control System Trouble - Unit 1
14. Control System Trouble - Unit 2
15. Unit 1 - Overspeed
16. Unit 2 - Overspeed
17. Unit 1 - Trashrack differential alarm
18. Unit 2 - Trashrack differential alarm
19. Unit 1 - Trouble
20. Unit 2 - Trouble
21. Unit 1 - Fault
22. Unit 2 - Fault
23. Transformer Differential
24. Transformer Trouble
25. Transformer Fault
26. Building Security
27. Fire Alarm
28. Fire Alarm System Trouble

29. Station Service Transfer
30. Station Auxiliary System Trouble
31. Powerhouse Flood Alarm
32. Flashboard Loss of Pressure

B. Control Points - Dry contact output (250 m/sec closure) relays used
- Clare GPS or equivalent.

1. Unit 1 - Start
2. Unit 1 - Stop
3. Unit 2 - Start
4. Unit 2 - Stop
5. Unit 1 - Automatic/Manual
6. Unit 2 - Automatic/Manual
7. Lower Flashboard

C. Analog Inputs - -5 to +5 V dc input range.

1. Headwater Level
2. Tailwater Level
3. kW Output - Unit 1
4. kW Output - Unit 2
5. Total Station Output (net) kW
6. Bus Voltage
7. kVAR Output - Unit 1
8. kVAR Output - Unit 2
9. 90% Reference (interval)
10. 90% Reference (interval)

D. Analog outputs 0-5 V dc output range.

1. Desired kW Generation - Unit 1
2. Desired kW Generation - Unit 2
3. Desired kVAR Generation - Unit 1
4. Desired kVAR Generation - Unit 2

4.4.4 - Unit Protection

4.4.4.1 - Devices Initiating a Normal Shutdown

The following is a representative list of protective devices and relays proposed for the unit protection. The list will be finalized when NYSEG's and turbine/generator supplier's requirements are fully known.

- 1) Generator guide bearing, high temperature (23GB)
- 2) Thrust bearing, high temperature(23THB)
- 3) Turbine guide bearing, high temperature (23 TB)
- 4) Trashrack differential pressure (TRDP)
- 5) Overspeed (12)
- 6) Stator temperature, high(49S)
- 7) Vibration detector (39)

4.4.4.2 - Devices Initiating an Emergency Shutdown

1) Loss of Excitation Relay	40	Type	CEH
2) Negative Phase Sequence Relay	46	Type	INC
3) Restrained voltage, overcurrent Relay	50/51	Type	IJCV
4) Overvoltage Relay	59	Type	IAV
5) Voltage Balance Relay	60	Type	CFVB
6) Stator Ground Relay	64-G	Type	IAV
7) Bus Ground Relay	64-B	Type	IAV
8) Field Ground Relay	64-F	Type	PJV
9) Over-frequency Relay	81H	Type	KF
10) Under-frequency Relay	81L	Type	KF
11) Generator Differential Relay	87G	Type	CFD
12) Split-Phase Differential Relay	87SP	(If required)	
13) Transformer Differential Relay	87T	Type	BDD
14) Over-Excitation (V/HZ) Relay	96EX	Type	STV
15) Excitation overcurrent Relay	50/51EX	Type	IAC
16) Governor oil pressure, low (65-63Q)			
17) Governor oil level, low (65-71Q)			

Lock-out Relays 86E & 86N will be Type HEA.

34.5 kv line protection and transformer protective relays will be NYSEG's responsibility.

4.4.5 - Devices Used on CM&R Panel

Control switches GE type SB1 or Westinghouse Type W
 Indicating lights GE type ET16
 Terminal blocks GE type EB25
 Test blocks Westinghouse type FT
 Protective relays GE various(see Section 4.4.4.2) or Westinghouse.
 Meters GE type AB or DB as required, or Westinghouse 1%
 Accuracy 250° white scale with black marking.

Color scheme for indicating lights:

Red: "Breaker Closed" or "Pump Motor Running"
 Green: "Breaker Open" or "Pump Motor Stopped"
 Amber: "Alarm" or "Abnormal Condition"
 White: "Power Supply Available"
 Blue: "Switch Off Normal"

Spare contacts of all lock-out relays will be wired to test blocks.

Panel wiring will be minimum No. 12 AWG Cu Type TA, TBS or SIS.

4.4.6 - Unit/Station Output Control

4.4.6.1 - Local (Manual)

In this mode of operation, the operator can select the MW output of each unit by operating the MW (gate opening) selector switch at the CM&R panel until the desired output is reached.

4.4.6.2 - Remote (Manual)

Depending upon NYSEG's SCADA equipment and the Gate Control Circuit, the MW output of each unit can be selected either:

- (a) By pre-selecting the MW after the unit has been synchronized, in which case the increase/decrease pulse to the Gate Control Motor are sent automatically, or
- (b) By continuously depressing the MW increase or decrease pushbutton until the desired level has been reached. Dependent upon the type of communication channel between Master and remote terminal unit, it may be required to operate the MW increase/decrease pushbuttons intermittently.

4.4.6.3 - Automatic

In this mode of operation, the station output will be automatically controlled by a micro-processor or other suitable device(s) to maximize the energy output from the station. This will be done by adjusting the wicket gates so that the head water level is maintained as close as possible to the top of the dam (flashboards) thus maximizing the head. The number of operating units will be automatically selected to maximize overall plant efficiency.

The above mode of operation will have to be modified at low discharge (below about 1500 cfs) to avoid rough operation of the unit.

Automatic control system details, such as required functions, extent of its application, manual override etc. will be further investigated and therefore a slight modification to the above stated operating philosophy may be possible.

4.5 - Transformer Yard

4.5.1 - General

The generators' output will be connected to a nominal 4160/34,500 V, 12/16/20 MVA step-up transformer.

The 34.5 kV output of the transformer will be connected to the existing NYSEG system through a manually operated disconnect switch.

4.5.2 - System Fault Levels

The maximum fault MVA available under any type of fault condition is 300 MVA.

4.5.3 - Generator Step-up Transformer

This will be a nominal 4160/34,500 V, 2 winding, three phase delta/wye grounded transformer.

The MVA rating will be 12/16/20 MVA.

Transformer cooling will be OA/FA/FA.

The transformer impedance will be within standard range.

The short circuit withstand capability of the transformer for through faults will be based on the latest ANSI Standard C57.12.00.

4.5.4 - 34.5 kV Transformer Disconnect Switch

A 600 A manually operated disconnect switch will be provided to isolate the 34.5 kV line to Mulberry Street Station.

4.5.5 - Grounding

For grounding design, NYSEG and IEEE STD 80 standards will be followed. Minimum size of the ground grid will be No. 4/0 AWG. This grid will be connected to the Powerhouse ground grid using two 500 MCM copper cables.

4.6 - Station Service Systems

4.6.1 - General

There will be three distribution systems:

- a) 480 V 3Ø for motor loads and other major power
- b) 120/208 V 3Ø for lighting and receptacles
- c) 125 V dc for control, alarms and other emergency systems

4.6.2 - 480 V Distribution

4.6.2.1 - General

This will be a 3Ø, 4W system with the neutral solidly grounded.

The system will be fed from the 4.16 kV generator bus (primary source) or the NYSEG 4.8 kV local feeder (secondary source). Each source will be stepped down to 480 V by a station service transformer (approximately 500 kVA). The transformers' output will be fed into a 480 V switchboard containing rack-out type breakers.

As the two sources are not in phase, the transformer secondary breakers will be interlocked to provide dead transfer.

The 480 V switchboard will supply motor control panels, cranes and hoists, 480 V distribution panels.

The switchboard construction will be standard type with dead front assembly.

4.6.2.2 - Motor Control Centers

Modular type control centers of standard construction will be provided for motor control:

- MCC will be Class II Type B or C
- All starters will be combination type (Motor circuit protector/contactor/thermal overload) with suitably sized individual control transformer
- Local disconnects will be provided for all motors not in direct-sight of the disconnecting device
- Local individual starters or starter group panels will be provided where necessary
- Starters will be sized compatible with Motor HP size but minimum will be size 1.
- Minimum compartment size will be 12"
- Motor ground protection will not be provided

4.6.2.3 - 480 V Distribution Panels

These will be fed from 480 V switchboard and located at strategic points to feed small loads, e.g., space heaters, 277 V lighting and 480/208-120 V distribution transformers.

The number and location of the panels will be finalized at the detailed design stage.

4.6.2.4 - Station Service Transformers

The 4160/480 V station service transformer (SST1) will be a 2 winding, 3Ø, 500 kVA (tentatively) Delta/grounded wye, dry type, indoor transformer with standard FCAN and FCBN taps.

The 4800/480 V station service transformer (SST2) will be similar to above except that it will be a pole mounted, primary fused, transformer supplied and installed by NYSEG.

4.6.3 - 120/208 V Distribution System

This will comprise distribution transformers, associated circuit breakers and miscellaneous lighting panelboards. The typical loads fed from the system are lighting, receptacles and miscellaneous power.

4.6.4 - 125 V DC System

This system consists of one battery charger, one set of station battery and DC distribution boards.

The load fed from this system includes station and unit control and protection, alarms and indication, emergency lighting, field flashing, etc.

The battery chargers will be solid state type with constant voltage, constant current characteristics.

The battery will be adequately sized to supply the required load for a period of up to 8 hours and have the capability of operating the one worst case contingency load at the end of the 8 hours period.

The battery/battery charger control panel will contain instruments such as float/equalize controls, charging ammeter, DC voltmeter, Ground Fault Indication etc. Alarms will include dc overvoltage, dc undervoltage, etc.

Ground faults on the DC system will be annunciated by a ground fault relay.

All DC branch circuits will be protected by fused disconnects.

4.6.5 - Spares & Spaces

An adequate number of spare breakers/fuses and spaces will be provided in all of the above panels/MCCs.

4.7 - Lightning & Overvoltage Protection

Generator protection against lightning and switching surges will be provided by installing lightning arresters and surge capacitors at, or as close as possible to the machine terminals. Similar arrestors will also be installed at 5 kV bus for step-up transformer low voltage winding.

4.8 - System and Equipment Grounding

The powerhouse grounding system will comprise a 500 MCM bare copper embedded ring around the periphery of the building. 500 MCM Cu drops will be mechanically connected to reinforcing steel and other embedded parts in the immediate vicinity of the water passage. A 500 MCM ground will be embedded for each elevation in the powerhouse.

All major electrical equipment will be grounded at two points using No. 4/0 AWG taps.

All non-electrical equipment and steel structures will be grounded using No. 2/0 AWG taps.

All embedded copper to copper connections will be made using exothermic process (e.g., Cadweld).

All exposed connections will be made using mechanical connectors. All grounding lugs will be 2 hole type.

Grounding bus within a switchboard, MCC or an electrical panel will be no less than 1/4" x 2" copper bus bar.

The generating station ground will be connected to the transformer ground grid by two 500 MCM copper cables.

4.9 - Lighting Design

Lighting Levels

Lighting quantity will generally be in accordance with IES. Some lighting levels are given below:

<u>Area</u>	<u>Lumens/sq ft</u> <u>(foot-candles)</u>
Battery room	20
Vertical face of switchboards	50
Rear of switchboard (vertical)	30
Emergency	5
Switchgear floor	30
Turbine basement	20
Erection bay	50
Dewatering pit	10
Dewatering pumps	20
Lavatories	30
Intake housing	30
Equipment galleries	20
Outdoor lighting	1

4.9.2 - Light Fixtures Type

The following type of lighting will be used:

High bays and outdoor	high pressure sodium
Pump rooms, galleries, etc.....	fluorescent
Intake housing, battery room, etc.....	incandescent
Emergency lighting	incandescent

4.9.3 - Lighting Controls

Lighting circuits will be switchable with automatic transfers to DC
Emergency lighting upon failure of AC lights.

4.10 - Electric Wire & Cable

All cable sizes will be in accordance with NEC. Minimum cable sizes will be as follows:

- power circuits: No. 12 AWG, copper minimum
- control circuits: No. 12 AWG, copper
- supervisory and alarm circuits: No. 16 AWG, copper
- current transformer leads: No. 10 AWG (maximum length 200 ft)
- potential transformer leads: No. 12 AWG up to 200', No. 10 AWG over 200'

Shielded cables where used will have their shields grounded at the sending end only. All cable and wire will be 600 V copper, cross-linked polyethylene, heat and moisture resistant insulation of EPR insulation with neoprene or hypalon jacket. Generator cable where used will be similar to above, except that it will be 5 kV, shielded.

Multi-conductor control cable will be 600 V type TC neoprene or hypalon jacketed.

Power cables of one circuit will not be combined in cables with either control wires or power wires of another circuit.

Approximately 25 percent spare conductors will be provided in the control cables.

4.11 - Raceway System

4.11.1 - Cable Trays

- a) Use of steel cable trays will be made to keep the long conduit runs to a minimum.
- b) Cable trays will be provided with barriers to segregate cables of different classes, e.g.
 - 5 kV power cable
 - 600 VAC power and 120 VAC control
 - 125 V DC
 - communication, supervisory
- c) #4/0 AWG bare copper will be bonded to cable trays along their entire length.

4.11.2 - Conduits

- a) RGS conduit will be used throughout except:
 - PVC may be used for embedded installations
 - flexible liquid tight conduit may be used for terminations to vibration producing equipment, e.g. motors.

- b) Minimum conduit size will be 3/4 in. except 1/2 in. size may be used for lighting fixtures.
- c) Conduits will generally be sized 1 size over.
- d) Conduits will not be used as grounding conductor.

4.12 - 4160V Switchboard

4.12.1 - General

The single-line diagram shows the 4160V switchboard arrangement. It will be a 3-circuit breaker assembly with necessary PT compartments. There will be one circuit breaker for each unit and one for the station service transformer. Grounding and test breaker device will be provided with the switchgear line-up.

4.12.2 - 4160V Circuit Breakers

These will be 3-pole, 4160V, indoor drawout type air circuit breakers. The interrupting capacity will be 250 MVA but may be modified to suit NYSEG's requirements. The unit circuit breakers will be rated at 1600A and the station service circuit breaker at 1200A.

SECTION 5

MECHANICAL SYSTEMS

SECTION 5 - MECHANICAL SYSTEMS

5.1 - Introduction

The design recommendations in Section 5.2 through 5.7 outline the basic parameters used in the design of the mechanical service systems for the Upper Mechanicville Hydroelectric Redevelopment Project. Each section covers a group of related systems and has subsections for each system outlining the regulation and code requirements, design requirements, major equipment and system details.

Requirements for piping materials; for service, line and system identification; and painting for the mechanical service systems described in Section 5 are detailed in Acres Mechanical Standards.

5.2 - Station Service Water

5.2.1 - General

The station service water requirements will be met by the following systems:

- Station service water intake;
- Cooling water and shaft seal water;
- Domestic water; and
- Service water

5.2.2 - Station Service Water Intake

(a) General

The station service water intake system consists of intake fittings, piping, valves and a strainer station supplying water to the service systems in the powerhouse.

(b) Design Requirements

Service water intake systems:

- System design pressure 100 lb/in²
- System operating pressure (max.) 20 lb/in²
- Maximum velocity (in intake line) 6.0 ft/s
- System design flow (one strainer) 600 gpm
- Flow per generating unit 230 gpm
- Maximum particle size 1/16 inch

(c) System Details

Water for the systems will be supplied from the forebay through three screened inlet openings. One intake opening will be located in each semi-spiral case and the third located near the upstream face of the intake. Compressed air connections will be provided for backflushing of the water inlet screens.

One automatic, rotary type backwash strainer will be provided in the powerhouse. It will be backwashed on an adjustable time cycle. A differential pressure switch will be provided across the strainer to activate the backwash should the strainer become clogged. A second pressure switch setting will be an alarm on high pressure drop.

A single basket type strainer will be provided in a valved bypass to allow servicing of the rotary strainer.

Each strainer will be designed to handle the full flow requirements of both units, or alternatively, the flow through one fire pump. Downstream of the strainers, the header will branch off into the fire protection system and the cooling water and shaft seal water systems.

(d) Terminal Points

The origins of the system are the intake fittings described in Section (c) above. The downstream terminal points occur at the downstream connection of the strainers.

(e) Major Equipment

Water intake fittings

- number three
- type of construction stainless steel bar grating
- velocity through grating 1.5 fps (maximum)*
- grating openings 2-1/2 in. x 3 in.
- pipe size 10 in.

Water strainers

- number two
- type one rotary automatic backwash, and one single basket type
- flow capacity (each)..... 600 gpm
- mesh size 1/16 in.
- allowable pressure drop 2 lb/in²
- backwash drive electric motor
- backwash control time cycle and differential pressure switch
- backwash alarm differential pressure switch

* Except when used for unit filling (see Section 5.2.2)

(f) Regulation and Code Requirements

- ANSI B31.1 - Power Piping
- AWS D1.1 - Structural Welding Code
- Uniform Building Code
- State Building Construction Code, State of New York
- Local Building or Plumbing Codes, if any
- OSHA

5.2.3 - Cooling Water and Shaft Seal Water

(a) General

The cooling water and shaft seal water system is a pump pressurized system. It includes the following:

- Generator air cooling and bearing oil cooling systems;
- Shaft seal water system
- Air compressor cooling system.

(b) Design Requirements

Each cooling water system will be designed to operate with a maximum water supply temperature of 30°C. The pressure and water supply requirements for each service are as follows:

Generator air coolers

- system design pressure 100 psi (see Note 1)
- system operating pressure 20 psi (nominal)
- system flow - maximum 420 gpm (both units)

Generator bearing oil coolers

- system design pressure 100 psi (see Note 1)
- system operating pressure 20 psi (nominal)
- system flow - maximum 20 gpm (both units)

Shaft seal water

- system design pressure See Note 2
- system operating pressure See Note 2
- system design flow 20 gpm (both units)
- maximum particle size See Note 2

Air compressor cooling

- system design pressure 100 psi
- system operating pressure 20 psi (nominal)
- system flow 10 gpm

Notes: (1) The design pressure specified is for supply systems to the generator air and bearing oil coolers. The design pressure for associated equipment will be selected by the generator supplier.

(2) To be established by turbine supplier

(c) System Details

The cooling water system will have two pumps connected in a parallel arrangement, with distribution piping supplying pump pressurized water to the generators and compressor aftercoolers through individual branch lines.

Each of the cooling water pumps will be sized to handle the full powerhouse cooling water requirements. The pumps will be operated in "main-standby" sequence with the main pump started manually and the standby pump started and stopped by pressure switch control. A manual selector switch will permit alternating the main and standby pumps.

- Generator Cooling Water: Distributing piping from the cooling water pumps will connect to the terminal points immediately inside the generator enclosure. The generator supplier will provide all piping, valves (including control valves), fittings, controls, supports and brackets required within the generator enclosure for operation of the system. The discharge from the cooling system will be directed by embedded piping to the draft tube gate guides. The heat from the water will be used to keep the draft tube gate guides free from ice accumulation.
- Shaft Seal Water: The shaft seal water for each unit will be taken from the generator cooling water supply. The system will be provided by the turbine supplier, and will include for each unit a pressure reducing valve if necessary, two filters in parallel, isolating valves to permit maintenance of one filter without stopping the flow through the other filter, and a flow switch to alarm low shaft seal water flow.
- Compressor Aftercooler: The cooling water system for the air compressor aftercoolers will consist of a branch take-off line from the supply header of the cooling water pumps. The compressors will be air or oil cooled (see Section 5.4). Cooling water is used in the aftercoolers only.

(d) Terminal Points

The upstream terminal points for the generator cooling system will be at the discharge connections of the strainers described in Section 5.2.2(c). The downstream terminal points are at the embedded drainage piping in the generator enclosures for the generator cooling water. Embedded piping will be provided to discharge cooling water from the generators to tailwater. Cooling water for the air compressor aftercoolers will be taken from downstream of the cooling water pumps and will be discharged into the drainage sump after use.

(e) Major Equipment

Major equipment for the generators including air coolers and bearing oil coolers will be designed and provided by the generator supplier.

Other major equipment will be as follows:

Cooling water pumps

- number two (including one standby)
- capacity (each) 465 gpm
- head 50 ft.
- type centrifugal
- duty continuous
- drive electric motor

Low pressure compressor aftercoolers

- number two
- flow quantity per unit [as required for units]

(f) Regulation and Code Requirements

ANSI B31.1 - Power Piping
AWS D1.1 - Structural Welding Code

5.2.4 - Domestic Water

(a) Drinking Water

Domestic water for drinking purposes will be brought to the powerhouse in portable containers.

(b) Battery Room Eyewash

An eyewash will be provided in the battery room. The eyewash will be a self contained unit complete with water storage tank.

(c) Regulation and Code Requirements

County Health Regulations
OSHA

5.2.5 - Service Water

(a) General

Service water (non-potable) will be provided for the washroom facilities at the plant.

(b) Design Requirements

System design pressure 100 psi
System operating pressure 50 psi
System design flow 5 gpm (approx.)

(c) System Details

A pumped service water system will supply water to the washrooms. The system will incorporate a packaged pump and diaphragm type pressure tank unit. Water will be taken from the station service water intake. The water will be filtered using a basket type filter unit. An electric hot water tank will be used to provide hot water.

(d) Major Equipment

Service water pumps

- number one
- capacity 5 gpm (approx.)
- head 130 ft (approx.)
- type centrifugal
- drive electric motor

Pressure tank

- number type
- type diaphragm
- capacity to suit
- design pressure (min.) 100 psi

Filter

- type duplex basket type
- filter size to be established later

Hot water tank

- capacity 30 gal
- heaters
 - type glass lined
 - number two
 - type electric immersion
- controls thermostat

(e) Regulation and Code Requirements

Uniform Building Code
New York State Building Construction Codes
Local Building or Plumbing Code, if any
County Health Regulations

5.3 - Fire Protection

5.3.1 - General

The station fire protection requirements will be met by the following systems:

- Station fire protection water;
- Generator sprinkler;
- Station fire alarm; and
- Portable fire protection equipment.

5.3.2 - Station Fire Protection Water System

(a) General

The station fire protection water system will be a pump pressurized system supplied from the station service water intake strainers (see Section 5.2). Pressure will be maintained in the system by a jockey

pump. Two centrifugal pumps will be provided, one electric motor driven and one diesel engine driven arranged to start on drop in system pressure. Service water outlets will be provided at most of the fire hose stations.

(b) Design Requirements

System design pressure	135 psi
System operating pressure	110 psi
System design flow	600 gpm
Total installed capacity	1200 gpm

Fire hose stations
(1-1/2 in. hose)

- location	to be established later
- fire hose station pressure (maximum)	100 psi at 75 gpm
- fire hose nozzle pressure (maximum)	80 psi at 75 gpm
- fire hose nozzle pressure (minimum)	50 psi at 40 gpm
- service water outlets (3/4 in. hose)	25 psi at 20 gpm

(c) System Details

Fire protection water will be drawn from the station water supply system (upstream of the cooling water pumps) and pumped into a looped header. Pressure will be maintained in the fire protection water header by a jockey pump. The jockey pump will be of sufficient capacity to provide service water for washdown use, without causing the main fire pump to start. An air charged pressure tank in the system will prevent continuous cycling of the jockey pump. An unloader valve will be provided with the jockey pump to ensure satisfactory pump running time. The main fire pumps will start automatically upon drop of pressure in the fire water main, or by operation of a pushbutton on the fire pump control panel and inside the entrance door. The pumps will be stopped manually. A pressure relief valve will be provided on the diesel engine driven pump to direct waste water to the tailwater.

The control sequence will be as follows:

Jockey pump

- on	100 lb/in ²
- off/unload	110 lb/in ²

Main fire pump

- on	90 lb/in ²
- off	manual

Diesel engine driven fire pumps

- on	75 lb/in ²
- off	manual

Over-pressure relief valve

- setting	135 lb/in ²
-----------------	------------------------

The fire protection water headers will be provided within the powerhouse with branch lines to all fire hose stations.

Orifice disc union will be provided on inlets to 1-1/2 inches fire hose valves, with orifices sized for the applicable location, to restrict pressure to 80 psi, at 75 gpm flow.

Branch connections of 3/4-inch diameter will be provided along the headers in each gallery for washing down the floors or equipment. Orifice disc unions will be provided at inlet to valves to restrict pressure to 25 psi at 20 gpm flow.

(d) Major Equipment

Electric motor driven fire pump

- number one
- capacity at rated head 600 gpm
- head to suit design requirements
- type centrifugal horizontal split case
- drive squirrel cage induction motor
- motor duty continuous
- power supply 480 volt, 3-phase, 60 hertz

Diesel engine driven fire pump

- number one
- capacity at rated head 600 gpm
- head to suit requirements
- type centrifugal horizontal split case
- drive diesel engine

Jockey pump

- number one
- capacity 25 gpm
- head to suit design requirements
- type turbine (peripheral)
- drive squirrel cage induction motor
- motor duty continuous
- power supply 480 volt, 3-phase, 60 hertz

Pressure tank

- number one
- capacity 100 gal (approx.)
- type diaphragm tank

(e) Regulation and Code Requirements

See Section 5.3.6

5.3.3 - Generator Sprinkler

(a) General

The generator sprinkler will be a deluge system. Water will be drawn from the water supply header at each unit and will be admitted to the sprinkler loops by means of a solenoid operated valve. The piping, fittings, and other items within the generator enclosure will be provided by the generator supplier.

(b) Design Requirements

- System design pressure 100 psi (nominal)
- Operating pressure determined by
generator manufacturer
- Capacity per unit determined by
generator manufacturer
- Nozzles water spray
- System dry type
- Detection to be selected later
- Controls electrical
- Alarm panel annunciation and
siren

(c) System Details

Fire protection water will be supplied to each generator from the fire protection water header (see Section 5.3.2). The supply line to sprinklers will be provided with a shut-off valve, strainer, solenoid operated control valve and test valve. Solenoid valve operation will be initiated by detectors in the generator enclosure in conjunction with electrical protective relays on the generator. After a predetermined delay, the control valve will open to admit water to the sprinkler loops. Two manually operated valves will be provided for use in testing the operation of the solenoid valve. During testing one of the valves will be closed to isolate the sprinkler loops, the other will be open to drain the flow through the solenoid valve. The valve used to isolate the sprinkler loop will be provided with an alarm contact so that an alarm may be sounded when the valve is in the closed position.

(d) Major Equipment

Deluge valves

- type solenoid, normally
closed, energize to
open
- power supply 125 V dc
- actuation electrical with manual
pressure

Generator sprinkler nozzles

- type low velocity spray

(e) Regulation and Code Requirements

See section 5.3.6.

5.3.4 - Fire Alarm

Annunciation will be provided on the main panel in the powerhouse, at a permanently maned location to be designated by NYSEG, and in the remote control room. In addition, alarms will sound in the powerhouse.

Annunciation will be provided for the following systems and areas:

- Main fire pump "Running";
- Generator sprinklers "Activated";
- Detectors in generator enclosure; and
- Detectors in other areas of the powerhouse (location to be established later).

5.3.5 - Portable Fire Protection Equipment

(a) General

Portable fire extinguishing equipment will be placed strategically throughout the station and will suit the basic classifications of fires as follows:

- Class A: Fires involving ordinary combustible materials such as wood, cloth, paper, rubber and many plastics.
- Class B: Fires involving flammable liquids, paint, gases and greases.
- Class C: Fires in energized electrical equipment where the electrical non-conductivity of the extinguishing media is of importance. (When electrical equipment is de-energized, extinguishers for Class A or B fires may be used safely).

(b) Design Requirements

<u>Area</u>	<u>Class</u>	<u>Type</u>	<u>Size</u>
Powerhouse floor	A, B & C	carbon dioxide dry chemical	10 lb.(two) 10 lb.(two)
Powerhouse crane	C	carbon dioxide	5 lb.
Pump and mechanical equipment areas	B & C	carbon dioxide	10 lb.
Stairwells	C	carbon dioxide	10 lb.
Battery and storage rooms	B & C	carbon dioxide	10 lb.

5.3.6 - Regulation and Code Requirements

- NFPA 13 - Sprinkler System
- NFPA 14 - Standpipe and Hose Systems
- NFPA 20 - Centrifugal Fire Pumps
- NFPA 24 - Outside Protection
- NFPA 10 - Installation of Portable Fire Extinguishers
- OSHA Safety and Health Standards

5.4 - Compressed Air

5.4.1 - General

The compressed air systems will satisfy the following requirements:

- brake and service air system
- draft tube water level depression system
- high pressure governor air system

5.4.2 - Brake and Service Air Systems

(a) General

The brake air system will provide air at 100 psi for slowing and stopping rotation of the generating units and holding the generators in a stopped position. The service air system will provide air at 100 psi for a general maintenance and air operated tools and water level controls

(b) Design Requirements

System design pressure	150 psi
System operating pressure	100 psi
Rated capacity	200 cfm

(c) System Details

The two compressors will be controlled by pressure switches and deliver air to the receivers.

The controls will be arranged to initiate compressor operation on an automatic lead and lag sequence. A manually operated switch will permit selection of lead compressor. The following is a tabulation of the control sequence:

Nominal system pressure	100 psi
Lead compressor "on"	90 psi
Lag compressor "on"	85 psi
All compressors "off"	100 psi
Minimum operating time (electric motor)	5 min.
Safety valve setting	110 psi

Each compressor will be controlled by an "Automatic-Off-Manual" switch; the automatic operation is described above and manual operation provides continuous operation. An unloader mechanism will be provided on each compressor to allow no-load starting and minimum running time. A minimum run timer and an elapsed time meter will be provided.

Two air receivers will be provided in the compressor room. One will be designated "service air" and the other will be designated "generator brake air". In the event of an abnormal pressure drop in the brake air system, an automatic valve will isolate the service air header from the rest of the system thereby giving priority to the brake air system.

Two compressed air distribution pipe headers will be supplied from the air receivers and are labelled "generator brake air" and "service air". Branch lines from the service header will extend to all areas of the powerhouse. Air blow out lines will also extend to base of the draft tube gate checks.

Generator brake air will be distributed by a single header with branch lines to the brake valves on the governor. A branch line will also be provided from the service air header for alternate brake air supply.

The cooling system for the compressor aftercoolers is described in Section 5.2.3.

(d) Major Equipment

Compressors

- number two
- type reciprocating air
cooled
- rated pressure 100 psi
- rated capacity (each) 100 cfm
- drive electric motor
- duty continuous
- air inlet temperature 70°F
- maximum noise level 75 dbA at 4 feet
- air aftercooler - number two
 - type shell and tube (air to
water)
- moisture separator two

Air Receivers

- number two
- capacity (each) 150 ft³
- design pressure 130 psi
- nominal operating pressure 100 psi

(e) Regulation and Code Requirements

See Section 5.4.5.

5.4.3 - Draft Tube Water Level Depression System

(a) General

The draft tube water level depression system will provide compressed air to depress the water around the turbine runner to permit the unit(s) to be motored in air.

(b) Design Requirements

System design pressure 150 psi
System operating pressure 100 psi (nominal)
Rated capacity see below

Sufficient receiver capacity will be provided to depress the water level around the runner for one unit assuming the following:

- no air is provided by the compressor;
- tailwater at El. 52.0
- the water level must be depressed at least 5 ft. below the bottom of the runner blades with the blades at their steepest angle;
- the initial receiver pressure is 100 psi;
- the receiver pressure after the water is depressed is equal to the back pressure from tailwater; and
- expansion is adiabatic.

Sufficient compressor capacity will be provided to refill the pressure tanks to 100 psi in 30 minutes, allowing 60 cfm leakage of air in the unit which is operating with the water level depressed.

The piping will be sized such that the water level is depressed below the runner blades in 10 seconds or less.

(c) System Details

The system will consist of two compressors with two or more air receivers together with necessary piping and controls. If the tailwater depression system is provided, the compressors can be combined with those of the brake and service air system described in Section 5.4.2. The separate receivers for brake and service air will still be provided however.

The compressor controls will be arranged to initiate compressor operation on an automatic lead and lag sequence. A manually operated switch will permit selection of lead compressor. The following is a tabulation of the control sequence:

5.4.4 - High Pressure Air

(a) General

High pressure air will be provided for the governor accumulator tanks for initial filling and for make-up air. Two small high-pressure air compressors will be installed to provide this air. The total compressor capacity will be sufficient to pressurize one accumulator tank from ambient pressure in about 6 hours.

(b) Design Requirements

- Design pressure 1100 psi
- Operating pressure 1000 psi
- Rated capacity 6 cfm

(c) System Details

The high-pressure air compressor equipment will consist of two small compressors with an air receiver.

The compressor will be controlled by a pressure switch on the air receiver. The following is a tabulation of the control set points:

- Nominal system pressure)
- Lead Compressor "on")
- Lag compressor "on")
- Compressors "off") To be established
- Low pressure alarm) later
- Safety valve setting)

The receiver will be maintained at a pressure higher than the governor oil pressure and will be connected to the two accumulator tanks through valves automatically controlled to maintain correct air-oil interface level in the accumulator tank. The governing system manufacturer will provide the necessary control equipment for automatic filling of the governor accumulator tanks. This air is not used for any other purpose.

(d) Major Equipment

Compressor

- number two
- type air-cooled reciprocating multistage
- rated pressure 1000 psi
- rated capacity 6 cfm
- drive electric motor
- air inlet temperature 70°F
- maximum noise level 75dBA at 4 ft
- aftercooler
 - number one
 - type air cooled

Air Receiver

- number two
- capacity 100 gal (approx.) (see Note 1)
- design pressure (min) 1000 psi

5.4.5 - Regulation and Code Requirements

- ANSI B31.1 - Power Piping
- AWS D1.1 - Structural Welding Code
- ASME Code for Unfired Pressure Vessels; Section 2, 8 and 9
- State of New York - Department of Labor Regulations
- OSHA - Safety and Health Standards

5.5 - Waste Handling

5.5.1 - General

The station waste handling requirements will be met by the following systems:

- unit dewatering and filling;
- floor, equipment and roof drainage; and
- sanitary drainage.

5.5.2 - Unit Dewatering and Filling

(a) General

The station dewatering and filling systems will consist of a pumped dewatering system and gravity filling system for the turbine water passages.

(b) Design Requirements

- Dewatering capacity (per unit) 960,000 gal (approx.)
- Dewatering time (per unit) 6 hr.
- Sump pressure at maximum forebay elevation 37 psi (at sump base)
- Pump equipment submersible
- Pump controls automatic with manual override

(c) System Details

- Dewatering System: The dewatering system will consist of a wet sump and embedded drain lines. A drain line from each draft tube and each semi-spiral case will discharge directly into the sump. Flow from each drain line into the sump will be controlled by a manually-operated butterfly valve. The dewatering sump will be designed to withstand full forebay pressure.

Water will be pumped from the sump directly to tailrace. Two pumps will be provided and will be controlled by water level devices as follows:

Lead pump starts	)	
Lag pump starts	)	
Both pumps stop	)	To be established
High level alarm	)	later
Sump base	)	
Floor level above sump	)	

The dewatering sump and the drainage sump detailed in Section 5.5.3 will be connected at the bottom by an embedded pipe with a manual control valve located in the dewatering sump. The sumps will also be connected at the top by an embedded overflow pipe with a flap valve to prevent backflow from the pressurized dewatering sump, into the drainage sump. The pump motor control panel will be mounted above maximum tailwater level in the powerhouse. The local control panel will be located in the sump area. Provision will be made for manually starting the pumps from the motor control panel should the local control panels become flooded.

Filling System: Filling the turbine water passages to tailwater level will be accomplished by permitting water from the tailrace to flow via the dewatering sump to the draft tube and semi-spiral case. The draft tube and spiral case drain lines along with the dewatering pump discharge line (with a bypass around the pumps) will be used for this purpose.

The semi-spiral case and intake water passages above tailwater will be filled by allowing reverse flow through the semi-spiral case water intake line (see Section 5.2.2), with water taken from the upstream intake and/or the semi-spiral case intake on the adjacent unit.

A vent pipe will be provided in the top of the dewatering sump terminating above maximum tailwater. A vent will also be provided at the semi-spiral case roof gate terminating above maximum headwater level.

(d) Major Equipment

Pumps	
- number	two
- capacity (each)	1300 gpm
- head	to suit design
- type	submersible
- drive	electric motor
- power supply	480 volts, 3-phase, 60 hertz
(e) - controls	air bubbler system

Regulation and Code Requirements

- AWS D1.1 - Structural Welding Code
- ANSI B31.1 - Power Piping
- AWWA C200 - Steel Pipe

5.5.3 - Floor, Equipment and Roof Drains Drainage System

(a) General

Drainage requirements for floor, equipment and roof drains will be met by a gravity drainage system and a pumped drainage system. Drainage above tailwater level will be discharged direct to tailrace. Drainage water below tailwater level including equipment drains will be collected at the drainage sump and then pumped to the tailrace.

(b) Design Requirements

Gravity system

- main header size (minimum) 10 inches

Pumped system

- design flow of pump discharge 400 gpm

- main embedded header size (minimum) 8 inches

(c) System Details

- Gravity System: The gravity drainage system will collect clear drainage water above tailwater level and discharge the water directly to tailrace. In particular to this system will be the intake and powerhouse roof drains, floor drains in the generator floor, and powerhouse strainer backwash drains. The discharge end of the gravity drains will be at least 6 feet below water to prevent freezing. In addition, the generator air cooler and oil cooler drains will be arranged to discharge near the draft tube gates to help keep the gate guides ice free in winter.

- Pumped System: The pumped system will collect the remainder of the powerhouse clearwater drainage with a network of floor and equipment drains. The drains will lead to a drainage sump which is equipped with duplicate pumps controlled by the water level devices as follows:

Lead pump starts	)
Lag pump starts	)
Both pumps stop	) To be established
High level alarm	) later
Sump base	)
Floor level above sump	)

The drainage sump pumps will discharge into the tailrace.

As discussed in Section 5.5.2 the drainage sump will be connected to the adjacent dewatering sump by an overflow pipe which will enable the dewatering pumps to handle excess flow into the drainage sump.

(d) Major Equipment

- Drainage pumps
- number two
 - capacity (each) 200 gpm
 - head to suit design requirements
 - type submersible
 - drive electric motor
 - power supply 480 volt, 3-phase, 60 hertz
 - controls air bubbler system

(e) Regulation and Code Requirements

- Uniform Building Code
- New York State Building Code
- Local Building Code
- New York State Department of Environmental Conservation
- Environmental Protection Agency

5.5.4 - Sanitary System

(a) General

Sanitary waste disposal facilities are required for the washroom. Sanitary drain lines will flow by gravity into a holding tank located underground on the west side of the powerhouse. The holding tank will be emptied at required intervals by a private contractor.

(b) Regulation and Code Requirements

- Uniform Building Code
- State Building Construction Code, State of New York
- Local Building or Plumbing Codes

5.6 - Heating and Ventilating

5.6.1 - General

The ventilation system will utilize roof-top exhaust fans for removal of fumes, heat or odor. Waste heat from the generators will be used to heat the powerhouse in the winter. Supplementary heating will be achieved by unit heaters along the outside walls of the powerhouse and at other selected locations.

5.6.2 - Design Requirements

The design of the heating and ventilating system will be based on the following requirements:

(a) General

Outside air temperatures (design)

- winter -10°F
- summer 90°F

Heating source waste heat from
generators plus
electric heaters
Ventilation system roof-top fans (two)
Air conditioning none

Louver design velocity 400 ft/m

(b) Powerhouse

<u>Room/Area</u>	<u>Heating Source</u>	<u>Air Change/Hr.</u>
Powerhouse floor	generators and unit heaters	1 1/2 (4 in summer)
Service galleries	unit heaters	4
Wash room	unit heaters	15
Battery room	unit heaters	6

5.6.3 - System Details

Powerhouse heating will be provided by warm air produced by the generators, supplemented by electric resistance type unit heaters. Thermostatically controlled intake and exhaust louvers on the generator enclosure will be provided by the generator manufacturer. Unit heaters will be provided at selected locations. These will be thermostatically controlled, and manual override switches will also be provided. The unit heaters will have enough capacity for maintaining the powerhouse air temperature about 50° F during a two unit outage in the winter.

Two rooftop exhaust fans, one above each unit, will provide ventilation for the powerhouse. These are designed to maintain an inside temperature of no more than 10°F above outside, under the summer conditions. Operation will be controlled by automatic thermometer controls with manual override capability. Intake louvers will be provided on the downstream wall, near the generator floor level. These will be gravity operated but will be capable of being manually locked in any position.

A small exhaust fan and duct will be provided for the washroom to obtain the necessary amount of air changes. The battery room will be provided with small air fans, as required. Fans will also be provided, as required, to promote air movement around electrical equipment.

5.6.4 - Major Equipment

Exhaust fans

- number 2
- capacity 25,000 cfm (approx.)
- type axial flow, roof-top unit
- drive belt driven
- blades fixed-blade design

Unit heaters

- number to suit powerhouse arrangement
- capacity 5 to 10 kW

5.6.5 - Regulation and Code Requirements

- ASHRAE Guide - For General Installation Procedures
- AMCA No. 99 - Recommended Practices for Air Moving Devices
- MACA No. 210 - Standard Test Code for Air Moving Devices
- NFPA 90A - Installation of Air Conditioning and Ventilating System
- SMACNA - For Fabrication and Installation Procedures

SECTION 6

MAJOR EQUIPMENT

SECTION 6 - MAJOR EQUIPMENT

6.1 - Turbines and Governors

6.1.1 - General

The turbines will be of the vertical adjustable-blade propeller type installed in concrete semi-spiral cases and draft tubes. Each turbine will be directly connected to a vertical shaft synchronous type generator. Water will be supplied through an intake structure, with two openings leading to each semi-spiral case. The draft tube will be of the elbow type. The horizontal section of the draft tube will incorporate two water passages of equal dimensions.

6.1.2 - Design Requirements

(a) General

- number of units	2
- headwater levels - maximum - extreme	E1 78.6
- maximum	E1 73.0
- normal	E1 69.1
- minimum	E1 66.1
- tailwater levels - maximum - extreme	E1 64.0
- maximum	E1 52.5
- minimum	E1 47.0
- net operating head	
- rated	19 ft
- maximum (full load operation)	20.5 ft
- maximum (with 1500 cfs discharge)	21.6 ft
- minimum	15.5 ft
- for runaway speed condition	21
- unit design flow - full gate	6000 ft ³ /sec
- best gate	3420 ft ³ /sec

(b) Turbine Data

- type	vertical Kaplan
- rated head	19 ft
- rated output at full gate	11,500 hp
- rated discharge	6000 ft ³ /sec
- best gate output	6900 hp
- rated speed	72 rpm
- "off-cam" runaway speed	195 rpm
- specific speed	195

- runner diameter 216.5 in.
- peripheral coefficient 1.95
- unit power 0.427
- cavitation coefficient 1.75
- centerline of distributor El 54.50
- centerline of runner El 47.01
- shaft rotation (viewed from above) clockwise
- heaviest lift 91 tons

(c) Governor

- type GS actuator
- normal operating pressure 1000 lb/in²

(d) Governor Pumping System

- normal operating pressure same as governor
- maximum allowable working pressure 110% of normal
operating pressure
- number of pumps 2 main plus 1 jockey
- main pump capacity (each) 1.25 x servo-volume
per min.
- jockey pump capacity 1.5 x estimated system
leakage per min.
- accumulator tank capacity 20 x servo-volume
- sump tank capacity 110% of total oil
volume (minimum)
(see Note 1)

Note: (1) The total oil volume will equal the volume in the servomotor, accumulator tank, piping and actuator plus the minimum storage volume. The minimum storage volume will be equal to at least 30 percent of the other volumes.

6.1.3 - Operating Conditions

The turbines will be capable of continuous operation at speed-no-load and at any flow between 1500 ft³/sec and 6000 ft³/sec and under the head conditions specified in Section 6.1.2, without objectionable surges in power output, detrimental vibrations or objectionable noises.

All parts of the turbine will be designed and constructed to withstand, without damage, continuous operation at a maximum "on-cam" and "off-cam" runaway speed with maximum head and no load on the generator.

6.1.4 - Design Stresses and Loadings

(a) Allowable Stresses

- (i) Ductile Materials - The allowable maximum principal stresses will not exceed one-third of the minimum specified yield strength of the material, except in the design of the stay vanes in compression, where the stresses will not exceed one-sixth of the minimum specified yield strength of the material.
- (ii) Brittle Materials (i.e. Cast Iron) - The stresses in cast iron will not exceed 2,000 lb/in² in tension and 10,000 lb/in² in compression.
- (iii) Miscellaneous Materials - Bearing pressures on concrete will not exceed 600 lb/in². Bearing pressures on babbit shells will not exceed 500 lb/in².

Welding will be in accordance with the ASME Boiler and Pressure Vessel Code.

(b) Normal Loading Conditions

The turbine will be designed for the most adverse combination of the loading conditions listed below plus any other conditions which the turbine manufacturer considers to be necessary without exceeding allowable stresses specified in Section 6.1.4(a).

- semi-spiral case pressure including pressure rise from normal full gate closure
- speed of turbine
- hydraulic thrust (down)
- hydraulic uplift
- loads imposed by operating the wicket gates either full stroke opening or closing under maximum net head
- weight of turbine parts
- weight and load of generator parts
- weight and load of concrete structures

The draft tube liner in the dewatered condition will be designed for a pressure equivalent to full head pressure at the interface between the liner and concrete with atmospheric pressure on the external (water passage) surface.

The draft tube access mandooors will be designed for a pressure of not less than 24 lb/in² on the water passage side, with consideration being made in the design to minimize vibration.

Support devices, for dismantling and assembly of equipment, will include in their design a minimum impact factor of 25 percent.

(c) Extreme Loading Conditions

The allowable stresses may be increased provided they do not exceed 67 percent of the specified minimum yield point of the material for parts subjected to the following extreme loading conditions:

- maximum pressure rise assuming no cushioning stroke on the servomotor;
- loads associated with operation of the turbine at maximum "on-cam" and "off-cam" runaway speed;
- maximum short circuit loads exerted by the generator.

6.1.5 - Turbine Guarantees

(a) Output

The rated full gate output of the turbine at 19 ft net head will not be less than 11,500 hp. The best gate output of the turbine at 19 ft net head will be 6900 hp.

(b) Efficiency

The guaranteed efficiency of the turbine will be based on existing model tests of a homologous turbine. The peak efficiency of the prototype turbine at the rated net head of 19 ft. will not be less than 93.69 percent at an output of 6900 hp at full gate, and the rated net head of 19 ft. The prototype turbine efficiency will not be less than 90.19 percent at an output of 11,500 hp. The turbine will be designed to have good efficiency over a wide range of gate openings for the heads specified in Section 6.1.2.

Prototype turbine efficiency will be calculated from model efficiency using the Hutton formula. A constant, step-up factor will be used, calculated at the peak model efficiency.

(c) Cavitation

The turbines will be designed such that the allowable metal loss due to cavitation in any 8,000 hour period of operation will not exceed the following:

- runner 25 lb
- non-rotating parts 12 lb

TOTAL ... 37 lb

6.2 - Generators and Exciters

6.2.1 - General

The generators will be of the vertical synchronous type direct connected to the hydraulic turbines.

6.2.2 - Design Requirements

(a) Generator Data

- type vertical synchronous
- rated power 8400 kVA
- power factor 0.95
- number of phases/connections 3/wye
- frequency 60 Hz
- voltage between phases 4160 V
- flywheel effect (WR^2) including turbine .. 20×10^6 lb-ft²
- inertia constant "H" 2.85 MW-sec/MVA
- heaviest lift 90 tons
- external thrust load (approx.) 267,000 lb
- construction umbrella type
- bearings combined thrust and guide
- cooling type air-to-water
- generator floor elevation E1 81.00
- generator-turbine coupling E1 59.00
- rated speed 72 rpm
- runaway speed

(b) Exciter

- type static

6.2.3 - Operating Conditions

The generator will be capable of continuous operation at an output up to 115 percent of the rated power output and at voltages from 100 percent to 105 percent of rated voltage stated in Section 6.2.2.

All parts of the generator will be designed and constructed to withstand, without damage, operation at maximum turbine "on-cam" and "off-cam" runaway speed with maximum head on the unit and no load on the generator for a period of not less than 4 hours.

6.2.4 - Design Stresses and Loadings

(a) Allowable Stresses

The allowable stresses for the generator will be the same as those specified for the turbine in Section 6.1.4(a).

(b) Normal Loading Conditions

The generator will be designed for the most adverse combination of loading conditions listed below plus other conditions which the generator manufacturer considers to be necessary without exceeding the allowable stresses specified in Section 6.1.4(a).

- speed of generator
- hydraulic exhaust (down)
- hydraulic uplift
- loads imposed by generator
- weight of turbine rotating parts
- weight and load of generator parts

(c) Extreme Loading Conditions

The stresses may be increased provided they do not exceed 67 percent of the specified minimum yield point of the material for parts subjected to the following extreme loading conditions:

- runaway speed
- maximum generator short circuit loads

6.2.5 - Temperature Rise Guarantees

With continuous operation at rated output the temperature rise of the stator and rotor windings will not exceed 60°C based on an ambient air temperature not exceeding 40°C.

With continuous operation at 115 percent rated output the temperature rise of the stator and rotor windings will not exceed 80°C. Ambient air temperature will be taken as the average of the measured temperatures of the air at the air outlets of the coolers.

6.3 - Gate Equipment

6.3.1 - General

(a) Design Codes

(1) Structural Design

- AISC Specification for Design Fabrication and Erection of Structural Steel for Buildings
- AWS Standard D1.1 Structural Welding Code
- ACI 318 Building Code Requirements for Reinforced Concrete

(2) Mechanical Design

- CMAA Specification No. 70 Specification for Electric Overhead Travelling Cranes
- AGMA Standard 420.04 Practice for Enclosed Speed Reducer or Increasers Using Spur, Helical, Herringbone and Bevel Gears

(3) Gate Roller and Roller Path Design

- ASCE Paper No. 3000 "Fixed-Wheel Gates for Penstock Intakes"

(b) Allowable Stresses

(1) Structural

For normal Loading Conditions, the allowable design stresses will not exceed those permitted by AISC Specification for Design, Fabrication and Erection of Structural Steel Buildings. For the extreme loading conditions, the permissible stresses may be increased by 33 percent provided they do not exceed 80 percent of the elastic limit of the material.

(2) Welded Connections

Basic allowable stresses in welded connections will not be greater than 90 percent of the values permitted by AWS Standard D1.1.

(3) Bolted Field Connections

All field connections for structural steel will be designed using high strength bolts in friction type connections, in accordance with AISC Standards. The loads will not exceed 90 percent of that permitted by AISC Standards.

(4) Mechanical Components

For normal loading conditions, the allowable stresses will not exceed 20 percent of the ultimate strength or 33 percent of the yield strength of the material, whichever is lower. Stresses may be increased 33 percent for bearing stresses in pin connections. Stresses in welded connections will not exceed 50 percent of the values permitted by AWS Standard D1.1.

For the design of wire rope, the safety factor on the lead line shall not be less than five.

The design of reduction gearing shall be in accordance with AGMA Standard 420.04.

For extreme loading conditions, stresses will not exceed 80 percent of the elastic limit of the material. The load on wire rope will not exceed 60 percent of the ultimate strength.

(c) Design Criteria

(1) Gate Leaf

Each gate leaf assembly will consist of a number of horizontal beams connected to end members designed to transfer the horizontal loads to the embedded guides. The skin plate will be designed as an integral part of the main horizontal beams and the whole assembly stiffened with vertical diaphragms and other secondary members. A corrosion allowance of 1/16 inch (total) will be made on all gate leaf members.

The weight of the gate leaf assembly will exceed the static friction forces by a minimum of 15 percent.

Each gate leaf assembly will be designed to satisfy the following criteria:

- Ductile Fracture Criteria

Biaxial stresses other than the biaxial tension will be in accordance with the Hencky-von Mises criteria of failure.*

$$\frac{F_y}{n} = (f_x^2 + f_y^2 - f_x \cdot f_y + 3T_{xy}^2)^{1/2}$$

where: F_y = minimum specified yield strength of the material

n = factor of safety which will be equal to or greater than 1.33

f_x = normal stress in x-direction which will not exceed $0.6 F_y$

f_y = normal stress in y-direction which will not exceed $0.6 F_y$

T_{xy} = shear stress which will not exceed $0.36 F_y$

* pg 188, "Mechanical Engineering Design" by Shigley

- Brittle Fracture Criteria

In the case of a biaxial tension state of stress, stress levels will be decreased from that permitted above for ductile fracture, in accordance with good engineering practice.

(2) Main Rollers

Crowned rollers will be designed in accordance with the criteria outlined in ASCE Paper No. 3000 "Fixed Wheel Gates for Penstock Intakes".

The maximum shear and compressive stresses in the rollers and roller path will not exceed the following:

- shear stress: $350 \times \text{roller BHN}$ in lb/in^2 or $90,000 \text{ lb/in}^2$ whichever is lower.
- compressive stress: $1000 \times \text{roller BHN}$ in lb/in^2 or $250,000 \text{ lb/in}^2$ whichever is lower.

The roller faces will have a surface hardness of 230 to 270 BHN and the roller paths will have a minimum hardness of 20 BHN above the roller minimum BHN.

The roller axles will be designed in accordance with ASCE Paper No. 3000. The design of rollers and their supports will take into consideration the radial load acting on the roller and an axial load equivalent to 30 percent of the radial load acting on the outer rim of the roller and roller path. The rollers will have tapered anti-friction bearings or self-lubricated bronze bearings. For anti-friction bearings, the ratio of the basic static load rating of the bearing, as defined in AFBMA Standard No. 11, to the equivalent static radial load will not be less than 1.0. For self-lubricated bronze bearings the stresses will not exceed $3,000 \text{ lb/in}^2$ for the radial load and $8,000 \text{ lb/in}^2$ for the combined loads of the radial and lateral load.

(3) Embedded Parts

The main vertical guide members will be designed as continuous beams on elastic foundations. The loads will be assumed to be proportionally distributed between the top and the bottom flanges of the support beam depending on the relative stiffness of the constituent subcomponents. The bearing stresses on the concrete will not exceed those allowed for $3,000 \text{ lb/in}^2$ concrete in ACI 318.

The roller path thickness will not be less than 10 times the depth of maximum shear stress. The roller path will be fully heat treated to hardness at least 20 BHN above the roller minimum BHN.

The vertical guide members, lintel beams, sill beams and their supporting anchors will be designed to withstand a differential head of water behind the embedded parts or behind the secondary concrete.

(4) Friction Forces

The following minimum friction coefficients will be used in calculations of vertical loads acting on the gate:

	<u>Static Friction</u>	<u>Moving Friction</u>
- anti-friction bearings using average bearing diameter and including seal and roller friction	0.02	0.01
- self lubricated "Lubrite", or equal, bearings	0.18	0.12
- rubber seals on steel	1.50	0.80
- rubber seals with fluorocarbon sealing surfaces on steel	0.2	0.1
- steel on steel (unlubricated) ...	0.50	0.25

6.3.2 - Intake Bulkhead Gates

(a) Arrangement

The intake bulkhead gates for one intake waterpassage will consist of 5 sections having a downstream skinplate and downstream seal. The vertical side and lintel seals will be of the molded rubber "J" type and the bottom seal will be rubber with rectangular cross section. Leaf springs on the upstream side of each section will provide an initial compressive load to preset the seals. The gate sections will be handled by a mobile crane and a follower.

(b) Hydraulic Conditions

headwater level - maximum	E1 78.6
- normal	E1 69.1
- minimum	E1 66.1
sill beam elevation	E1 21.00
maximum head at sill with water passages dewatered	57.5 ft

(c) Design Parameters

(1) Gates

number of sets	2
number of sections per set	see below
type	bulkhead
clear width of opening	22 ft-9 in
height of opening	35 ft-6 in
skin plate location	downstream
seal location	downstream

(2) Guides

number of sets	4
sill beam	El 21.00
lintel seal	El 57.33 (approx.)
top of check	El 83.00

The number of gate sections will be selected to facilitate handling with a mobile crane.

(d) Design Loads

(1) Load Conditions

<u>Load</u>	<u>Description</u>
A	weight of gate section;
B	weight of follower;
C	hydrostatic water load on gate with headwater at El 78.6 gate in closed position and turbine water passages dewatered;
D	friction due to spring loads on bearing bars and precompression of seals, using static coefficients;
E	loads resulting from a jammed gate being raised by a mobile crane, and load being taken through one follower hook;
F	loads resulting from jammed follower being raised by a mobile crane; and
G	impact load of 30 percent

(2) Structural Design

Gates

Normal loading conditions:

G-I A + C

G-II A + D + G (for design of pickup points)

Extreme loading conditions:

G-III E

Each of the four lower gate sections will be designed for a hydraulic load equivalent to that acting on the bottom gate section.

Guides

Normal loading conditions:

G-IV A + C

(3) Mechanical Design (follower)

Normal loading conditions:

H-I A + B + D + G

Extreme loading conditions:

H-II E

H-III F

6.3.3 - Draft Tube Gates

(a) Arrangement

The draft tube gates will be of the fixed roller vertical lift type handled by the powerhouse crane using a follower. The gates will have an upstream skin plate and upstream seals. The gate bottom will be tapered to give a well defined spring point for water flow at the upstream edge. The vertical side and lintel seals will be of the molded rubber double bulb type to permit sealing against both upstream and downstream flow and the bottom seal will be rubber with rectangular cross section.

The draft tube gates will normally be raised or lowered only when the turbine wicket gates are closed and there is no flow through the unit. The draft tube gates will be designed to close under emergency conditions with the turbine operating at runaway speed with maximum differential and a flow of approximately 11,000 ft³/sec. The gates

will be designed to be "cracked" and raised against headwater pressure, for removal of the draft tube gate once the water passages have been refilled and the intake bulkhead gates removed.

(b) Hydraulic Conditions

headwater level - maximum	E1 78.6
- normal	E1 69.1
- minimum	E1 66.1
tailwater level - maximum	E1 47.0
- minimum	E1 64.0
sill beam elevation	E1 8.81
maximum head on sill with draft	
tube dewatered	55.19 ft
maximum differential head from	
headwater pressure	22 ft

(c) Design Parameters

(1) Gates

number	4
type	fixed roller
clear width of opening	23 ft-3 in
height of opening	17 ft-5-5/8 in
skin plate location	upstream
seal location	upstream

(2) Guides

number of sets	4
sill beam	E1 8.81
lintel seal (centerline)	E1 26.68 (approx.)
top of check	E1 67.0

(d) Design Loads

(1) Load Conditions

<u>Load</u>	<u>Description</u>
A	weight of gate
B	weight of follower.
C	hydrostatic water load on gate with maximum tailwater, gate in closed position and turbine water passages dewatered;
D	hydrostatic water load on gate from headwater level, with a differential head of 22 ft across the gate;

- E roller and seal friction loads with headwater level acting on the gate and a differential head of 22 ft across the gate;
- F impact load of 30 percent;
- G maximum hydraulic downpull of 50,000 lb;
- H load resulting from a jammed gate being raised with the powerhouse crane; and load being taken by one follower hook; and
- I loads resulting from a jammed follower being raised by powerhouse crane.

(2) Structural Design

Gates

Normal loading conditions:

- G-I $A + C$
- G-II $A + D + E$
- G-III $2 \times A$ (for dogging connection design)
- G-IV $A + G$

Extreme loading conditions:

- G-V $A + D + E + F$
- G-VI $D + H$

Guides

Normal loading conditions:

- G-VII $A + C$
- G-VIII $A + D$

Extreme loading conditions:

Loading as in G-VIII, considering a 50 percent roller overload due to a main roller not touching the roller path and the load transferred to the roller patch through adjacent rollers.

(3) Mechanical Design (follower)

Normal loading conditions

- H-I $A + B + D + E + F$
- H-II $A + B + F + G$

Extreme loading conditions

- H-III H
- H-IV I

6.3.4 - Trashracks

(a) Arrangement

Trashracks will be provided in each intake opening to prevent large debris from entering the turbine water passages. The trashracks will be in sections which will be interchangeable. The trashracks will be handled by a mobile crane using the follower and will be installed in guides at the upstream face of the intake.

(b) Design Parameters

(1) Trashracks

number of sets	4
number of sets required for one unit	2
number of sections per set	5
clear width	24 ft-0 in
height of opening	42 ft-0 in
height of each section	8 ft-7 in (approx.)
bar spacing	6 in
minimum ratio of net to gross area	0.75
velocity across trashrack bars	
at rated turbine flow	3 ft/sec (gross)
design differential head	15 ft

(2) Guides

number of sets	4
base of guides	EL 21.00
top of check.....	EL 83.00

(c) Design Loads

(1) Load Conditions

Description

A	weight of trashracks
B	weight of follower
C	load due to differential pressure across the trashracks equivalent to a head of 15 ft of water;
D	weight of trash - 5000 lb;
E	impact load of 30 percent;
F	load resulting from a jammed trashrack section being raised by a mobile crane
G	loads resulting from a jammed follower being raised by a mobile crane

(2) Structural Design

Normal loading conditions:

G-I A + C

G-II A + D + E (for design of pick-up points)

A corrosion allowance of 1/16 inch will be used for trashrack design.

Extreme loading conditions:

G-III F

The trashrack bars shall be designed in accordance with the criteria for maximum unsupported length to prevent vibration provided on page 24-16 of "Handbook of Applied Hydraulics", Third Edition, by C.V. Davis. In addition the minimum rack bar thickness will be 3/8 in.

(3) Mechanical Design (follower)

Normal loading conditions:

H - I A + B + D + E

Extreme Loading Conditions

H-II F

H-III G

6.4 - Flashboards

6.4.1 - Arrangement

Flashboards will be provided along the dam to permit raising of the headwater level 2.5 ft. The flashboards dam will be designed to lower automatically. The flashboards will be manually raised.

6.4.2 - Hydraulic Conditions

Headwater - maximum	El 78.6
- normal	El 69.1
- minimum	El 66.1

Crest of dam	El 66.6
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6.4.3 - Design Parameters

Length	700 ft
Height	2.5 ft
Water level at which flashboards lower.....	El 72.6

6.5 - Powerhouse Crane

6.5.1 - General

The powerhouse crane will be of the electric overhead travelling type with main and auxiliary hoists. The crane will be used for the installation and servicing of the turbines, generators and other powerhouse equipment, as well as for installation and removal of the draft tube gates. The crane will have pendant control. A "dummy" cab will be provided on the downstream side of the bridge.

6.5.2 - Design Code

- CMAA Specification No. 70 - Specifications for Electric Overhead Travelling Cranes

6.5.3 - Design Parameters

type electric overhead
travelling type

rated capacity
- main hook 100 tons
- auxiliary hook 25 tons

minimum clearance
- downstream wall 4 in.
- upstream wall 4 in.
- overhead 10 in.

speed

	High Speed Minimum	Low Speed Maximum
- bridge	60 ft/min	6 ft/min
- trolley	50 ft/min	5 ft/min
- main hook	4 ft/min	0.4 ft/min
- auxiliary hook	30 ft/min	3 ft/min

lift
- main hook 70 ft
- auxiliary hook 90 ft

crane rail elevation El 107.00

elevation of hooks in maximum raised position
- main hook El 105.00 or higher
- auxiliary hook El 105.00 or higher

motion tolerances

- bridge 3/8 in.
- trolley 1/4 in.
- main hook 1/16 in.
- auxiliary hook 1/8 in.
- operating environment indoor, heated

crane classification

- main hoist Class A1
- auxiliary hoist and bridge and trolley drive Class C

6.5.4 - Design Loads

The powerhouse crane will be designed in accordance with CMAA Specification No. 70, Specifications for Electric Overhead Travelling Cranes.