DOE/ID/12356--T1

UNITED STATES DEPARTMENT OF ENERGY
DOE CONTRACT NO. DE-AC07-82ID12356

REPORT ON SIPHON PENSTOCKS FOR HYDROELECTRIC PROJECTS

February 1989

ACRES INTERNATIONAL CORPORATION
140 John James Audubon Parkway
Amherst, New York 14228-1180

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ACRES

This report has been prepared as a joint effort by the following organizations:

Acres International Corporation
140 John James Audubon Parkway
Amherst, New York 14228-1180

– Report Preparation

CHI Engineering Services
111 Market Street
Unit 1
Portsmith, New Hampshire 03801

– Project: Columbia Mills Hydroelectric Plant

Clearwater Hydro
634 East Inskip #80
Knoxville, Tennessee 37912

– Project: Second Broad River Hydroelectric Project

Gannett Fleming Water Resources Engineers, Inc.
P.O. Box 1963
Harrisburg, Pennsylvania 17105-1963

– Project: Pine Grove Dam Hydroelectric Station

Harza Engineering Company
150 South Wacker Drive
Chicago, Illinois 60606

– Project: Superior Dam Power Station

J. Kenneth Fraser and Associates, P.C.
22 High Street
Rensselaer, New York 12144

– Project: Tierckenkill Falls Hydroelectric Project

Mead and Hunt, Inc.
6501 Watts Road
Suite 101
Madison, Wisconsin 53719-1361

– Projects: Jim Falls Minimum Flow Unit Hydro Development
Lac Courte Oreilles Hydro Development

TKO Power - Ott Water Engineers, Inc
P.O. Box 494310
Redding, California 96049

– Project: Schaads Reservoir Hydroelectric Project

Williams and Broome, Inc.
15 Fawn Drive
Reading, Pennsylvania 19607

– Projects: Ontelaunee Hydroelectric Project
Pocono Lake Hydroelectric Project
Traicao Hydroelectric Project

SIPHON PENSTOCKS FOR HYDROELECTRIC PROJECTS

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Section 1
INTRODUCTION

This report on the use of siphon penstocks for hydroelectric installations has been prepared under DOE Contract DE-AC07-82ID12356 by Acres International Corporation and draws extensively on the information and data assembled by the following organizations:

- CHI Engineering Services;
- Clearwater Hydro;
- Gannett Fleming Water Resources Engineers, Inc.;
- Harza Engineering Company;
- J. Kenneth Fraser and Associates, P.C.;
- Mead and Hunt, Inc.;
- TKO Power - Ott Water Engineers, Inc; and
- Williams and Broome, Inc.

The purpose of the study was to review the design, construction, operation, and maintenance considerations for siphon penstocks. The discussions, data, and information presented are based on experiences with the following operational siphon penstock plants:

- Columbia Mills Hydroelectric Plant, Virginia;
- Jim Falls Minimum Flow Unit Hydro Development, Wisconsin;
- Lac Courte Oreilles Hydro Development, Wisconsin;
- Ontelaunee Hydroelectric Project, Pennsylvania;
- Pine Grove Dam Hydroelectric Station, Pennsylvania;
- Pocono Lake Hydroelectric Project, Pennsylvania;
- Schaads Reservoir Hydroelectric Project, California;
- Second Broad River Hydroelectric Project, North Carolina;
- Superior Dam Power Station, Michigan;
- Tierckenkill Falls Hydroelectric Project, New York; and
- Traicao Hydroelectric Project, Brazil.

The principal data for these projects are summarized on Table 1-1.

A general description of siphon penstocks is presented in Section 2. The benefits and drawbacks of siphon penstocks are summarized in Section 3. Sections 4, 5, 6, and 7 contain a review of the design, construction, operation, and maintenance considerations. The comparative costs of siphon penstocks versus conventional designs are discussed in Section 8. Recommendations for future design, based on the experiences with the above listed projects, are presented in Section 9. Section 10 contains the conclusions which have been made from the review of siphon penstock installations.

Descriptions, data, drawings, and photographs for the projects are included as appendices to this report.

TABLE 1-1
PROJECT DATA SUMMARY

Project	Plant Capacity (kW)	Head (ft)	Plant Flow (cfs)	Number of Units	Siphon Penstocks Number	Siphon Penstocks Diameter (ft)
Columbia Mills	417	17.2	334	1	1	9.8x13.8*
Jim Falls	500	30.4	240	1	1	6.5
Lac Courte Oreilles	3,450	30.0	1,500	3	2	9.0
Ontelaunee	530	35.0	210	1	1	6.0
Pine Grove Dam	478	39.0	175	1	1	6.0
Pocono Lake	285	24.0	180	3	1	5.0
Schaads Reservoir	240	97.0	42	2**	1	2.5
Second Broad River	288	21.0	246	3	3	4.3
Superior Dam	570	14.0	567	1	1	8.0
Tierckenkill Falls	70	100.0	11.9	2	1	1.4
Traicao	8,570	21.3	8,333	4	4	12.4x33.4*

* Rectangular
** The Schaads Reservoir project has two generators and three turbines; one of the generators is driven by two turbines.

Section 2
DESCRIPTION OF SIPHON PENSTOCKS

At a "conventional" hydroelectric installation, the penstock conveys water from the forebay of the intake to the turbine, and passes through the water retaining structure (dam). The penstock has a downward gradient from the intake to the turbine. Therefore, when the penstock is filled with water, the internal pressure in the penstock is always positive. At a siphon penstock installation, the intake is below forebay (headwater) level as in a conventional installation, but the penstock rises to above the dam, or at least to above forebay level, before sloping down to the turbine. Water is conveyed through the penstock by siphon action; therefore, the pressure in the section of penstock above forebay level is negative. Figure 2-1 shows a general comparison between a conventional penstock installation and a siphon penstock installation.

Conveyance of water using a siphon is not new technology. Archaeological studies have indicated the use of siphons in Egypt around 1500 B.C. Lead pipe siphons were used by the Greeks and Romans to convey drinking water over heights. Siphons up to 20 ft in diameter are used on modern-day water supply and irrigation projects.

Siphon type installations were used on some of the early low-head hydroelectric stations. These plants had low specific speed Francis turbines with a relatively high runner setting; consequently, the wheel case was above headwater level. The siphon type intake was, therefore, necessary to convey water from the forebay to the turbine. An early siphon installation is illustrated in Figure 2-2. The trend toward physically large turbines with a low setting relative to tailwater level to prevent cavitation damage, and also the use of large horizontal units on low-head projects, has precluded the use of siphon type intakes. Over the past 10 years, however, with renewed activity in the development of small hydroelectric projects, there is increased interest in the use of siphon type penstocks, particularly at projects where a dam already exists.

There are two basic configurations of siphon penstocks:

- Siphon integral with the intake and powerhouse structure (Figure 2-3). The siphon is not a true "penstock", but rather an intake conduit.
- Siphon which is separate from the intake and powerhouse (Figure 2-4).

The latter configuration is most common for smaller, more recent siphon installations at hydroelectric projects.

The primary differences between a conventional hydro installation and a siphon penstock installation are:

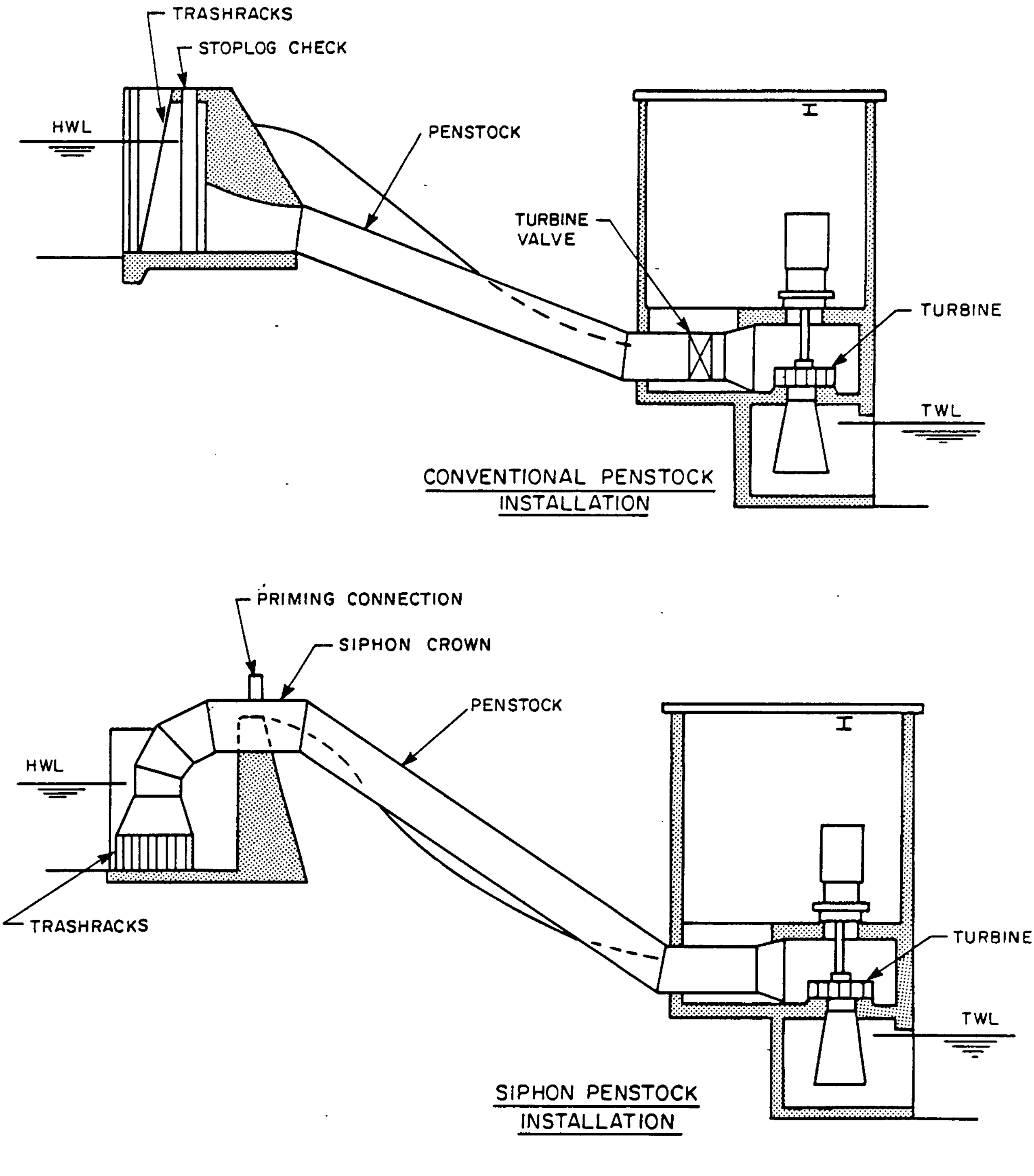


Figure 2-1 Comparison of Conventional and Siphon Penstock Installations

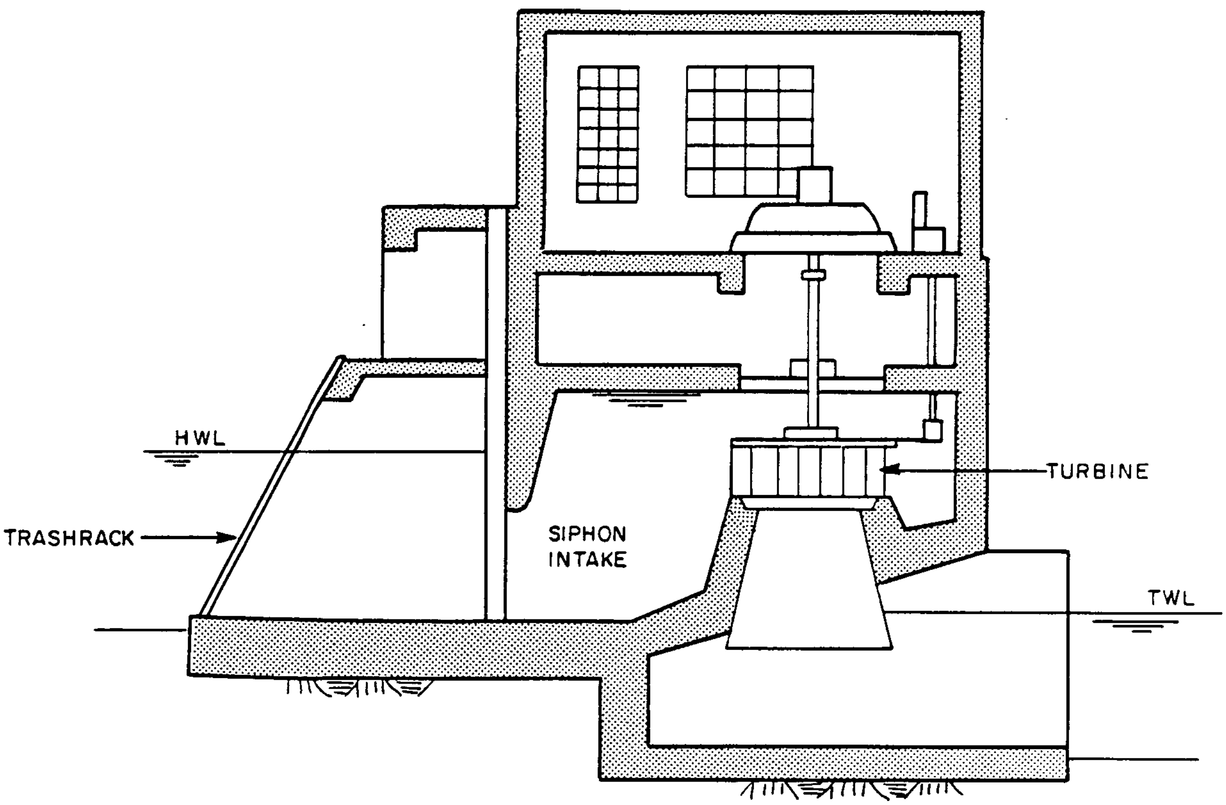


Figure 2-2 Early Siphon Installation

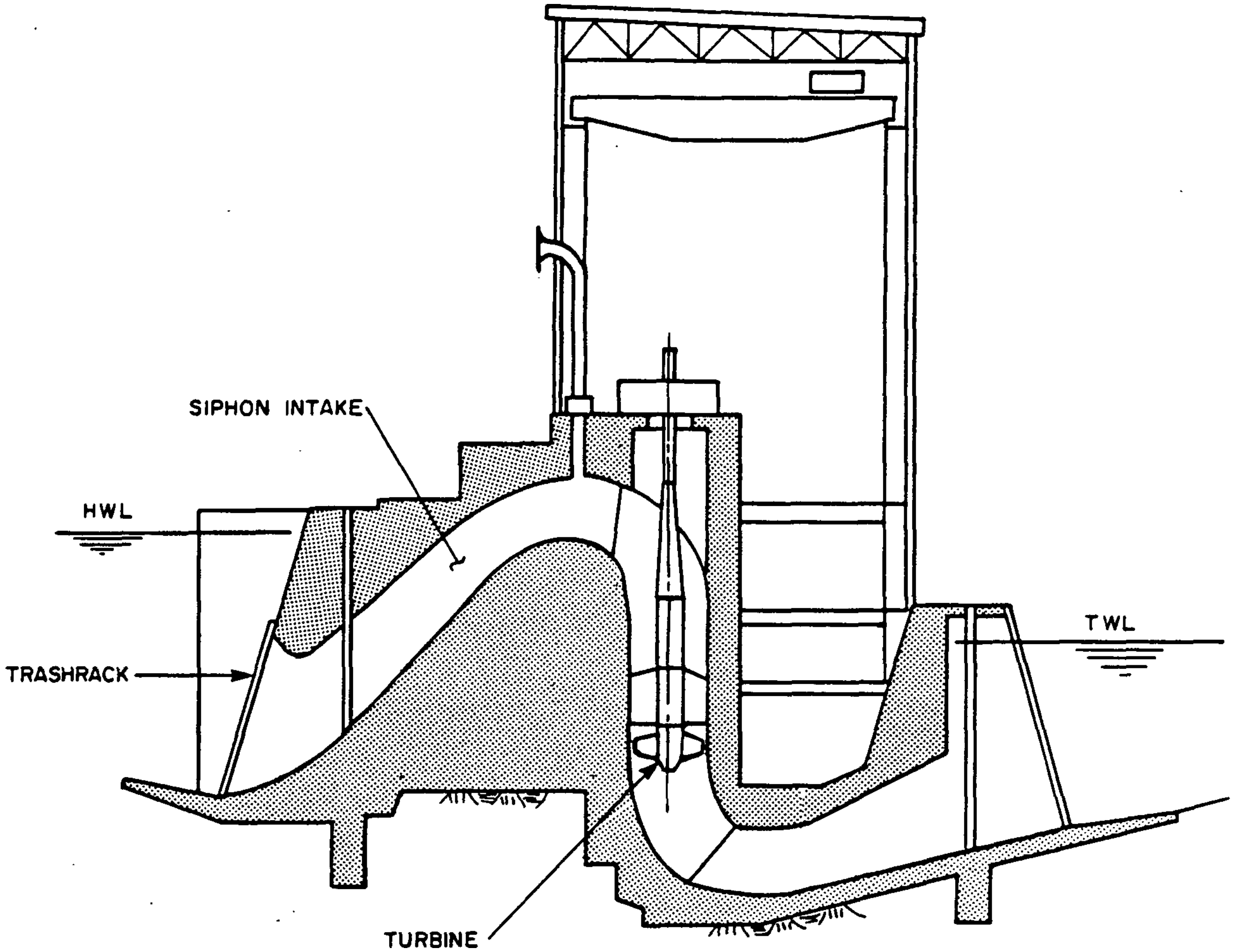


Figure 2-3 Siphon Integral with Intake and Powerhouse

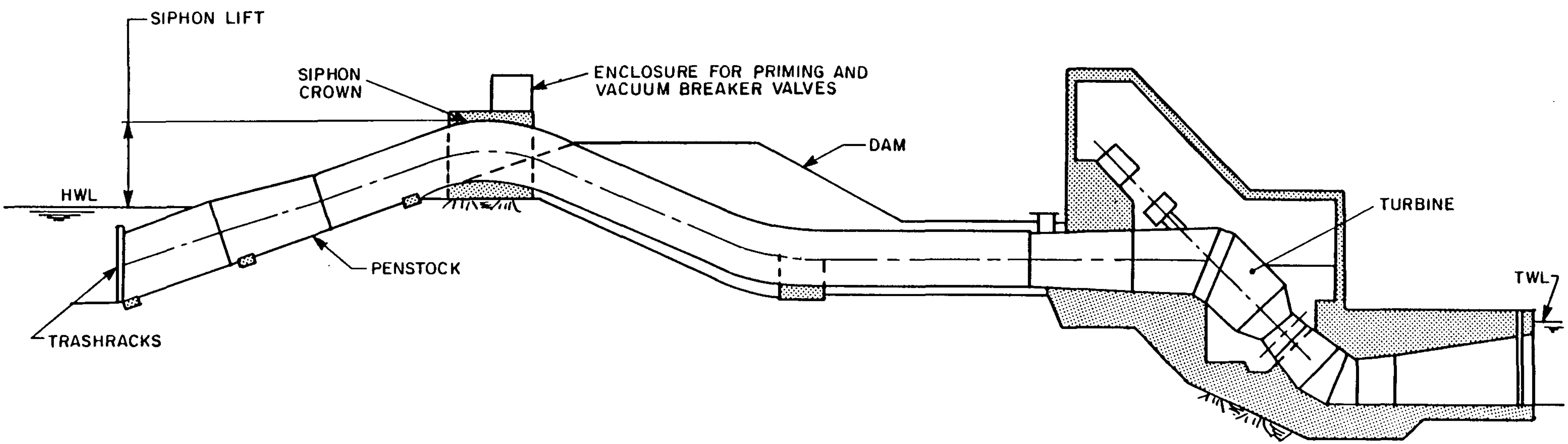


Figure 2-4 Siphon Separate from Intake and Powerhouse

- At a conventional installation the pressure in the penstock is always positive; at a siphon installation the pressure is negative in the siphon area.

- A conventional installation requires an intake gate or valve to isolate the turbine waterpassages from the forebay; at a siphon installation the waterpassages can be isolated by admitting air into the crown of the siphon, thus "breaking" the siphon.

- At a conventional installation, the waterpassages may be filled by gravity to start the unit, either with the intake gate or valve, or with suitable piping. At a siphon penstock installation, a system such as a vacuum pump is required to fill the section of penstock above forebay level with water, thereby "priming" the siphon.

The principal limiting design factor for siphon penstocks is the siphon lift. The theoretical maximum height which a siphon can raise water is atmospheric pressure, which is about 33 ft of water (depending on the location relative to sea level). Various other factors (see Section 4.3) limit the practical siphon lift to approximately 25 ft. Therefore, the highest elevation of the siphon (i.e. the siphon crown as shown in Figure 2-4) must not be more than about 25 ft above minimum operating headwater level for the siphon to operate satisfactorily.

Section 3
BENEFITS AND DRAWBACKS OF SIPHON PENSTOCKS

There are several benefits to using siphon penstocks for hydroelectric projects. These include:

- Elimination of a Shutoff Device Upstream of the Turbines. Almost all hydroelectric installations have intake gates or valves upstream of a turbine to allow dewatering of the turbine for inspection and maintenance. The gate or valve is usually designed to be closed in an emergency, under flowing water conditions, to stop flow through the turbine in the event of loss of control of the turbine wicket gates. With a siphon installation, both the normal and emergency functions can be accomplished by simply admitting air into the crown of the siphon, thereby breaking the siphon and stopping the flow of water.

- Minimal Impact on Existing Dam. Installation of a conventional intake at an existing dam will usually require demolition of a segment of the dam. This requires extensive analysis and careful construction techniques to insure the structural integrity of the dam, particularly at older dams. The conduit passing through the dam will also have a negative influence on the stability of the dam. At earthen dams, a conventional intake with a penstock passing through the dam has the potential for a leak developing around the conduit, thereby resulting in dam failure due to piping. A pressure conduit through an earthfill dam is often prohibited by the dam owner.

  In addition to the design problems associated with modification of an existing dam structure, there may also be questions of legal liability.

  The use of a siphon penstock which conveys water over the top of a dam will usually have little or no impact on the dam. Problems and concerns with existing dams are therefore minimized.

- Elimination of Upstream Cofferdam. For most hydroelectric projects incorporating a conventional intake and pressure conduit, a cofferdam is required for construction of the plant. The cofferdam must be appropriately sized to prevent overtopping during construction.

  For siphon installations at an existing dam, the power plant can be constructed behind the dam. In many installations, the siphon penstock and intake may be prefabricated and then lowered in place. The upstream cofferdam will then be unnecessary. This has a benefit from a capital cost point of view and may also allow a shorter construction period.

The above benefits enable construction costs to be minimized.

There are, however, a number of drawbacks of siphon penstocks, and these must be considered when evaluating the use of a siphon penstock for a particular project.

- Penstock Length and Configuration. A "straight-through" pressure conduit for a conventional intake-penstock arrangement is often shorter than a siphon penstock which must go up and over a dam. The increased length including additional bends will increase the capital cost of the penstock and may also increase head losses which will reduce generation.

- Limits with Regard to Siphon Lift. The maximum practical suction lift is approximately 25 ft. Where there is a large variation in headwater level, it may not be feasible to install a siphon penstock because of excessive suction lift requirements at low water level. If the top of the dam is significantly above headwater level (for example, at a flood control storage reservoir), a siphon penstock will not be feasible without making modifications to the dam. This will negate some of the advantages of the siphon penstock.

- Problems with Exposed Section of Penstocks. A siphon penstock which passes over a dam will usually have a larger length of exposed area when compared to a conventional pressurized penstock which passes through the dam. Consequently, there will be increased susceptibility to freezing. Exposed sections of penstock may also be subject to vandalism.

- Limits on Size. Siphon penstocks are not readily adaptable to large plant flows because the physically large penstock sections become more difficult to fabricate and unwieldy to install. With large diameters, penstock bend radii are increased, adding to the required length of the penstock. Furthermore, with the larger diameter, siphon lift may become a problem because the height to the top of the penstock must be considered when designing the siphon penstock. To reduce siphon lift, multiple penstocks may be installed and/or the cross section changed to rectangular. Usually these alternatives will be more costly than a single circular section pipe.

Section 4
DESIGN CONSIDERATIONS

4.1 - General

The layout for a hydroelectric installation is usually site specific, as no two sites have exactly the same features and characteristics. This is true whether the project includes a conventional or a siphon penstock arrangement. Therefore, neither the conventional nor the siphon penstock concepts lend themselves to standardized project "off-the-shelf" designs. Each of the principal design considerations for a siphon penstock project, i.e. siphon lift, siphon priming, removal of accumulated air, siphon break system, prevention of siphon overflow, intake, penstock design, penstock material, penstock support, and penstock freeze protection have to be studied for each project. None of the siphon penstocks described in this report are based on a standard design, although the siphon penstock for the Columbia Mills project was designed by the turbine manufacturer (ESAC) and was based on previous facilities which are operating in France. The arrangement for Columbia Mills is shown on Figure 4-1.

The standard electrical and mechanical components (e.g. vacuum pumps and valves, etc.) which are part of the siphon system, are "off-the-shelf" designs. In addition, standard pipe may be used for penstocks at very small installations.

The various design considerations for siphon penstock systems at hydroelectric projects are described in detail in the following subsections, after a discussion on the possible uses of model tests.

4.2 - Siphon Penstock Model Tests

A physical hydraulic model is often a valuable tool for the design of a hydroelectric project. Nevertheless, of all the siphon penstock designs described in this report, model tests were only performed on the Traicao project. At Traicao, model tests were conducted by the pump-turbine manufacturer (S. Morgan Smith) in 1938 on the complete waterpassages. Further tests were made in 1945 to improve turbine and pumping performance. Except for the Traicao and Lac Courte Oreilles projects, all of the plants are less than 600 kW capacity. Because of their small size, reasonably conservative design concepts were adopted rather than constructing and testing a hydraulic model.

For a siphon penstock plant, normally only the intake and penstock near the intake would be modeled. The purpose of the tests would typically be to ensure minimal head losses in the intake area, check there is satisfactory flow distribution at the intake, and ensure there are no adverse vortex formations at the intake. Siphon operations, such as priming and breaking the siphon and air accumulation at the siphon crown, is difficult to quantitatively model, as they represent two-phase flow phenomena which cannot be directly scaled to prototype size.

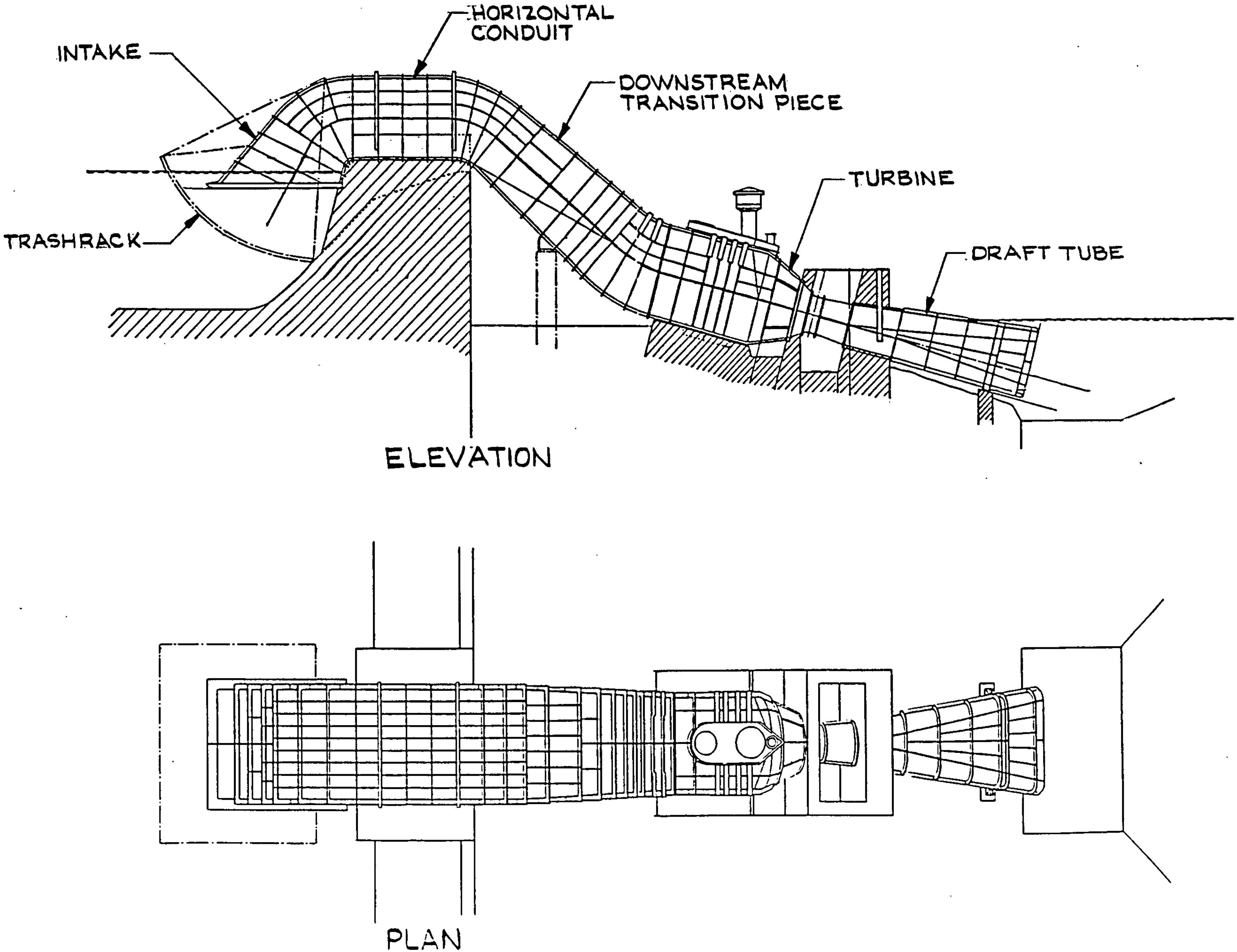


Figure 4-1 Columbia Mills Hydroelectric Plant

Two "generic" model studies which have been completed for siphon penstocks for hydroelectric projects are:

- "Cost and Design of Modular Small Hydroelectric Plants" EPRI EM 3334, June 1984; and

- "Evaluation of Siphon Performance", Phase II Draft Report, Energy Mines and Resources Canada, March 1987.

Topics addressed in these studies include:

- Intake submergence;
- Siphon priming;
- Siphon break;
- Air accumulation; and
- Effect of air on turbine performance.

It is recommended that model tests be considered for large siphon penstock installations, say greater than 1 MW, where there are concerns about head losses, flow distribution, and vortices.

4.3 - Siphon Lift

All siphons have a theoretical maximum lift between water level and the crown of the siphon, equivalent to one atmosphere of pressure (i.e., 33.9 ft of water at sea level). In practice this maximum lift must be reduced to allow for:

- The reduction in atmospheric pressure due to the elevation of the siphon;

- A reduction in local atmospheric pressure due to weather phenomena;

- The limits of the vacuum system which is used to prime the siphon and to remove accumulated air from the siphon crown; and

- The head losses from the intake to the crown of the siphon, plus the velocity head at the siphon crown.

The maximum recommended static lift for siphons is typically in the 20 to 25 ft range. The maximum static siphon lift for the various projects covered in this report is as follows:

Project	Maximum Static Lift from Headwater to Crown of Siphon
Columbia Mills	17.3 ft
Jim Falls	8.5 ft
Lac Courte Oreilles	25.5 ft
Ontelaunee	8.1 ft
Pine Grove Dam	22.0 ft
Pocono Lake	7.3 ft
Schaads Reservoir	10.0 ft
Second Broad River	9.4 ft
Superior Dam	13.0 ft
Tierckenkill Falls	3.8 ft
Traicao	19.9 ft

At Lac Courte Oreilles the maximum siphon lift exceeds the recommended lift when all of the influencing factors listed above are considered. However, this maximum lift only occurs with unusually low headwater levels (approximately once in 10 years). It was postulated by the designers that under these extreme conditions, the plant could operate with the penstock only half full at the apex, reducing the maximum siphon lift to 21 ft.

4.4 - Siphon Priming

General

When preparing a plant with siphon penstocks for operation, a method is required to fill the section of the penstock above headwater level with water (i.e., priming the siphon) prior to operation of the system. The plants covered by this report have a vacuum pumping system which evacuates air from the apex of the penstock, thereby priming the siphon. One or more electric motor-driven vacuum pumps are typically used.

At the Schaads Reservoir project, where normal headwater level is at or above the crown of the siphon, the penstock is first filled by gravity from the reservoir. (During operation, the hydraulic gradient drops below the siphon crown because of head losses and velocity head.) When headwater is below the siphon crown level, a portable, gasoline engine-driven vacuum pump is used to prime the siphon.

At some projects, a method is used to fill the section of penstock downstream of the siphon crown prior to operation of the vacuum system:

- A pump is provided at the Lac Courte Oreilles plant to pump water from tailwater to initially fill the section of the penstock between the siphon crown and the turbine. The vacuum system completes the priming operation. Special care was taken in machining the turbine wicket gates to ensure minimal leakage through the gates when filling the penstock.

- The Pine Grove Dam station has a long length of 6 ft diameter penstock (1230 ft) between the siphon crown and the turbine, and this is initially filled to headwater level through an 8 inch priming siphon, which is primed by the main vacuum system. Once the penstock downstream of the siphon is filled to headwater, the vacuum system completes the siphon priming.

Most installations have a method of positively stopping flow at the unit, either through turbine wicket gates or an intake valve. Starting of a unit is therefore done in two steps:

- With the shutoff device closed, the penstock is filled and the siphon primed; and

- The wicket gates or valve is opened to start the flow of water through the siphon and start the unit.

When the unit is shut down, only the wicket gates or the valve is closed, and the siphon is left primed. The siphon prime is broken only in an emergency or to dewater the penstock.

With more than one fixed discharge turbine on a common penstock, (e.g., Pocono Lake, Schaads Reservoir, Tierckenkill Falls) positive shutoff valves enable starting, stopping and isolating individual units. For this type of installation the priming is done under no-flow conditions with the valves closed.

Some turbines, however, have no shutoff device (Columbia Mills, Ontelaunee, and Traicao have semi-Kaplan turbines with no wicket gates; Second Broad River has fixed discharge units), and siphon priming and unit startup are one operation. Air is removed from the penstock with the vacuum system, and when water starts flowing over the invert of the siphon and through the turbine, the unit starts to rotate. The vacuum system continues to evacuate the air from the penstock to complete the priming, and this is assisted to some degree by air being drawn with the water through the turbine. With this type of installation, the siphon is broken each time the unit is shut down and must be primed for each startup.

Vacuum System

There are several designs of vacuum systems for siphon priming, ranging from rather simple systems with a single vacuum pump connected directly through piping to the crown of the siphon, to more complex systems incorporating multiple pumps and vacuum tanks. The arrangement depends on economic considerations, the size of the siphon penstock installation, and the preference of the owner/designer. Typical schematics for vacuum systems are shown on Figures 4-2 to 4-4, and various vacuum system components are shown in Figures 4-5 to 4-8. At plants with more than one siphon penstock, a common vacuum system may be provided.

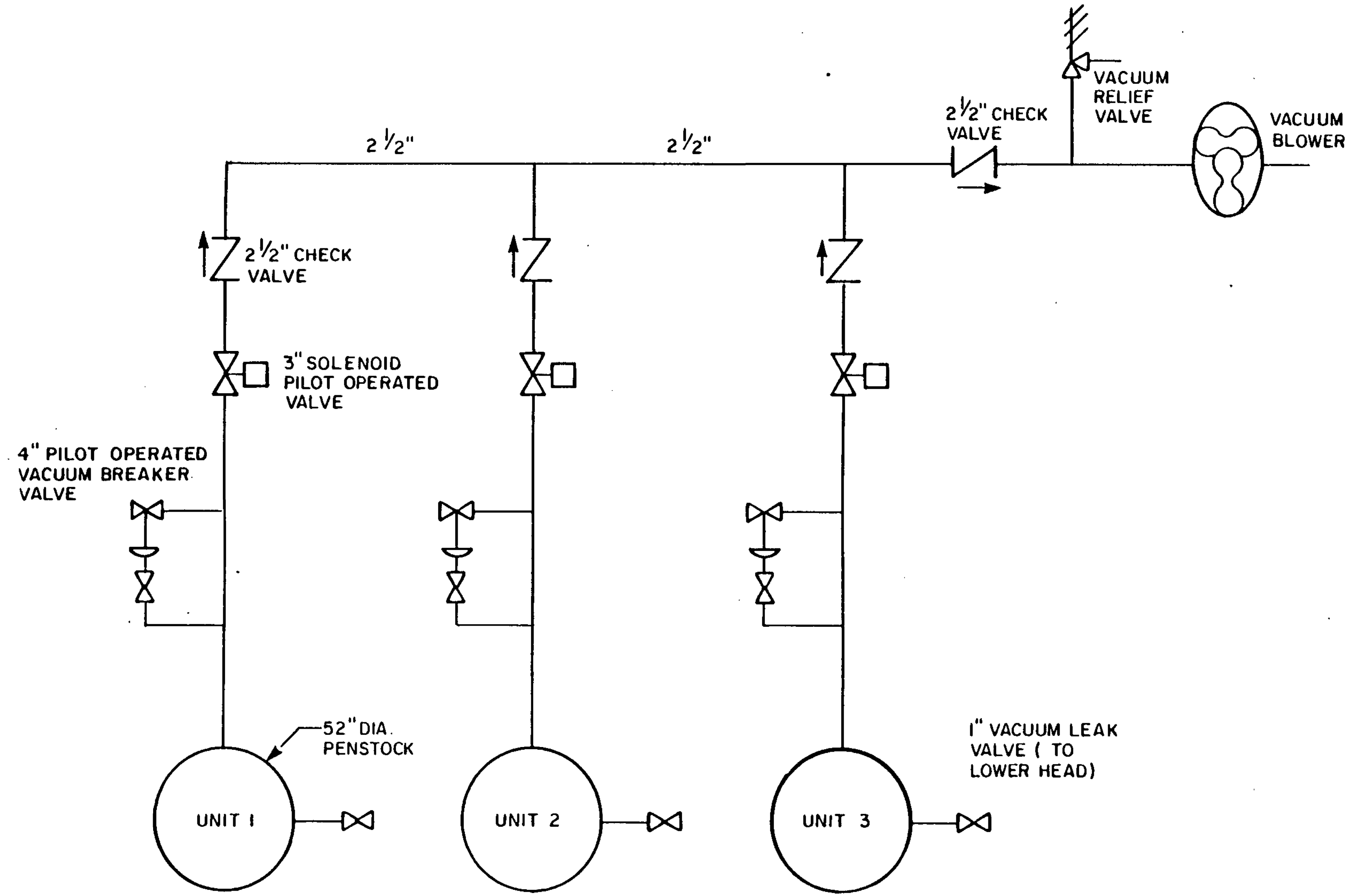


Figure 4-2 Vacuum System - Second Broad River Hydroelectric Project

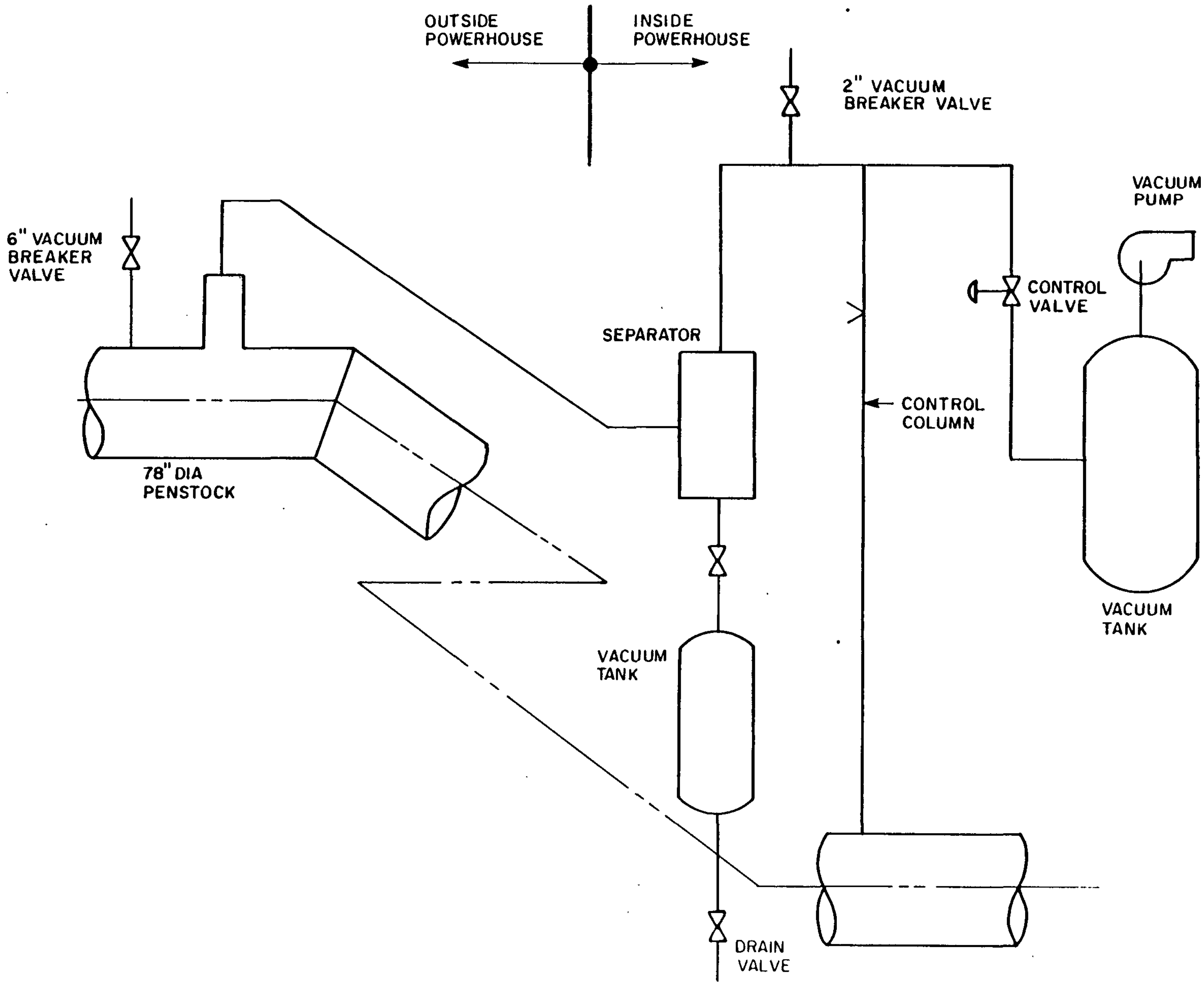


Figure 4-3 Vacuum System - Jim Falls Minimum Flow Unit Hydro Development

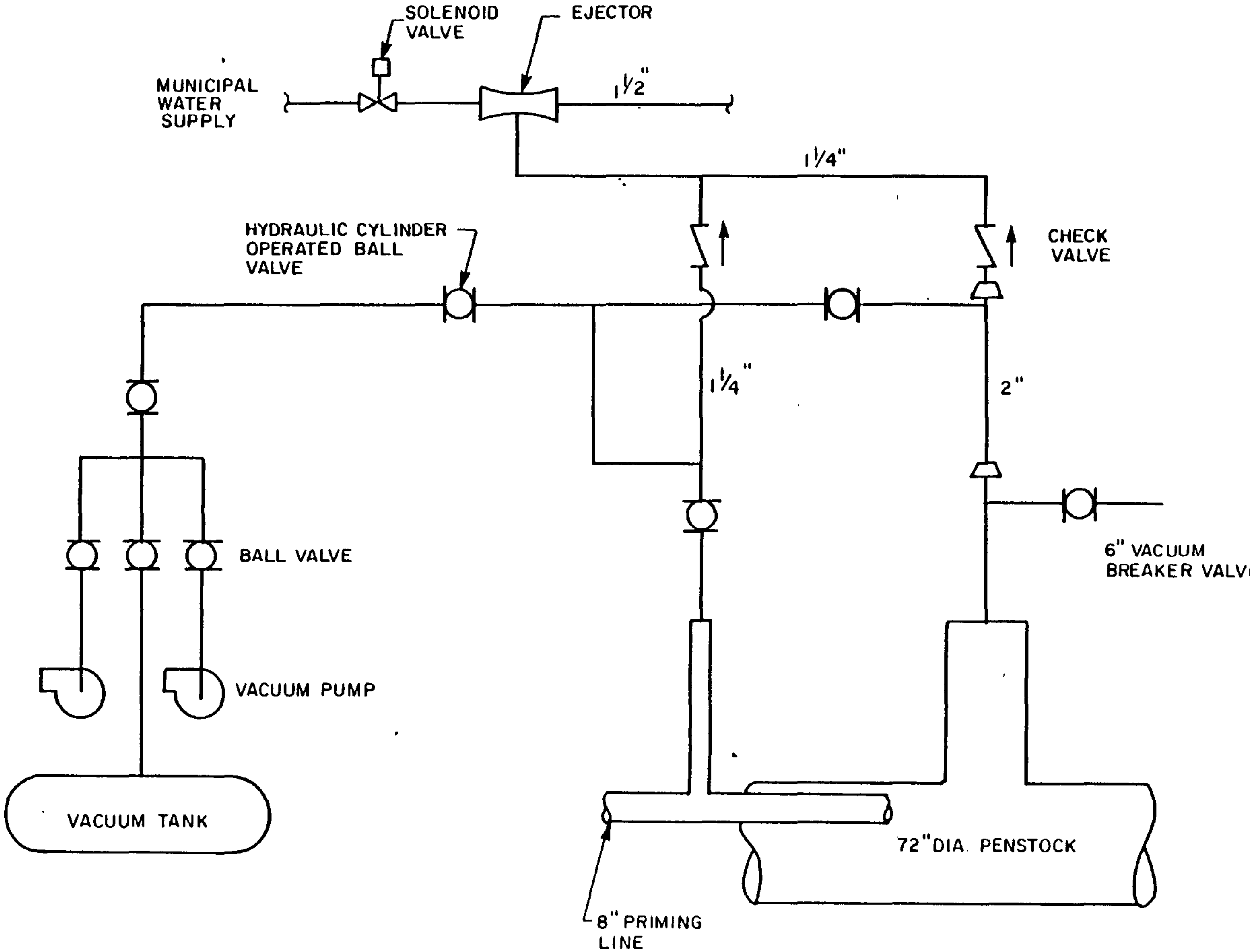


Figure 4-4 Vacuum System - Pine Grove Dam Hydroelectric Station

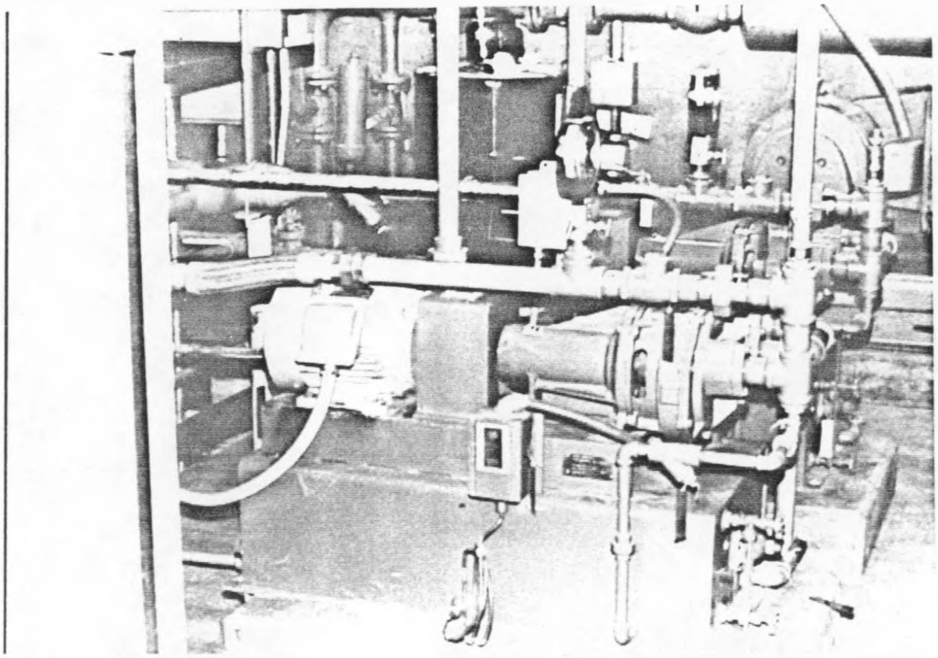


Figure 4-5 Vacuum Pump - Jim Falls Minimum Flow Unit Hydro Development

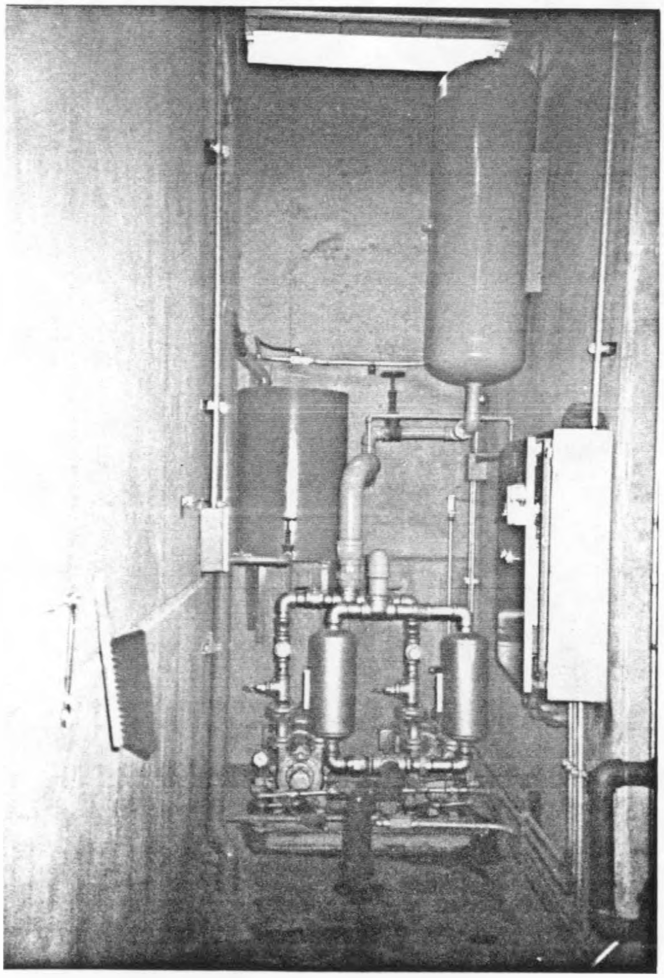


Figure 4-6 Vacuum System - Superior Dam Power Station

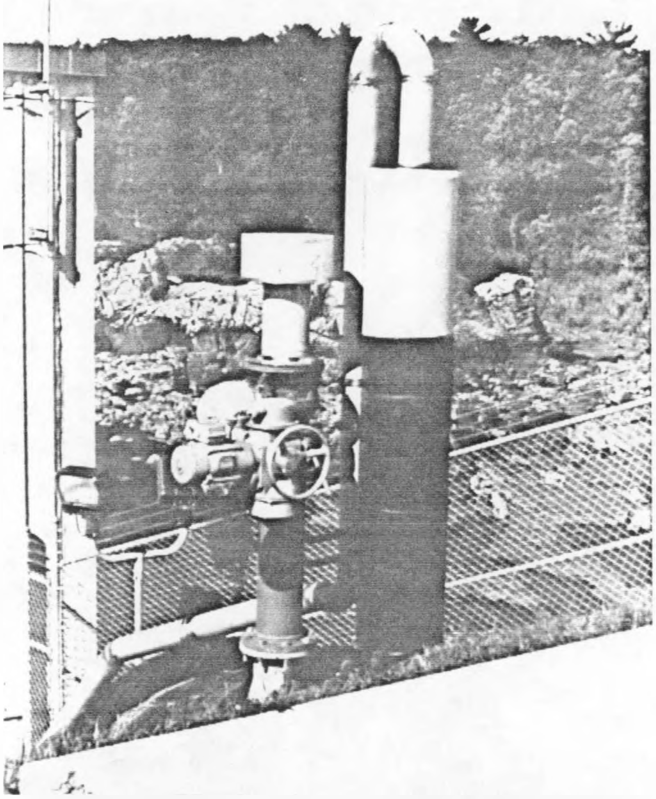


Figure 4-7 Siphon Priming Column and Vacuum Breaker Valve - Jim Falls Minimum Flow Unit Hydro Development

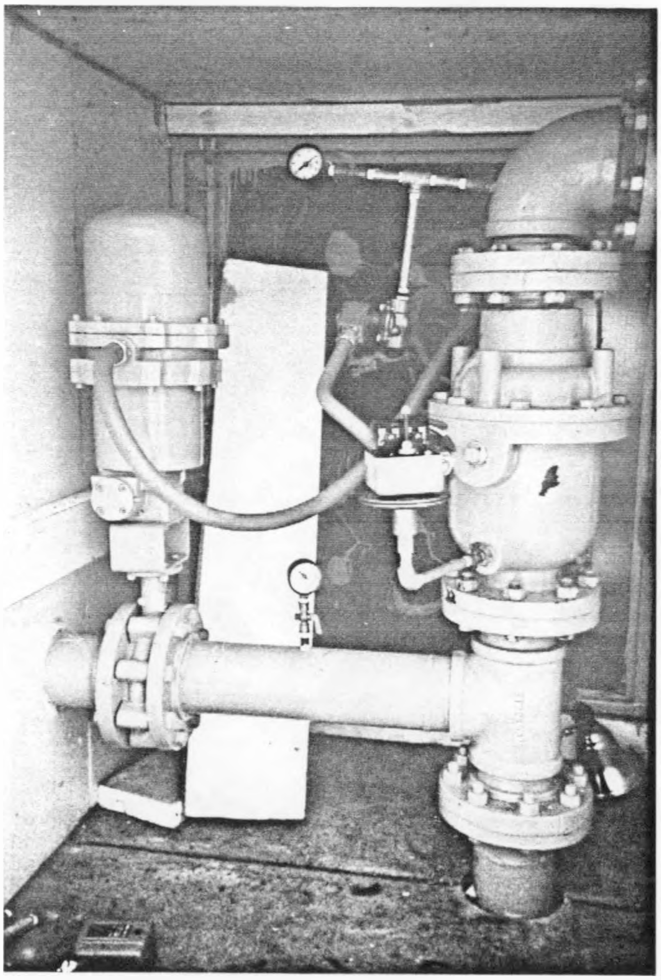


Figure 4-8 Siphon Priming Valve and Vacuum Breaker Valve - Superior Dam Power Station

Except for the Schaads Reservoir project, which normally does not require a vacuum pump, all of the plants have ac electric motor-driven vacuum pumps. A summary of vacuum pump data for the various projects is given on Table 4-1.

Rotary liquid ring seal pumps are the most common. Pump power requirements range from 1.5 to 75 hp. The pump capacity depends on the volume of air to be removed and the desired priming time.

While a single vacuum pump is satisfactory for siphon priming, some plants have two pumps. The second pump provides backup in the event of failure of the first and also allows a more rapid initial priming of the penstock when the two pumps are operated together.

The Pine Grove Dam project, in addition to two vacuum pumps, has a 1-1/4 inch ejector which can be used to evacuate air in the event of loss of electrical power for the vacuum pumps. The ejector uses pressurized water from a nearby water main.

For vacuum systems with the vacuum pump(s) connected directly to the siphon crown, the pumps are controlled by water level switches or vacuum pressure switches in the siphon crown (pressure switches are unsatisfactory if there is significant variation in headwater level). At the Second Broad River plant, where there are no shutoff devices at the turbines and water flows through the unit as the siphon primes, it was found that the shutoff point for the vacuum pump could be determined by the rotational speed of the turbine/generator unit.

A vacuum tank is incorporated into some of the systems, and this serves to prevent frequent cycling of the vacuum pump(s), especially when the vacuum system is being used for removal of air accumulating at the siphon crown while the plant is operating. With a vacuum tank, the vacuum pump is controlled by vacuum pressure switches (similar to a compressor-receiver combination). A valve in the system allows air to be drawn from the penstock into the vacuum tank. The ratio of vacuum tank size (in cubic feet) to vacuum pump capacity (in cubic feet per minute) ranges from 0.04 to 1.6 for the different projects.

Where a single vacuum system is provided for more than one siphon penstock, suitable piping, valves, and controls are provided to allow priming of one siphon at a time.

The vacuum pumps and associated vacuum tanks may be located within the powerhouse with a vacuum line extending to the siphon crown. Alternatively, the complete system may be located near the siphon crown. A protective enclosure (building) is usually provided for the vacuum system when it is located near the siphon crown.

Siphon Priming Time

Siphon priming time is the time required to fill the penstock with water, including the apex of the penstock above headwater level, starting from the dewatered condition with atmospheric pressure in the siphon crown. The priming time is a function of the penstock volume and the capacity of the priming system.

TABLE 4-1
SIPHON PENSTOCK VACUUM SYSTEM
VACUUM PUMP DATA

Project	Number of Vacuum Pumps	Capacity* (cfm)	Power* (hp)	Type	Manufacturer
Columbia Mills	1	360	15.0	Positive Displacement	Sutorbilt
Jim Falls	2	43	5.0	Liquid Ring Seal	Nash
Lac Courte Oreilles	2	170	10.0	Liquid Ring Seal	Nash
Ontelaunee	2	136	7.5	Liquid Ring Seal	Nash
Pine Grove Dam	2	77	5.0	Liquid Ring Seal	Nash
Pocono Lake	1	39	3.0	Liquid Ring Seal	Sullair Corporation
Second Broad River	1	140	5.0	Positive Displacement	Holmes
Superior Dam	2	153	10.0	Liquid Ring Seal	SIHI
Tierckenkill Falls	1	16	1.5	Rotary Vane	ITT Pneumotive
Traicao	3	800 (2) 1100 (1)	50.0 (2) 75.0 (1)	Liquid Ring Seal	Nash (2) Voith (1)

*Each pump

The siphon priming time for the various projects is summarized on Table 4-2. Priming times vary from 2.5 minutes to 390 minutes per siphon. The selection of siphon priming time depends on:

- The volume of air to be removed; and
- The expected frequency of priming operation.

Because of the impracticality of providing a very large priming system, the priming time is typically longer for installations with a large penstock volume.

At plants which have a positive shutoff device at the turbine and do not require siphon priming each time a unit is started, a longer siphon priming time can be tolerated because priming is infrequent. Shorter times are usually selected where the siphon must be primed each time a unit is started.

4.5 - Removal of Accumulated Air

In a siphon system there is a tendency for air, which becomes entrained in the water, to separate out and accumulate at the crown of the siphon. If the air accumulation becomes very large, head loss will increase, and the siphon could eventually be broken. The amount of air which becomes entrained increases if there is turbulent water in the forebay or if there are vortices at the intake.

For most plants, provision is made for removal of accumulated air with the vacuum system used for penstock priming. The vacuum system is automatically operated by level or pressure controls. Experience at operating plants has shown that the flow of water through the penstock removes accumulated air quite well, and at the Columbia Mills, Ontelaunee, and Second Broad River plants, automatic air removal with the vacuum system was found to be unnecessary.

At Schaads Reservoir, where the siphon lift is very low, there is no provision for removal of accumulated air when the penstock is in operation.

4.6 - Siphon Break System

As mentioned in Section 3, one advantage of a siphon penstock is the ability to stop the flow of water through the unit by admitting air into the penstock to break the siphon. In effect, the device acts as an intake gate or valve.

The siphon break system consists simply of an air inlet (vacuum breaker) valve which, when opened, admits air into the penstock. At the Schaads Reservoir, Tierckenkill Falls, and Pine Grove Dam plants, the air inlet valve is manually operated. At all the other plants the valves are operated through automatic controls. Most of the automatically operated valves also have provisions for manual operation. The valve may be interconnected with the turbine control system, similar to an intake gate or valve, to break the siphon on turbine overspeed or unit creep.

TABLE 4-2
SIPHON PRIMING TIME

Project	Volume of Air To Be Removed For Siphon Priming (ft³)	Priming Time* (Min.)	Average Rate of Air Removal (ft³/min.)	Priming Required For Each Unit Start
Columbia Mills	650	5	130	Yes
Jim Falls	2,664	45	59	No
Lac Courte Oreilles	15,300	49	312	No
Ontelaunee	3,024	25	121	Yes
Pine Grove Dam	41,000	390	105	No
Pocono Lake	410	8	51	No
Schaads Reservoir	2,800	30	93	No
Second Broad River	920	2.5-8	174	Yes
Superior Dam	8,000	45	178	No
Tierckenkill Falls	750	45	17	No
Traicao	--	15-20	--	Yes

*per siphon

The air inlet (vacuum breaker) valve must be of substantial size, otherwise the air drawn through the valve will be swept through the turbine by the flowing water. The sizes of the valves used for the various plants are given in Table 4-3.

4.7 - Preventing Siphon Flow (During High Water Conditions)

A difficulty with siphon penstocks is the inability to stop flow during high water conditions if the headwater is above the high point of the siphon penstock. At plants where there is a positive shutoff device at the turbine, this is not a problem other than the loss of the emergency shutdown feature (i.e., the ability to break the siphon) and the inconvenience of not being able to dewater the penstock during high water. However, at plants with no shutoff device, a means must be provided to prevent rotation of the turbine when the unit is shut down.

At the Ontelaunee project, during high water conditions, the water level in the siphon can be depressed below the high point in the siphon by injecting low pressure compressed air into the siphon crown. The compressed air is provided by a vacuum system through valving which allows the liquid ring vacuum pump to act as an air compressor. The depression system is automatically activated by the station programmable controller which senses high water level and the unit off-line. The valving around the vacuum pump/compressor is solenoid operated.

At Columbia Mills, during flood conditions when the unit is shut down, the unit is manually secured with a chain wrapped around the torque tube between the generator and the speed increaser. This approach has proven to be unsatisfactory because the water level may rise rapidly, and the station operator may not always be available on short notice.

4.8 - Intakes

Intake Configuration

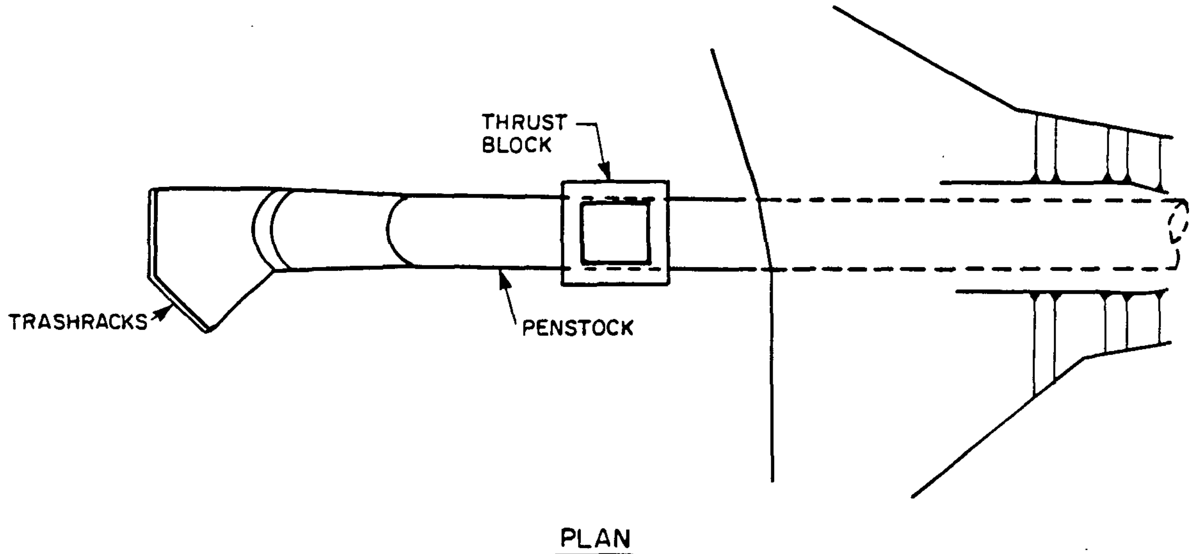
A horizontal intake (i.e., the flow direction is horizontal) with a vertical opening is usually most suitable for a conventional penstock design, except for a high head installation where the intake may be a vertical morning glory type. Many siphon penstock installations, where the penstock slopes up from the intake to the top of the dam, lend themselves to vertical (inverted morning glory) or inclined intakes with horizontal or nearly horizontal openings. Where the upstream face of the dam has a shallow slope, a horizontal intake is still suitable. Examples of intake configurations are shown on Figures 4-9 to 4-12.

The Tierckenkill Falls plant has a somewhat unique intake configuration (Figure 4-12). The plant flow is relatively small (12 cfs), and the intake consists of a horizontal extension of the penstock, with several intake openings cut in the side of the pipe.

TABLE 4-3
AIR INLET (VACUUM BREAKER) VALVES

Project	Valve Diameter (in.)	Penstock Diameter (in.)	Valve/ Penstock Diameter	Type of Valve	Type of Operator
Columbia Mills	6	157*	0.038	Butterfly	Hydraulic Cylinder/ Counter-weight
Jim Falls	6	78	0.077	Butterfly	Motor
Lac Courte Oreilles	12	108	0.111	Butterfly	Hydraulic Cylinder
Ontelaunee	12	72	0.167	Butterfly	Motor
Pine Grove Dam	6	72	0.083	Ball	Manual
Pocono Lake	2	60	0.033		Solenoid
Schaads Reservoir	4	30	0.133	Ball	Automatic
Second Broad River	4	52	0.077	Custom Made	Piston Operated
Superior Dam	4	96	0.042	Butterfly	Solenoid Operated
Tierckenkill Falls	3	16	0.188	Ball Valve	Motor
Traicao	20**	276*	0.072	Custom Made	Hydraulic Cylinder

* Equivalent diameter, conduit is actually rectangular in configuration.
** Each of two valves.



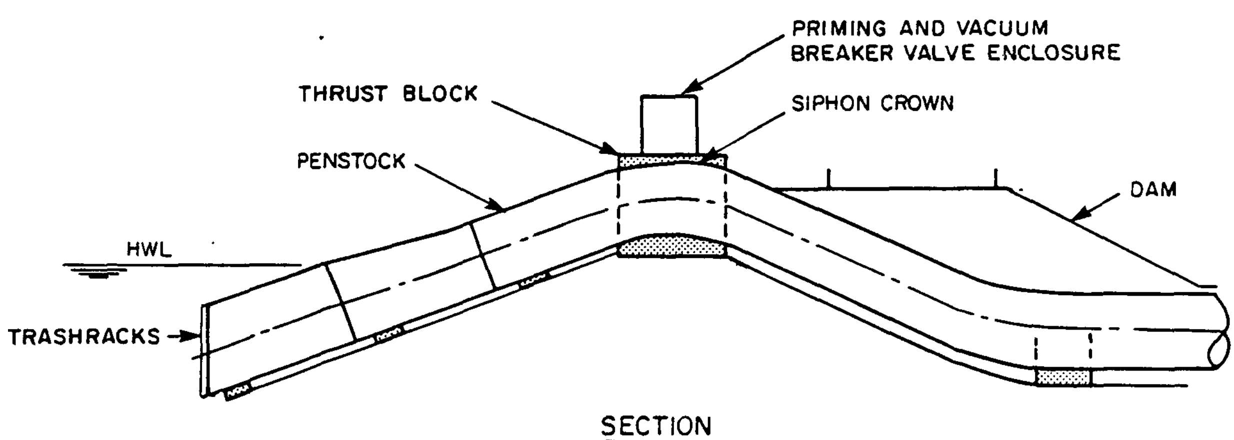
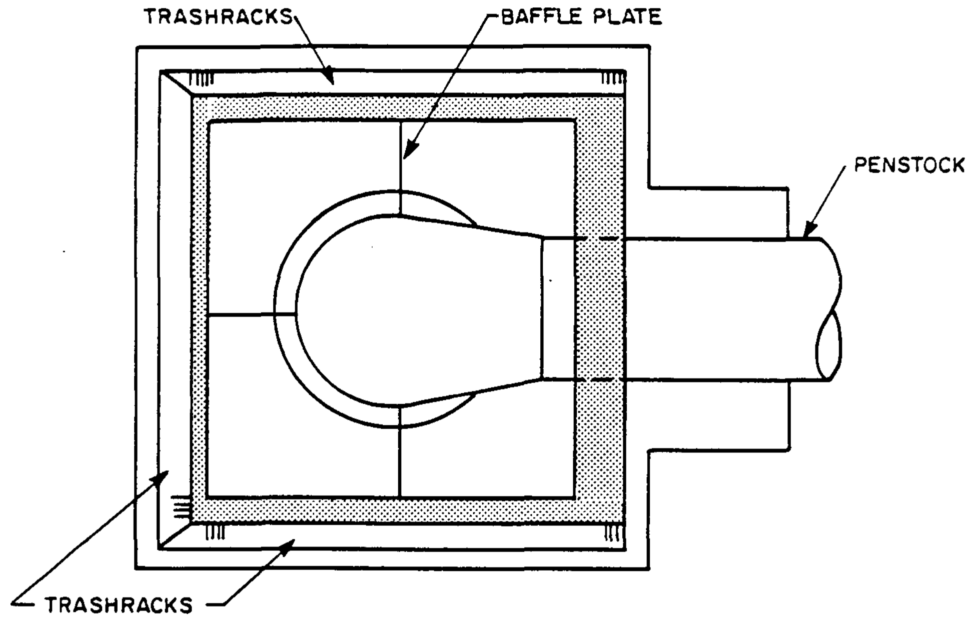
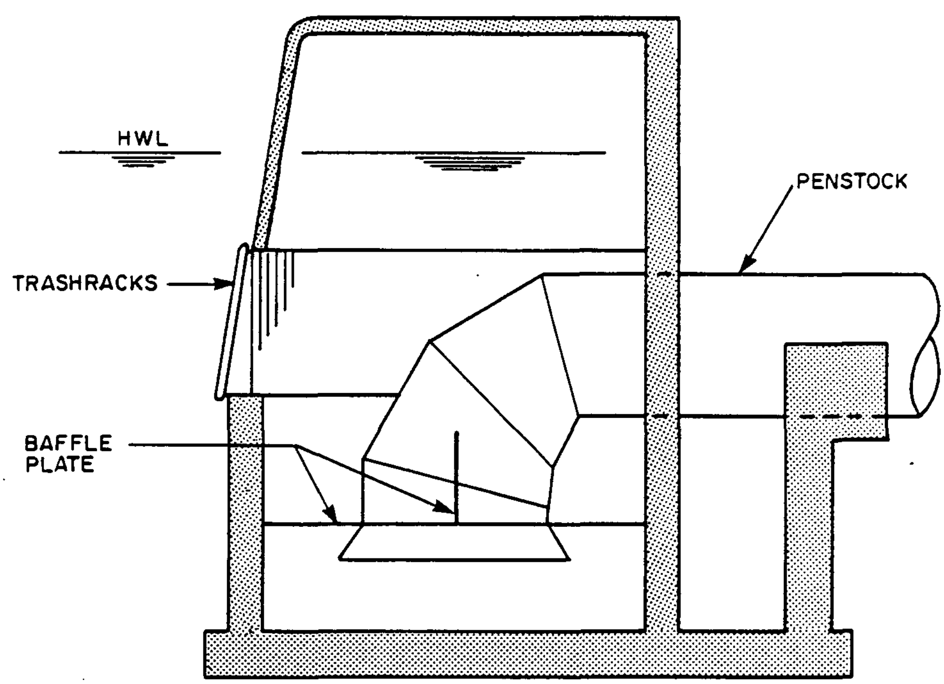


Figure 4-9 Horizontal Intake - Superior Dam Power Station

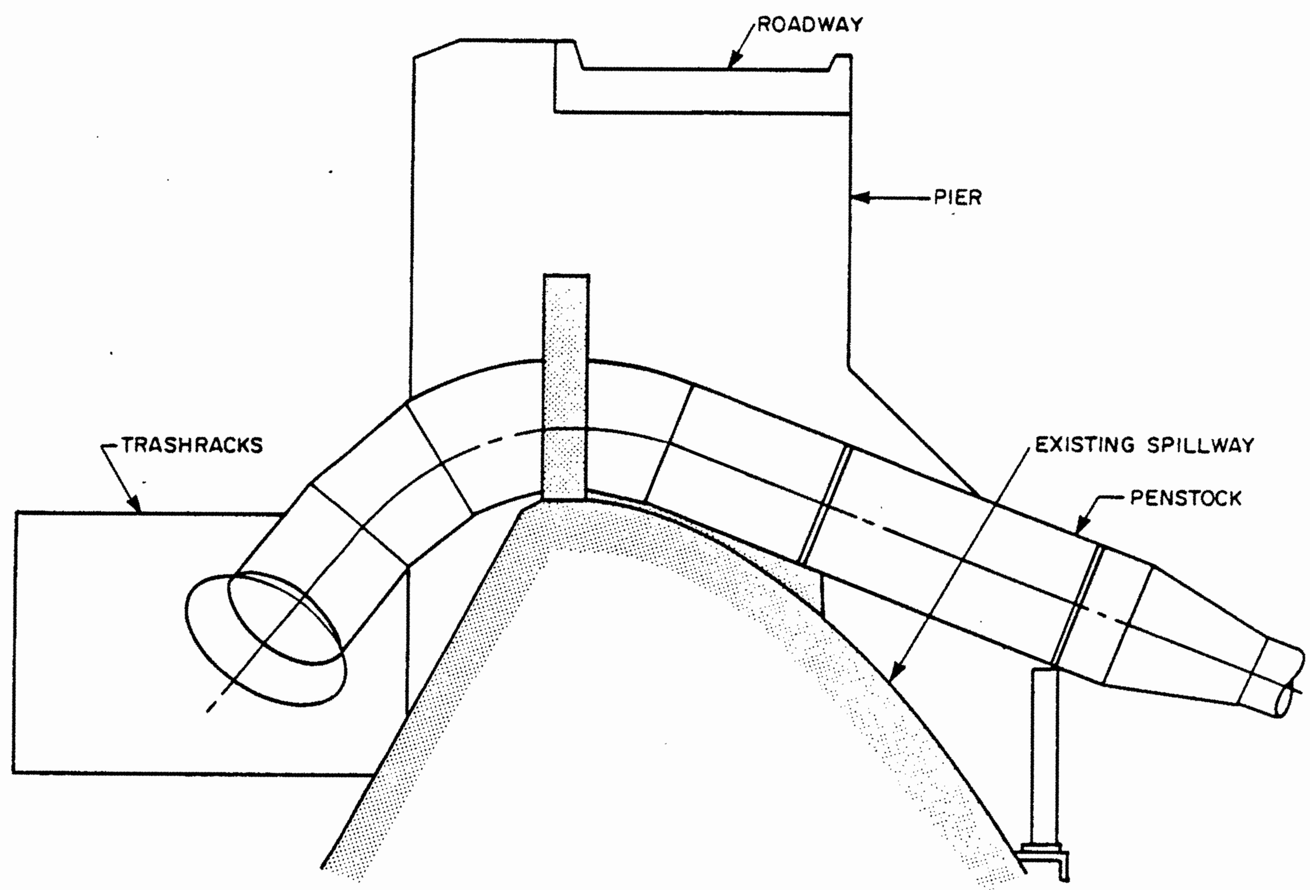


SECTIONAL PLAN

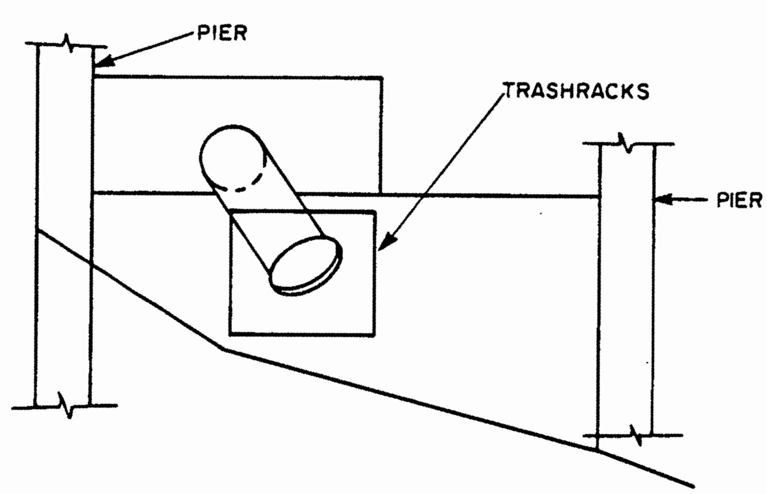


SECTION

Figure 4-10 Vertical Bellmouth Intake - Pine Grove Dam Hydroelectric Station

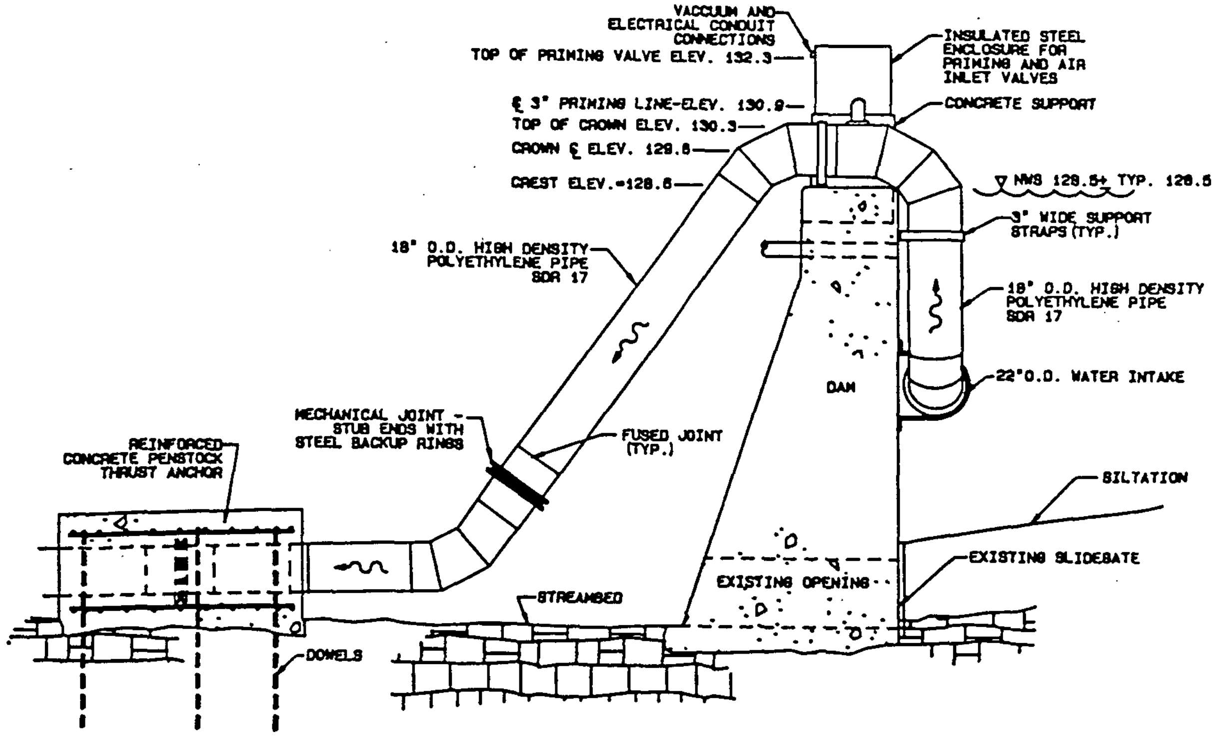


SECTION AT PENSTOCK INTAKE

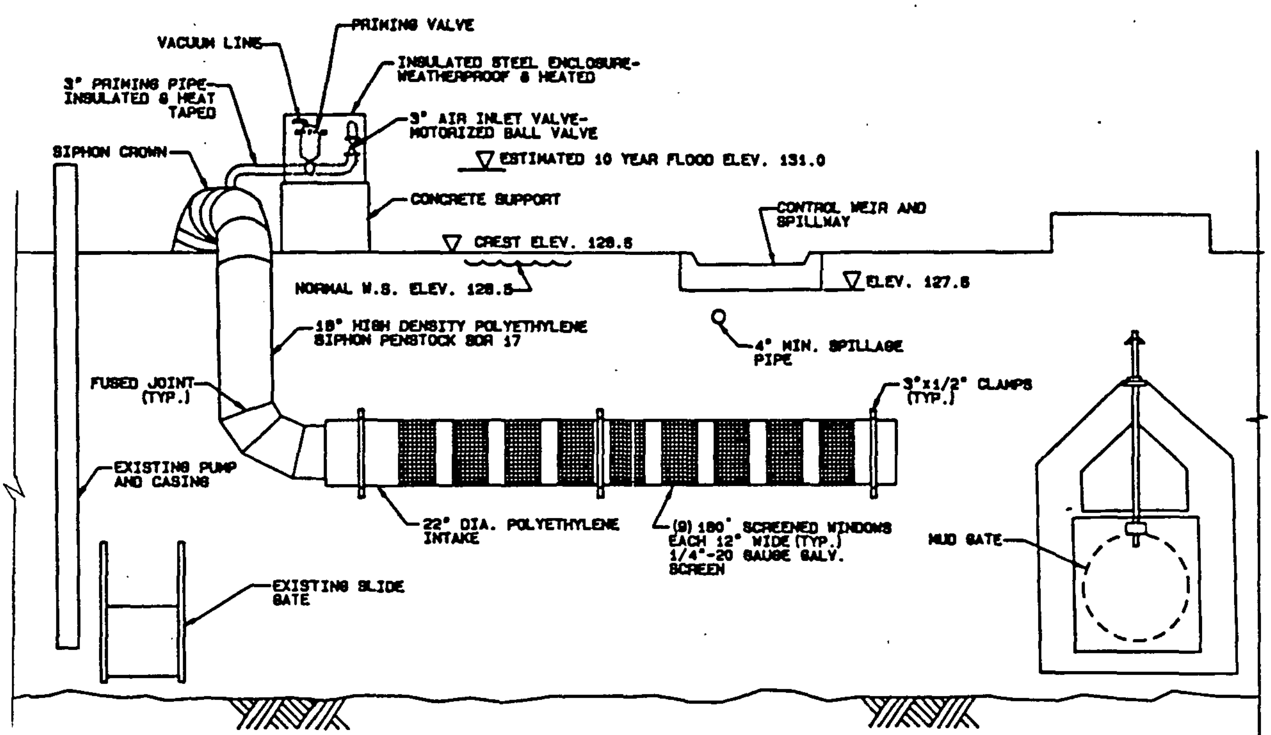


UPSTREAM ELEVATION

Figure 4-11 Inclined Bellmouth Intake - Pocono Lake Hydroelectric Project



SIPHON INTAKE PROFILE



FRONT ELEVATION-DAM

Figure 4-12 Horizontal Pipe Type Intake - Tierckenkill Falls Hydroelectric Project

Intake Submergence

Intakes for both conventional and siphon penstock designs must have suitable submergence to prevent air entraining vortices from forming in the water surface near the intake. The vortices may increase head loss, reduce unit power, and cause rough operation of the turbine equipment. In addition, for siphon penstock designs, the vortices could considerably increase the rate of air accumulation at the crown of the siphon. This will result in increased operation of the vacuum system.

To reduce civil costs, intake submergence is usually kept to a minimum, consistent with ensuring that the water surface is free from harmful vortices. There is no exact analytical approach for determining the minimum submergence requirement to prevent vortex formation. The problem is a complex one depending on intake configuration, size, flow rate, and inlet channel flow conditions. On large projects, model tests of the intake are common. Except for the Traicao project, there were no model tests for any of the projects on which this report is based.

An approximate approach to quantitatively analyzing intake submergence is to compare the relative submergence of the intake with the Froude number. A comparison of these parameters for both vertical and horizontal intake configurations is shown on Figures 4-13 and 4-14. Superimposed on the figures are suggested guidelines for intake submergence derived by Energy Mines and Resources Canada[(1)] for vertical intakes and by Gulliver et al[(2)] for horizontal intakes.

At the Columbia Mills project, the intake has a semi-circular lip (Figure 4-15). The intake was designed by ESAC, the turbine manufacturer, and from their experience, the semi-circular lip assists in preventing vortex formation.

At the Lac Courte Oreilles project, an anti-vortex wall was constructed after the plant went into operation to eliminate vortices which were observed during initial operation (Figures 4-16 and 4-17). Anti-vortex baffles were also incorporated into the Pine Grove Dam intake (Figure 4-10).

To prevent vortices at the Pocono Lake intake, a timber grid was constructed to float immediately below the minimum water surface. The grid consists of 2 inch by 12 inch cypress timbers constructed horizontally on 12 inch centers and mounted under the platform on the top of the steel frame trashrack structure.

Plastic bottles floating behind the trashracks are used to prevent vortices at the penstock intakes for the Second Broad River plant.

Trashracks

Trashracks are provided at penstock intakes to prevent debris from entering the penstock and turbine waterpassages, and jamming in the wicket gates or damaging turbine components.

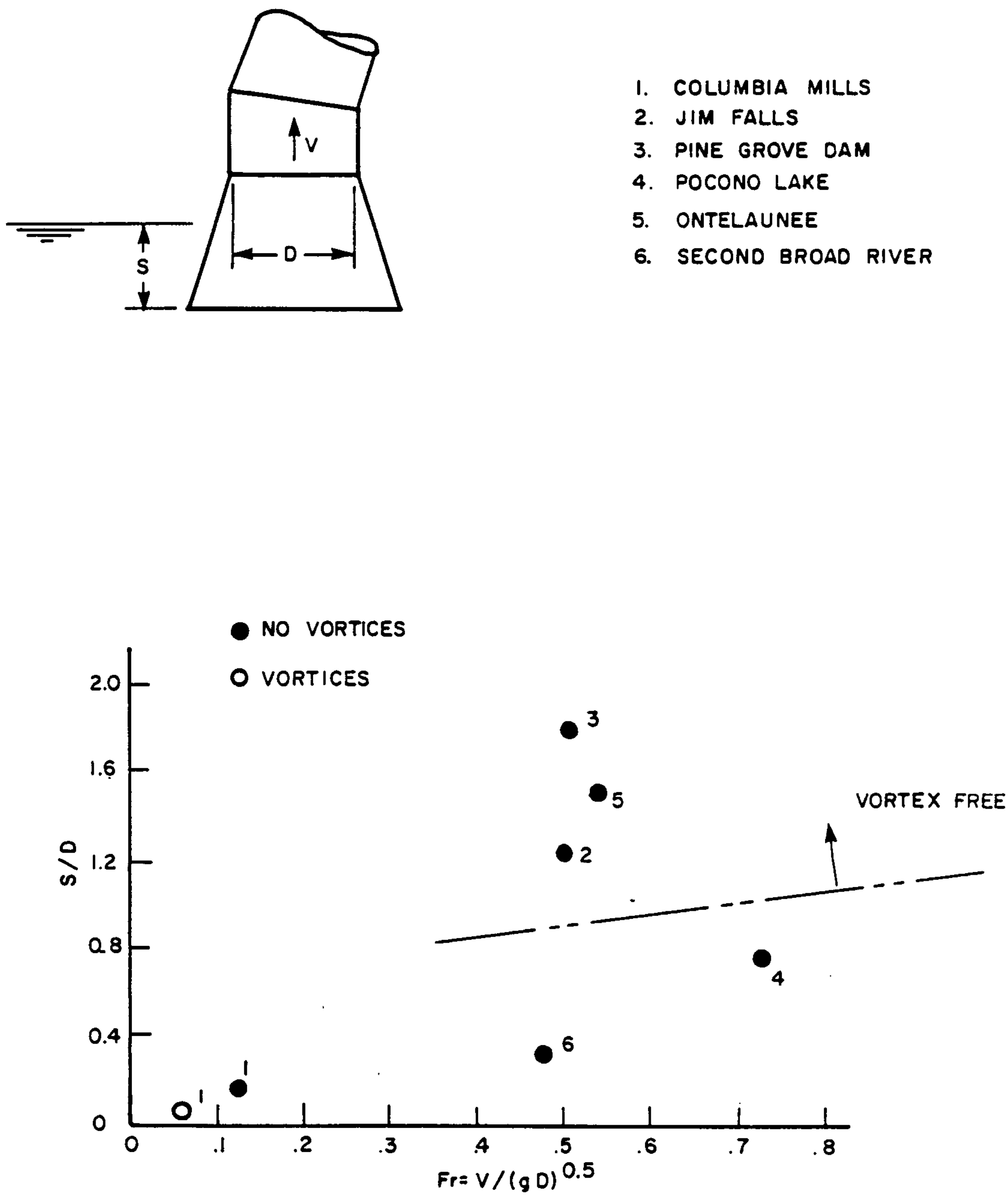


Figure 4-13 Intake Submergence - Vertical Intakes

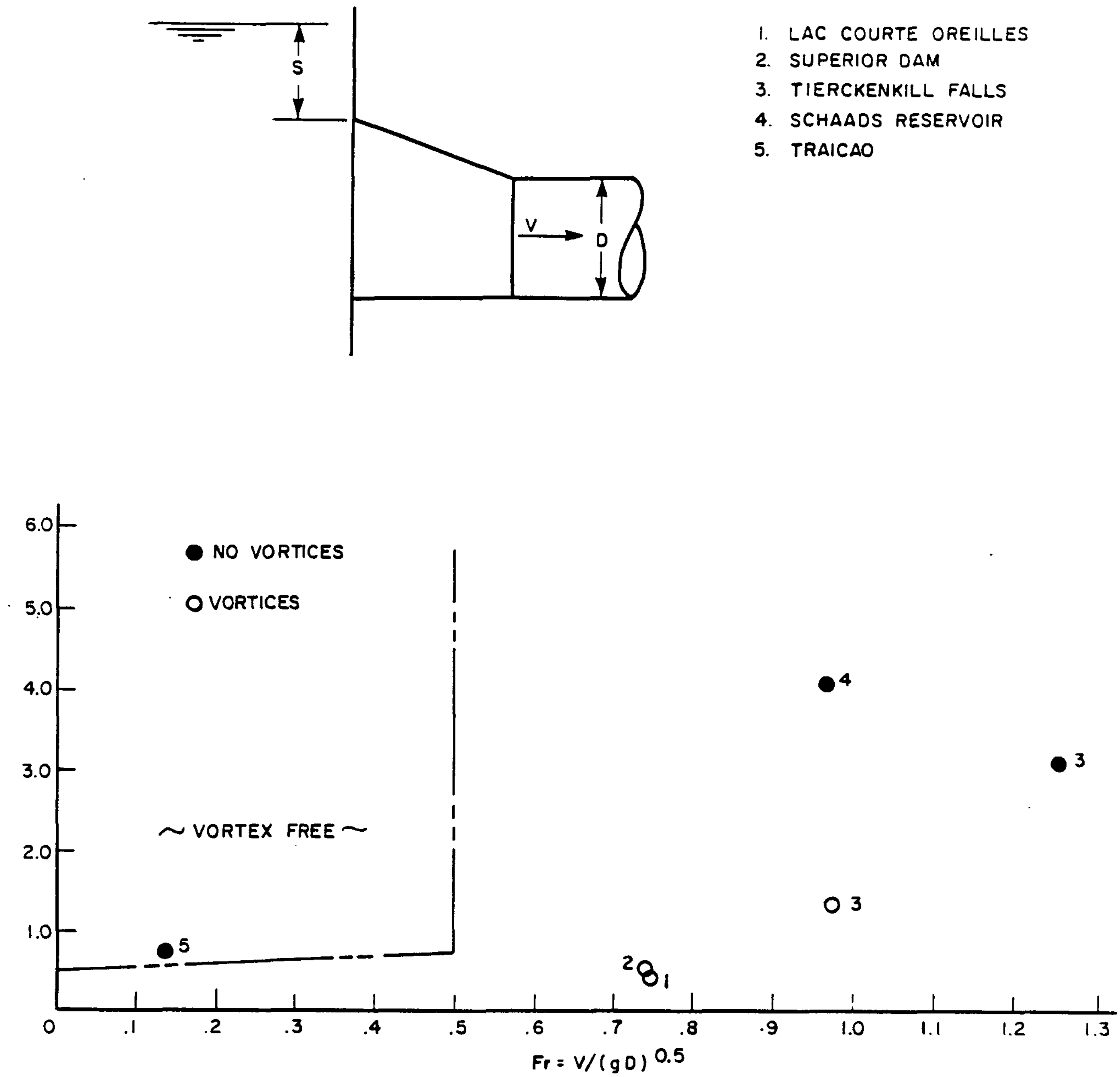


Figure 4-14 Intake Submergence - Horizontal Intakes

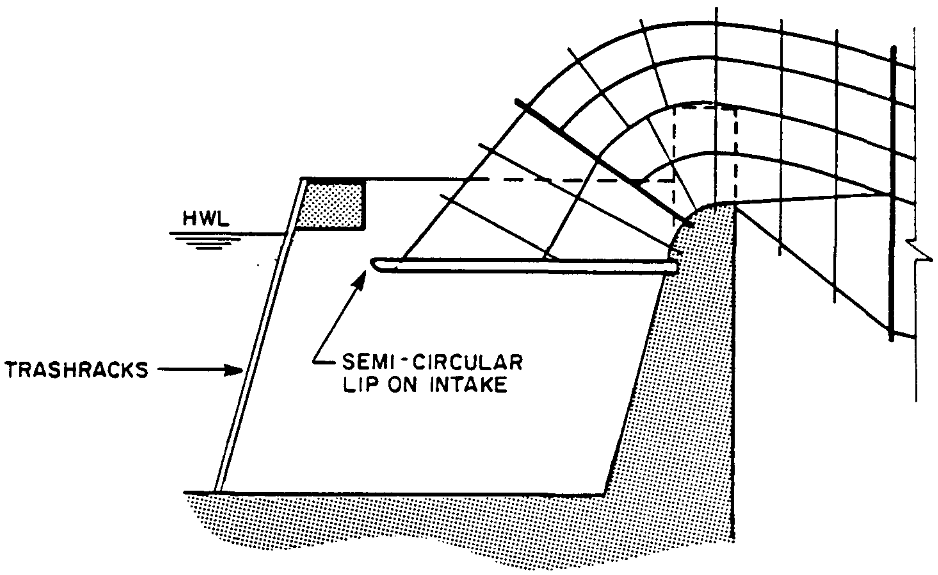


Figure 4-15 Vertical Intake with Semi-Circular Lip

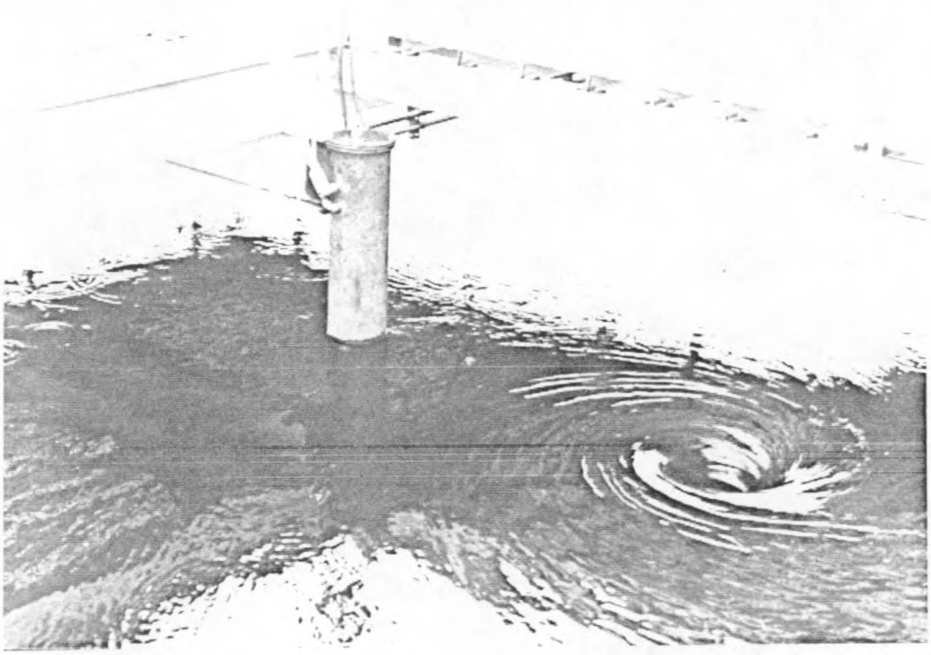
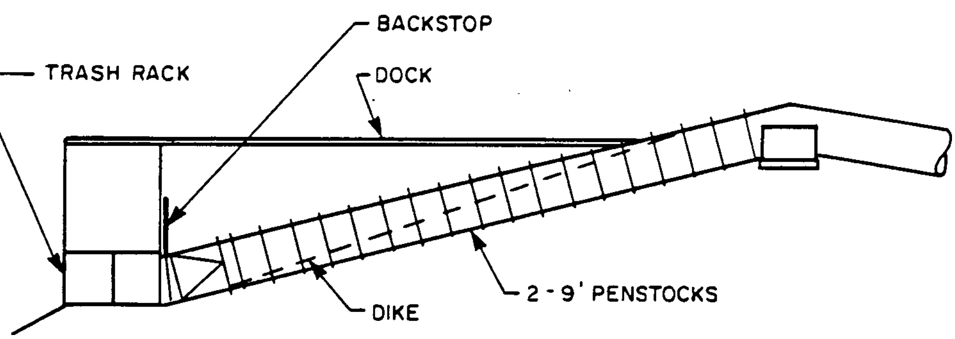
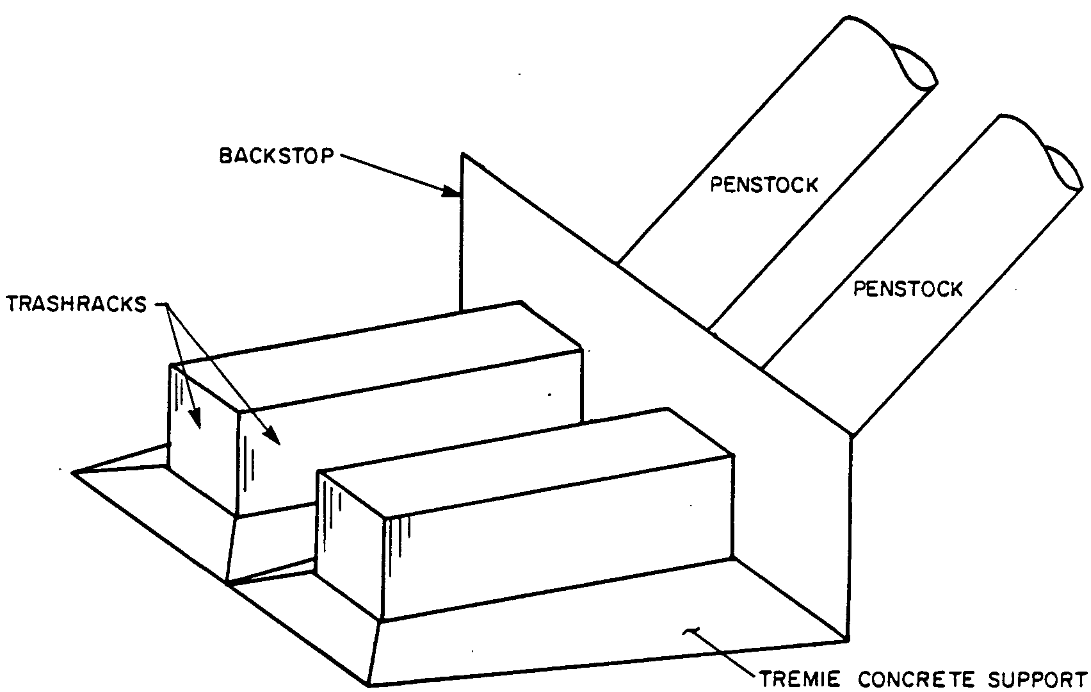


Figure 4-16 Vortex at Lac Courte Oreilles Hydro Development



SECTION AT PENSTOCK INTAKE



ISOMETRIC OF INTAKE

Figure 4-17 Anti-Vortex Backstop - Lac Courte Oreilles Hydro Development

Trashracks are usually made of vertical steel bars with horizontal spacers and supports. Standard steel grating was used on the Second Broad River project; however, it was found that the racks were difficult to clean because of the interference of the horizontal bars. Wire mesh was installed on the Tierckenkill Falls intake; but the 12-gage mesh was judged to have insufficient rigidity to withstand blockage from debris even with the relatively small (12 inch by 35 inch) intake openings. Aluminum bars were used on the 4 ft by 3 ft by 3 ft rectangular box type intake for the Schaads Reservoir project.

Most horizontal intakes have the trashracks installed on the vertical or inclined face of the intake. Alternatively, a box type intake structure may be installed in front of the intake to reduce rack velocities. Vertical intakes usually incorporate a multi-sided rack structure with trashracks on three sides. A summary of trashrack data for the various projects is presented on Table 4-4.

Trashrack bar spacing depends on the size of the turbine and clearance in the runner waterpassages and wicket gates. The spacings vary from 0.5 inch at Tierckenkill Falls to 5.9 inches at Traicao. Considerations for fish entrainment may also govern the rack spacing in which case spacing may be limited to about 1 inch maximum (e.g., Second Broad River Plant).

Trashrack velocities vary from 0.14 to 2.9 ft/sec based on gross area at the racks. Where fish entrainment is a consideration, velocities have been limited to 0.3 to 1 ft/sec. The vertical intake with the rack structure on three sides lends itself quite well to low rack velocities.

The structural design considerations for trashracks are the same as for conventional installations and include:

- Differential head due to rack blockage; and
- Rack bar vibration due to vortex shedding with water flow past the rack bars.

For installations in northern climates (e.g. Jim Falls, Ontelaunee and Pocono Lake), the trashrack support structure which extends above water must be designed for horizontal ice load. A typical ice load would be 5,000 to 10,000 lbs per linear foot acting over a 2 ft depth at the water surface.

Trashrack Cleaning

Most of the plants with siphon penstocks are relatively small in both capacity and physical size, and the trashracks are manually cleaned. A deck is normally provided over the rack area which allows access for cleaning.

TABLE 4-4
SUMMARY OF TRASHRACK DATA

Project	Trashrack Area (ft^2)	Plant Flow (cfs)	Velocity Based on Gross Area (ft^2)	Bar Clear Spacing (in)	Turbine Runner Diameter (in.)	Intake Orientation*	Environ-mental Constraints In Design
Columbia Mills	624	334	0.54	2.8	55.13	V	No
Jim Falls	137	240	1.8	3.0	53.0	V	No
Lac Courte Oreilles	738	1,500	2.0	3.0	34.0**	H	No
Ontelaunee	1,550	210	0.14	2.0	47.25	I	Yes
Pine Grove Dam	288	175	0.61	2.5	39.37	V	No
Pocono Lake	640	180	0.28	2.0	21.6**	I	Yes
Schaads Reservoir	54	42	0.78	1.1	12.0**	I	Yes
Second Broad River	492	246	0.50	1.0	42.0	V	Yes
Superior Dam	194	567	2.9	3.5	74.8	H	No
Tierckenkill Falls	24	11.9	0.5	0.5	8.0	H	No
Traicao	3,908	8,333	2.1	5.9	138	H	No

* V = Vertical
H = Horizontal
I = Inclined

** Smallest unit

At the Second Broad River project, a small custom made trash rake made from a "T" section and a chain hoist was installed. However, because of operating difficulties, its use was discontinued.

A manual hoist is installed at the Columbia Mills intake to assist in the removal of large trees which accumulate on the trashracks during flood periods.

Cleaning the trash screens at the Tierckenkill Falls plant is accomplished by drawing the water level down below the intake using a slide gate in the dam. A water hose is then used to clean the screens.

Siphon installations with penstocks on the upstream sloping face of an earthfill dam do not lend themselves to cleaning, either manual or mechanical, because of the horizontal distance from the waterline to the racks. In some cases there is no provision for cleaning. Some degree of rack cleaning can be achieved by breaking the siphon and allowing the reverse flow in the penstock between the siphon and the intake to dislodge debris from the racks. This method is employed at the Lac Courte Oreilles plant (in addition to manual cleaning); however, its effectiveness has not been determined. At Superior Dam, this approach is also used, but is not entirely satisfactory. There have been difficulties at Superior Dam with rack blockage resulting in increased velocities and causing vortex formation.

At Schaads Reservoir, the small intake was set 25 ft below headwater to minimize the possibility of blockage with debris.

4.9 - Penstock Design

The design approach for siphon penstocks is similar to that for conventional pressurized penstock design. Typical design codes and standards are:

- ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2;
- U.S. Bureau of Reclamation (USBR), "Welded Steel Penstocks," Engineering Monograph No. 3;
- Arthur, H.G. and Walker, J.W., "New Design Criteria for USBR Penstocks," Journal of the Power Division, ASCE. January 1970;
- Amstutz, E., "Buckling of Pressure-Shaft and Tunnel Linings," Water Power, November 1970;
- AISC "Manual of Steel Construction";
- U.S. Bureau of Reclamation (USBR), "Stress Analysis of Wye Branches," Engineering Monograph No. 32;

- Parmakian, J. "Minimum Thickness for Handling Steel Pipes", Water Power and Dam Construction, June 1982;
- AISI & SPFA "Steel Penstocks and Tunnel Liners," Steel Plate Engineering Data - Volume 4; and
- AWWA-MII - "Steel Pipe - A Guide for Design and Installation".

Load conditions which were considered on the various projects included as appropriate:

- Dead loads - pipe weight plus permanently connected appurtenances;
- Live loads - construction loads, wind loads, snow loads, and ice impact loads at the water line;
- Water pressure including waterhammer;
- Uplift due to air trapped at the crown of the siphon;
- Thrust loads;
- Earth pressure and weight of backfill;
- Temperature loads; and
- Earthquake.

For siphon penstocks the siphon crown plus adjacent piping above headwater must be designed for negative pressure. The negative pressure is the sum of:

- Maximum static suction lift;
- Head losses from the intake to the crown of the siphon; and
- Negative waterhammer due to flow acceleration (a consideration when the length of penstock upstream of the siphon crown is significant).

Commonly used formulae for circular steel penstock design for negative pressure are as follows:

$$P_{CRIT} = 73.4 \times 10^6 \frac{(t/D)^{5/2}}{(L/D)} \text{ (with stiffeners)}$$

$$P_{CRIT} = 50.2 \times 10^6 (t/D)^3 \text{ (without stiffeners)}$$

where

P_{CRIT} = critical buckling pressure (psi)
t = penstock material thickness (in.)
D = penstock inside diameter (in.)
L = spacing of stiffener rings (in.)

The first formula (pipe with stiffeners) is attributed to Saunders and Windenburg and is otherwise known as "Roark's Short Tube Formula". It is valid if D/t >20. The second formula (pipe without stiffeners) is known as the Stewart formula and automatically accounts for wall thickness variations, out-of-roundness, and other manufacturing tolerances. It is valid if D/t >43, P_{CRIT} is 581 psi or less, and L/D >6.

Several other formulae may be used and are listed in "ISO Views on Buckling" by V. Helden (Reference 3).

The rectangular penstock for the Columbia Mills project was designed using flat plate formulae. Stiffener spacing was selected to minimize vibration, based on the designer's experience with similar installations.

On some of the designs with steel penstocks, a corrosion allowance of 1/16 inch was applied when calculating the required thickness, but the majority did not consider such an allowance necessary.

Siphon penstocks were typically designed for the maximum possible negative pressure which could occur during operation. Some of the penstocks were designed for a full negative pressure of 1 atmosphere (14.7 psi). An exception is the Schaads Reservoir project, which has a relief valve in the penstock to prevent negative pressure from exceeding 10 ft of water (4.3 psi) in the event that the reservoir is drawn down too far. Safety factors for buckling varied considerably ranging from 1.5 to 5.7. A safety factor of 2 was generally adopted.

Penstock diameter is typically based on an economic evaluation of penstock cost and lost generation associated with head loss. Penstock velocities for projects covered by this report range from 2.5 ft/sec to 11.8 ft/sec, based on plant flow (Table 4-5), and are similar to velocities in conventional penstock designs.

4.10 - Penstock Material

Penstock materials for the projects covered in this report are summarized on Table 4-5. Structural grade steel is the most common material because of the relatively low design pressures.

While none of the projects has used glass fiber reinforced thermosetting resin pipe (RTR), it was evaluated for the Superior Dam project but rejected because of economic considerations and also concern for vandalism. However, RTR pipe has been used for numerous conventional penstocks and is suitable for siphon penstock designs.

TABLE 4-5
PENSTOCK DATA

Project	Penstock Diameter (ft)	Velocity at Plant Flow (ft/sec)	Penstock Material	Type of Field Joint
Columbia Mills	9.8x13.8*	2.47	A36 Steel	Bolted/Flanged and Welded
Jim Falls	6.5	7.23	A36 Steel	Butt Welded
Lac Courte Oreilles	9.0	11.79	A36 Steel	Butt Welded
Ontelaunee	6.0	7.43	A53 Grade B Steel Helically Welded	Flanged/Bolted and Butt Welded
Pine Grove Dam	6.0	6.19	Steel and Prestressed Concrete	Lap Welded (Steel) Gasketed Bell and Spigot (Concrete)
Pocono Lake	5.0	9.17	ASTM A53 Grade B Steel	Flanged/Bolted and Butt Welded
Schaads Reservoir	2.5	8.56	A283 Grade D Steel	Welded
Second Broad River	4.3	5.56	A36 Steel	Butt Welded
Superior Dam	8.0	11.28	Reinforced Concrete with Embedded Steel Cylinder	Rubber Gasketed Bell and Spigot (Joints Sealed with Epoxy Mortar)
Tierckenkill Falls	1.4	8.21	High Density Polyethylene Pipe	Fusion Joints
Traicao	12.4x33.4*	5.03	Concrete	None

*Rectangular

At the Traicao project, the siphon is integral with the concrete powerhouse substructure.

Polyethylene pipe is commercially available in sizes up to 48 inches. At the Tierckenkill Falls project, the high density polyethylene pipe penstock has a nominal (outside) diameter of 18 inches.

A criterion used to select the pipe material at some of the projects was its resistance to vandalism. The advantage of reinforced concrete pipe is that it is less susceptible to this type of damage than other types of pipe. High density polyethylene pipe is the material most susceptible to vandalism, while RTR pipe may also present problems. Buried pipe is not considered susceptible to vandalism, and a shallow embankment was placed over sections of the Tierckenkill Falls penstock as a deterrent.

The protective coating systems for the steel penstocks are summarized on Table 4-6. Coal tar epoxy protective coating in accordance with AWWA C210 is most common. At Columbia Mills, it was decided not to paint the penstock because of delays in the project schedule. The interior of the penstocks at the Second Broad River plant were not painted because interior erosion did not appear to be a problem at other plants on the same river. However, shortly after the Second Broad River plant went into operation, rust build-up which increased friction losses was apparent, and it was concluded an interior coating would have been beneficial.

The exterior of the reinforced concrete penstock at Superior Dam was coated with white epoxy.

4.11 - Penstock Support

The method of penstock support is dependent on the arrangement and configuration of the penstock, the penstock material, the dam construction, and the surrounding site conditions. Considerations for design of various support systems included:

- Prevention of sliding;
- Penstock expansion;
- Resistance to uplift; and
- Containment of hydraulic forces.

The methods used on the various projects are as follows:

Columbia Mills (Figure 4-18). The short siphon penstock, which is rectangular in cross section, is installed over the crest of an existing dam. The dam was constructed of loose laid limestone with a concrete cap and an impervious upstream facing constructed of clay with a sand and gravel barrier. A new concrete support was poured for the penstock. This support incorporates dowels, which are drilled and grouted into the sloped surface of the existing concrete cap. The dowels serve as shear connectors to prevent sliding and tension connectors in the event the river is at flood stage (above the crown of the siphon), and there

TABLE 4-6
PROTECTIVE COATING FOR STEEL PENSTOCKS

Project	Protective Coating Interior	Protective Coating Exterior (Exposed)	Protective Coating Exterior (Buried)
Columbia Mills	None	None	--
Jim Falls	Coal tar epoxy per AWWA C210	Inorganic zinc epoxy tie coat aliphatic polyurethane top coat	Cold applied primer Tape wrap system
Lac Courte Oreilles	Coal tar epoxy	Coal tar epoxy	Coal tar epoxy
Ontelaunee	Coal tar epoxy per AWWA C210	Coal tar epoxy per AWWA C210	--
Pine Grove Dam	Coal tar epoxy	High-build polyamide epoxy	Coal tar epoxy per AWWA C203
Pocono Lake	Coal tar epoxy per AWWA C210	Coal tar epoxy per AWWA C210	--
Schaads Reservoir	Coal tar epoxy	None	None
Second Broad River	None	Primer	--

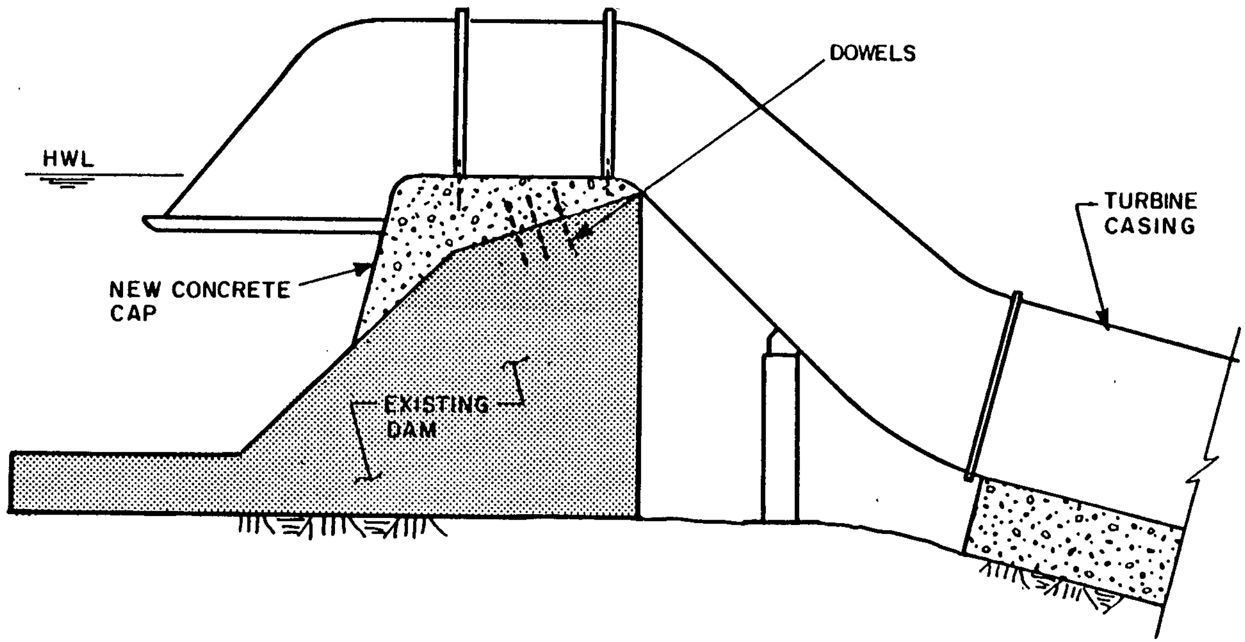


Figure 4-18 Penstock Support - Columbia Mills Hydroelectric Plant

is a pocket of air in the siphon crown. The reinforcing steel for the new concrete support is interlocked with the stiffeners for the steel penstock.

- Jim Falls (Figure 4-19). The penstock is located over an existing concrete wall and earth dike. The penstock is supported at two points on the concrete wall and at the powerhouse. The supports incorporate teflon sliding surfaces to allow unrestrained movement. Thrust rings are provided at the powerhouse wall.

- Lac Courte Oreilles (Figure 4-20). The penstock is constructed on an earth dike and is continuously supported by a compacted, free-draining, gravel bedding over a 120 degree arc on the bottom side of the penstock. The upstream section of penstock has polystyrene insulation to retard frost penetration and heave under the penstock at the waterline. Concrete cradles are provided at the penstock intake, over the core wall at the apex of the siphon, and at the powerhouse.

- Ontelaunee (Figure 4-21). The penstock spans an existing concrete dam and is supported at the dam crest, upstream of the dam crest and at the intake. The supports are constructed of steel tubular columns which fit between circular stiffeners welded to the penstock. The base plates are held by anchor bolts, with elastomeric bearings provided for expansion. The penstock is also anchored at the turbine/generator foundation.

- Pine Grove Dam (Figure 4-22). The penstock is constructed on an existing earthfill dam and is supported on a continuous concrete saddle. The penstock is anchored at the siphon priming structure located at the top of the siphon.

- Pocono Lake (Figure 4-23). The siphon penstock is supported on an existing spillway crest. Concrete bedding was placed on the spillway crest, and the penstock is anchored by a new concrete abutment wall cast over the penstock. Structural steel supports are provided on the downstream side of the siphon crown.

- Schaads Reservoir (Figure 4-24). The majority of the penstock for the Schaads Reservoir project is buried in the earthfill dam. The area which passes through the core of the dam is concrete encased. The penstock is exposed upstream of the apex and has a floating concrete support.

- Second Broad River (Figure 4-25). The penstock is installed over an existing masonry dam and is supported on a concrete slab poured on top of the dam, as well as on a concrete pier on the downstream side of the dam. The slab on the top of the dam was poured around the penstock and is bolted to the existing dam.

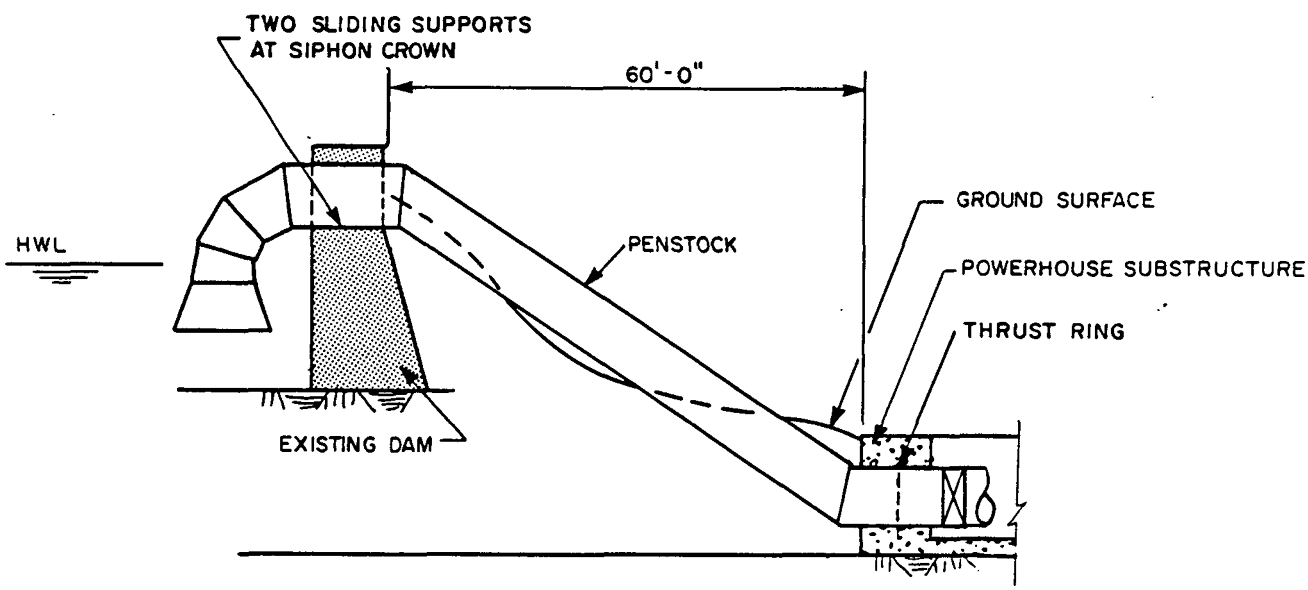


Figure 4-19 Penstock Support - Jim Falls Minimum Flow Unit Hydro Development

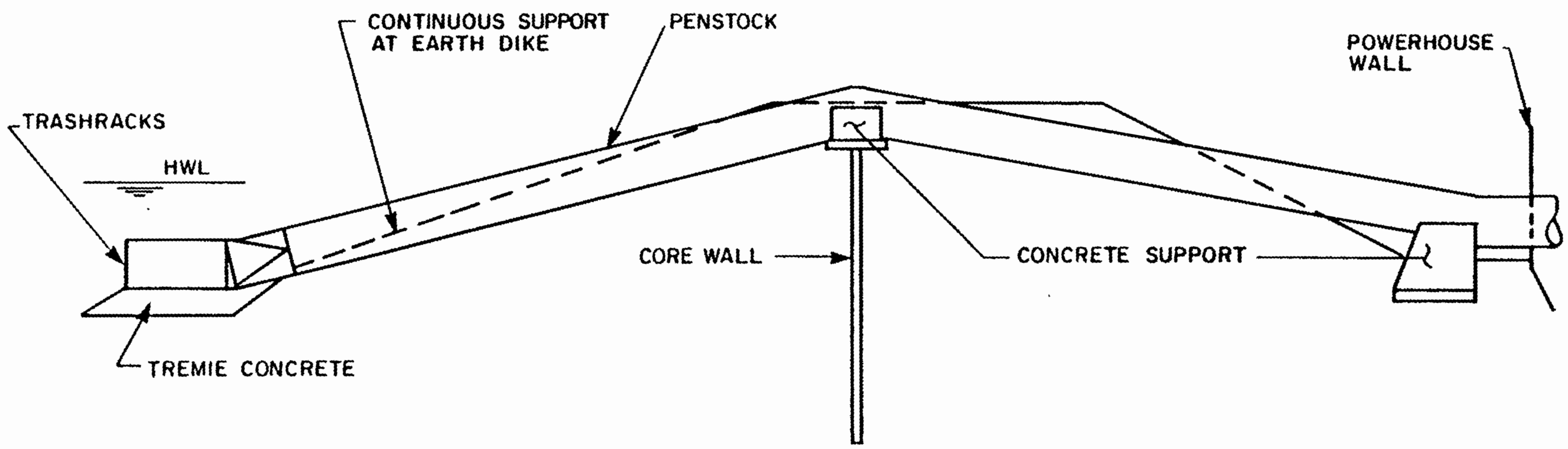


Figure 4-20 Penstock Support - Lac Courte Oreilles Hydro Development

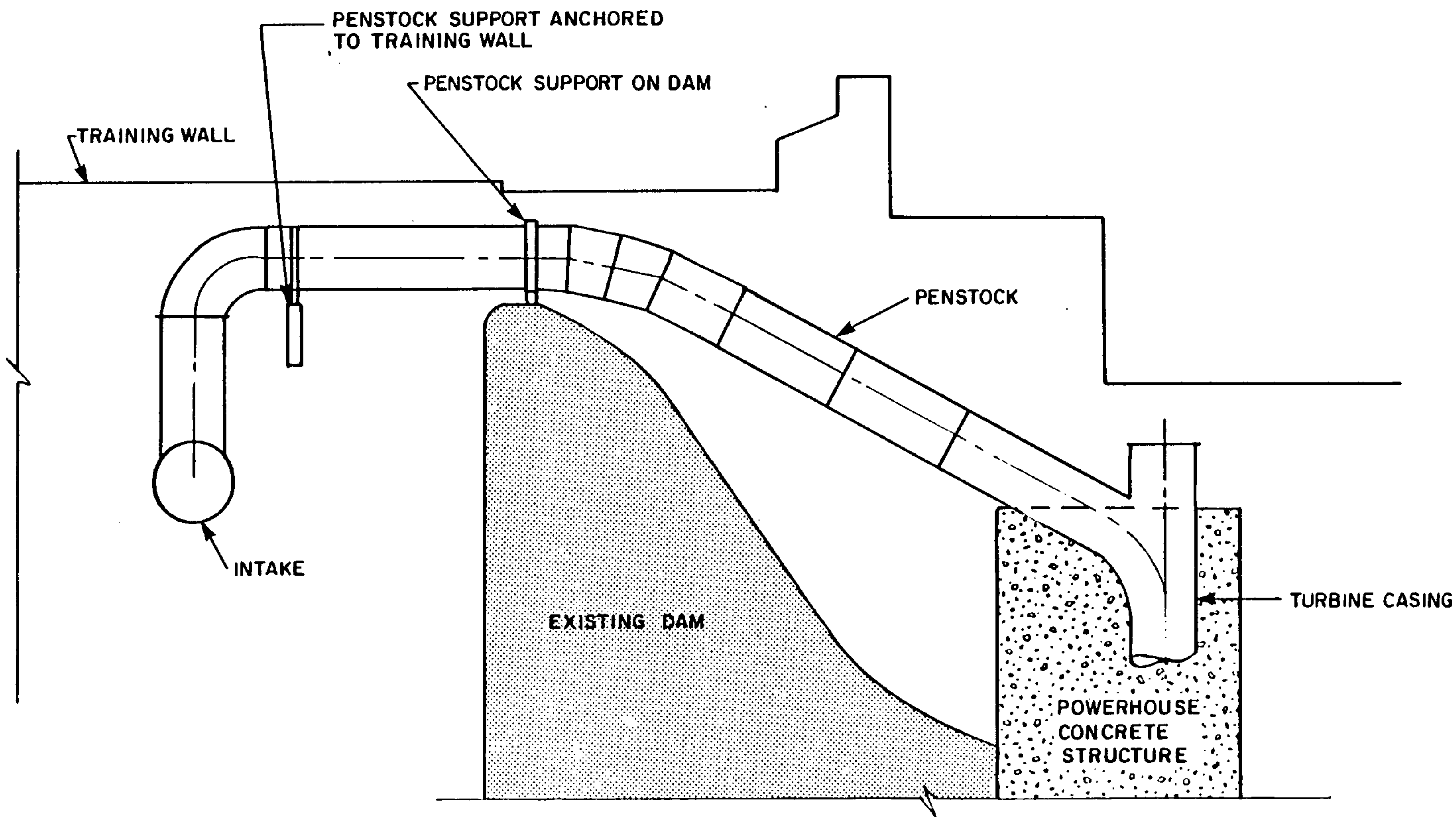


Figure 4-21 Penstock Support - Ontelaunee Hydroelectric Project

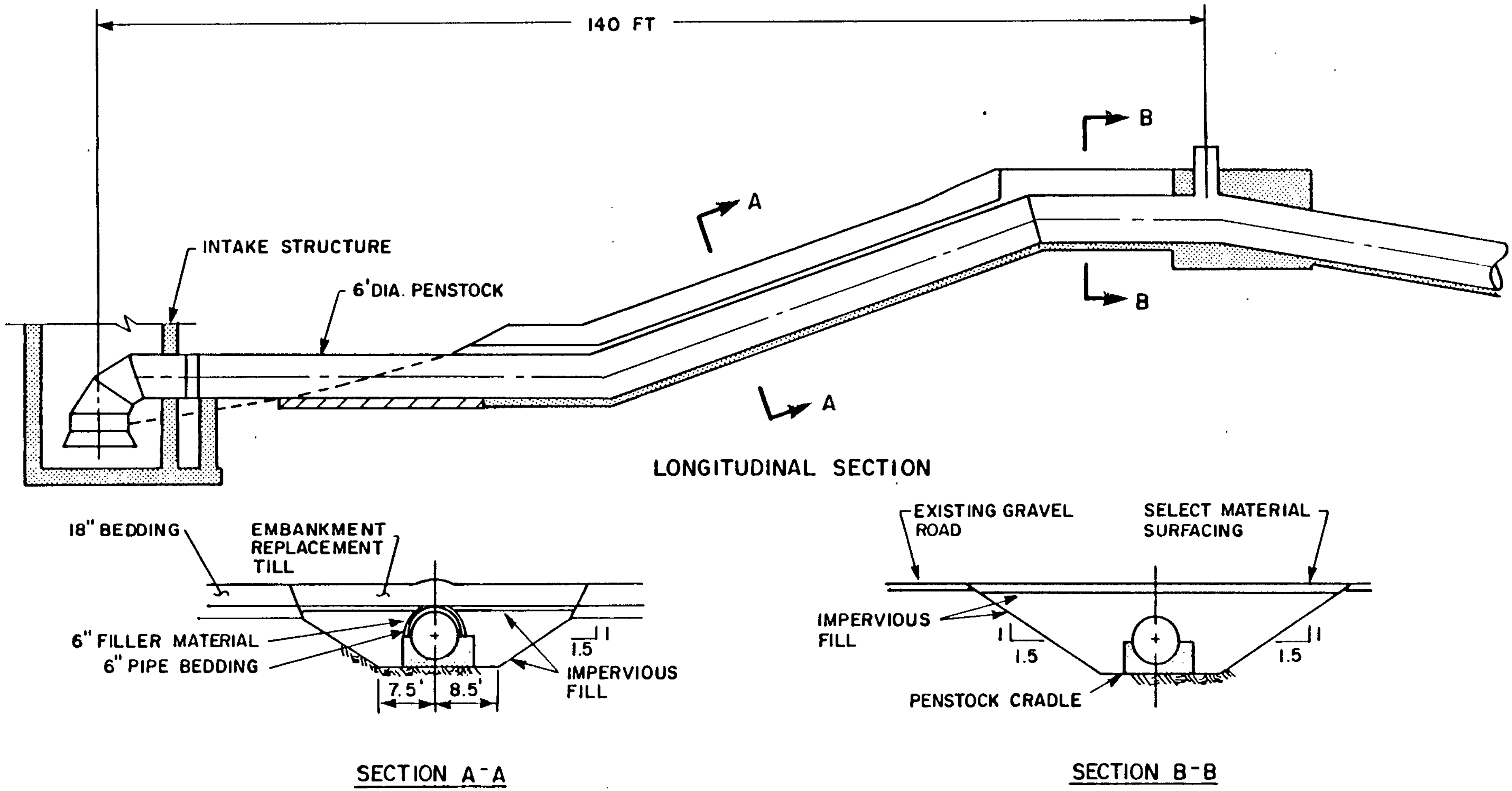


Figure 4-22 Penstock Support - Pine Grove Dam Hydroelectric Station

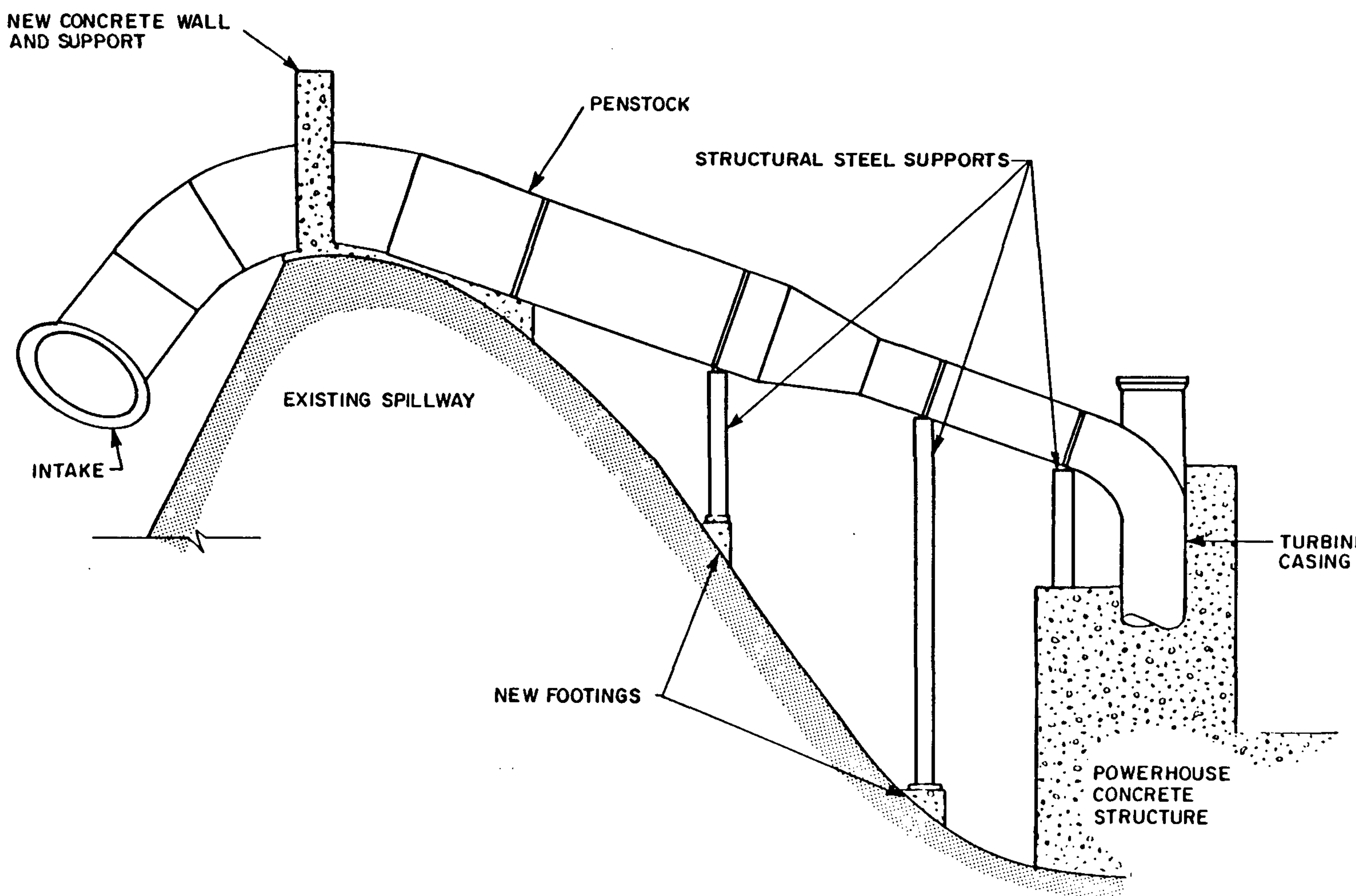


Figure 4-23 Penstock Support - Pocono Lake Hydroelectric Project

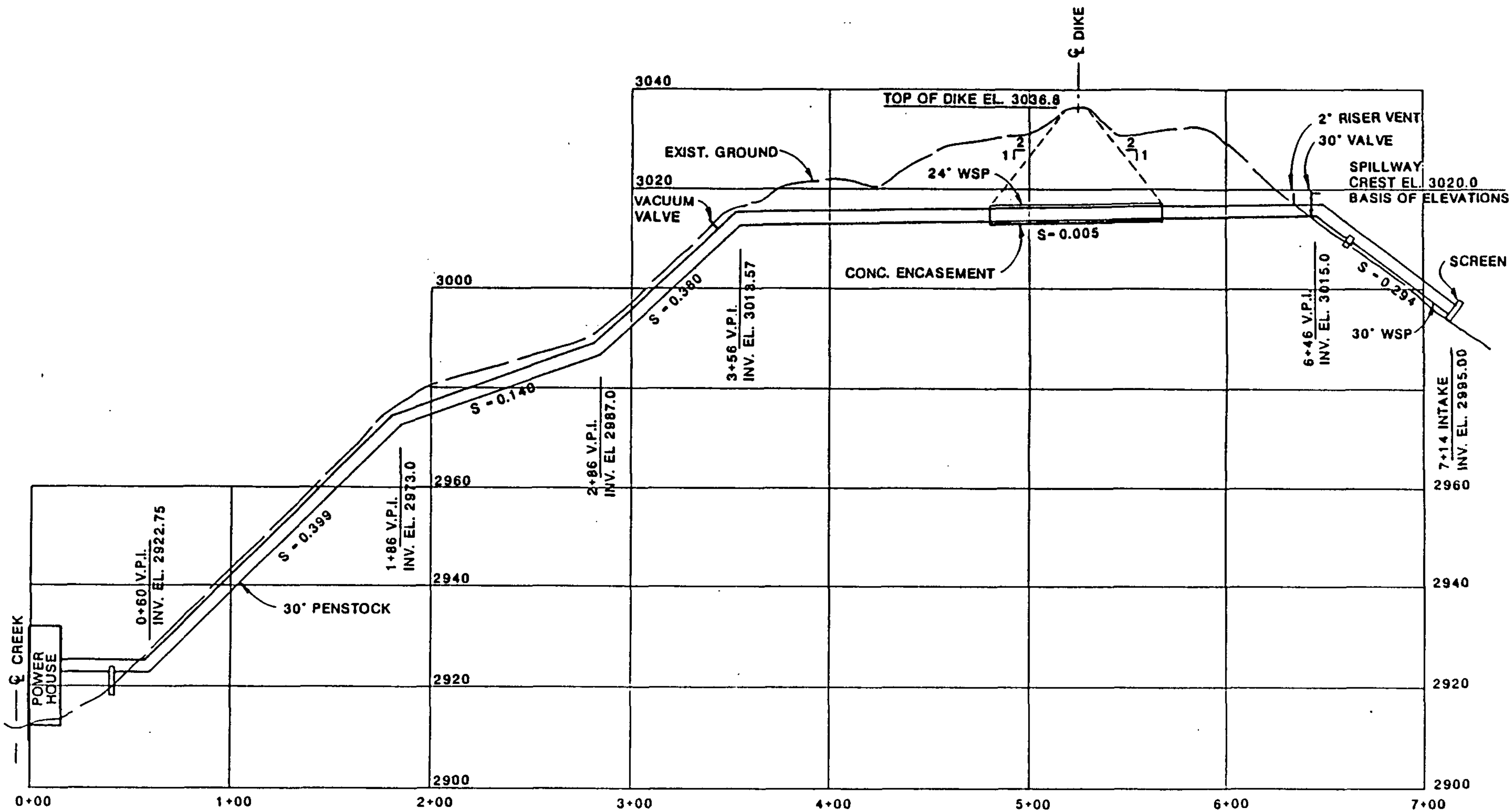


Figure 4-24 Penstock - Schaads Reservoir Hydroelectric Project

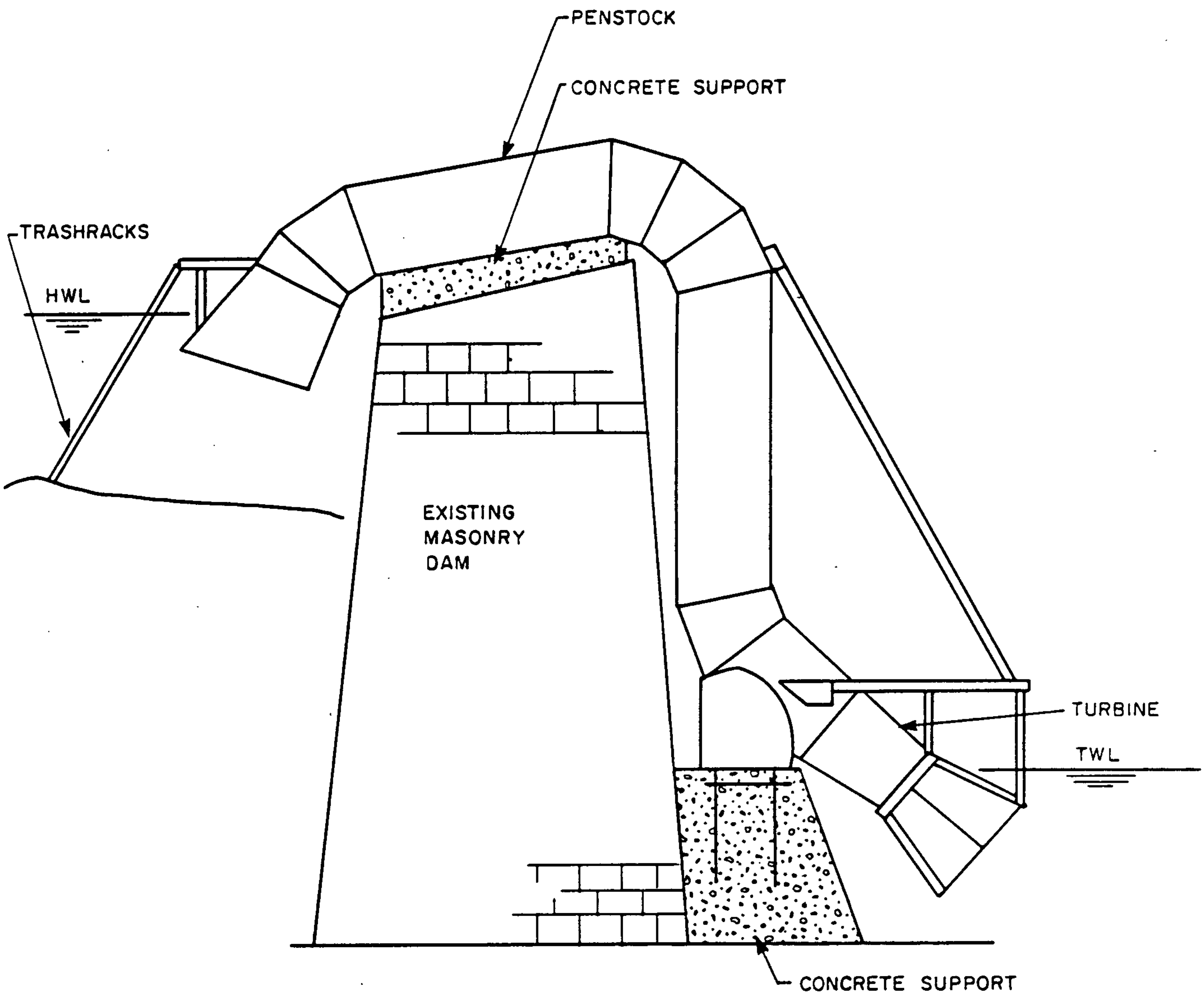


Figure 4-25 Penstock Support - Second Broad River Hydroelectric Project

- Superior Dam (Figure 4-26). The portion of the penstock upstream of the siphon crown is continuously supported on a gravel bed. To prevent flotation under conditions of net uplift, the penstock is tied with steel straps to concrete blocks set into the gravel bed. The penstock is supported and anchored at the siphon crown by a cast-in-place concrete thrust block. On the downstream side of the siphon crown, the penstock is buried. A second downstream thrust block is located where the penstock bends to horizontal.

- Tierckenkill Falls (Figures 4-27 and 4-28). The penstock is made from high density polyethelene pipe with fusion joints. The intake, which consists of a horizontal pipe with screened openings, is clamped to the upstream face of the existing dam. The penstock is also clamped to the top of the dam at the siphon crown. The 500 ft of penstock between the siphon crown and the powerhouse follows a curved path and rests on the rock surface. Surface preparation or special support was not required. The penstock has two concrete anchor blocks, one located near the siphon crown and the other about 300 ft from the powerhouse. The penstock is also anchored at the powerhouse. The penstock has flanged joints cast into the concrete anchor blocks, which in turn are keyed and dowelled to the rock surface. The curved path of the penstock allows for thermal expansion. Loose chain anchors are also provided at intermediate points to restrain lateral movement.

4.12 - Protection From Freezing

At most of the siphon penstock installations, the piping at the crown of the siphon for the priming and vacuum break system is exposed to the environment. This presents potential problems with freezing during low temperature conditions.

Air bubblers are provided at some intakes to prevent ice formation in the trashrack and intake area (Figure 4-29).

At many plants, there is no special provision to prevent penstock freezing. While there is flow in the penstock, freezing is minimal. Methods used to prevent penstock freezing when the unit is shut down included:

- Breaking the siphon and allowing the penstock to drain;

- Providing a small bypass line near the generating unit to allow some flow in the penstock even when the units are shut down;

- Depressing the water level inside the penstock with compressed air; warm air is then forced into the penstock and bubbles out the intake; and

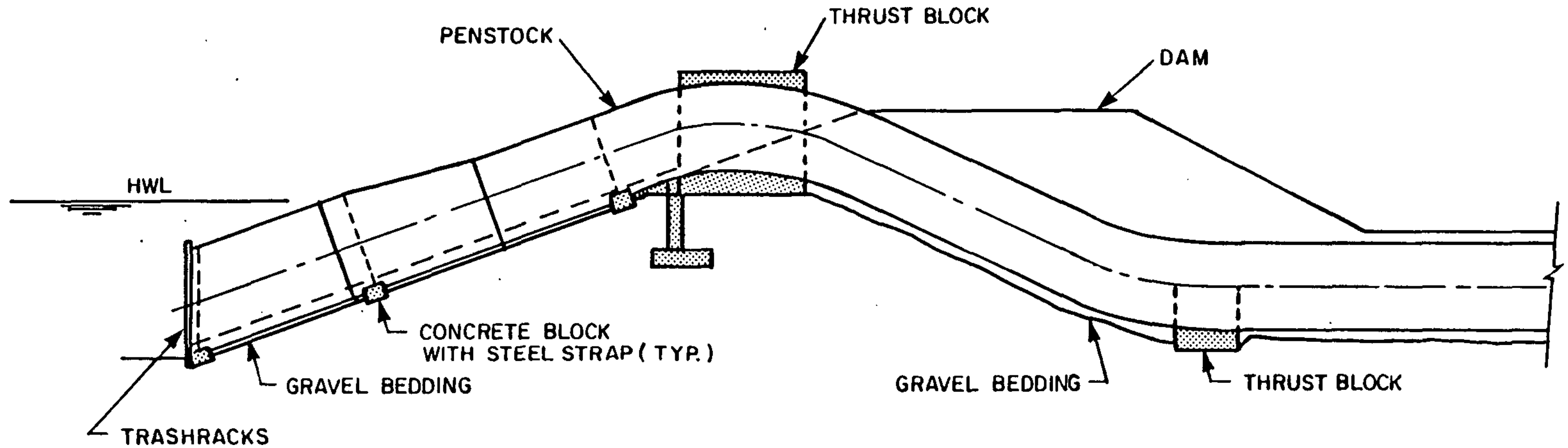


Figure 4-26 Penstock Support - Superior Dam Power Station

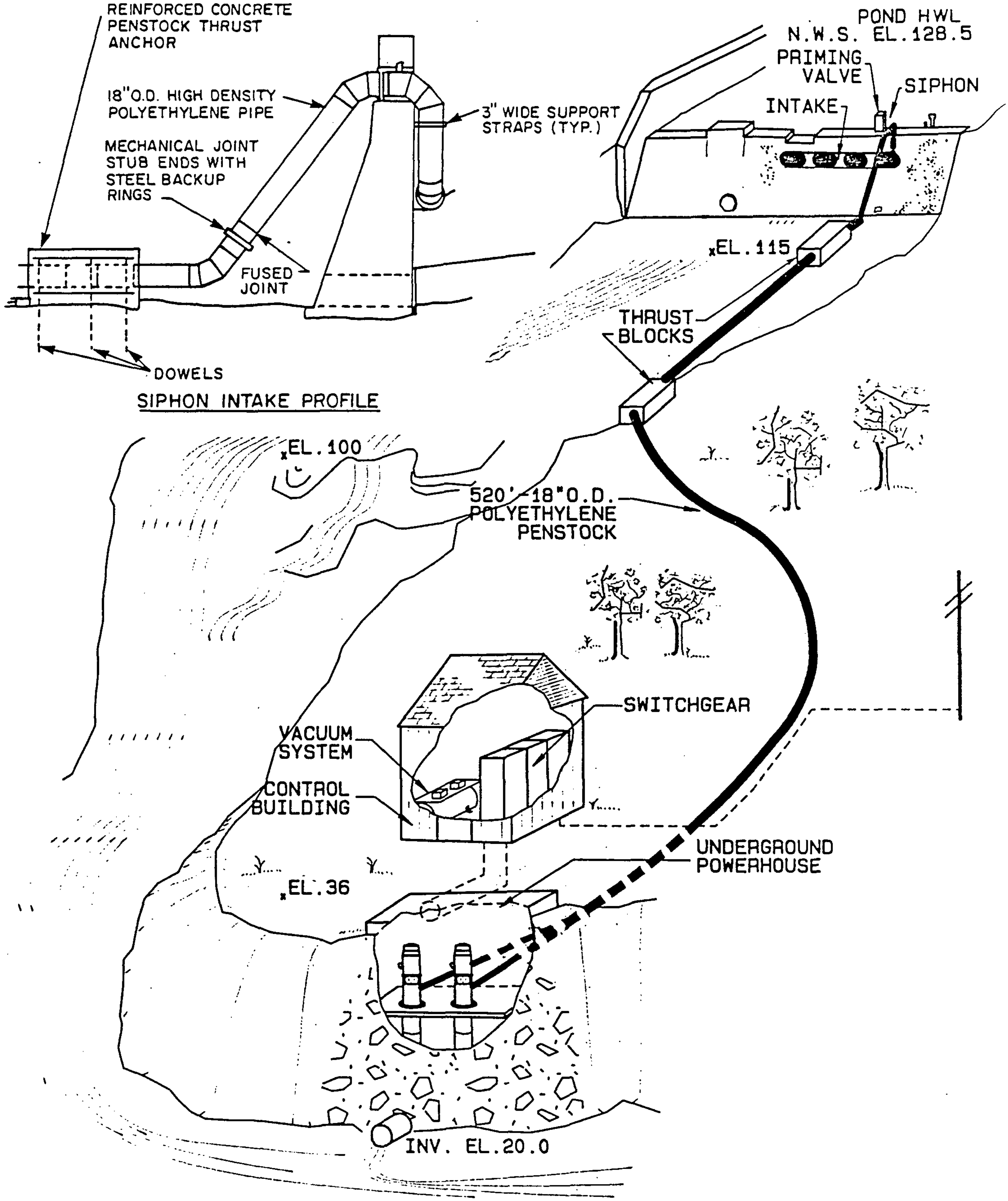


Figure 4-27 Penstock - Tierckenkill Falls Hydroelectric Project

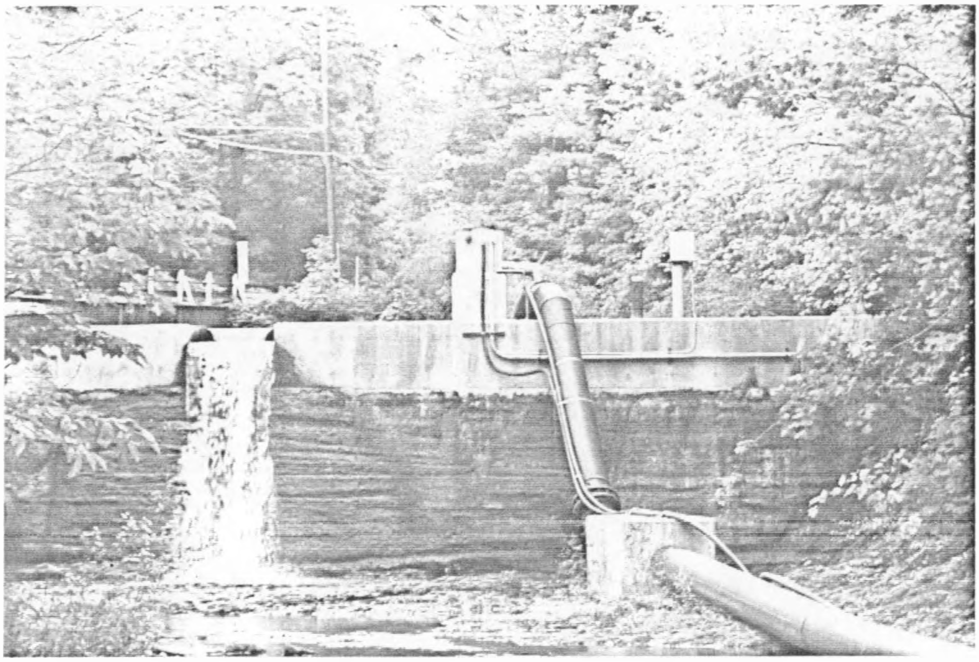


Figure 4-28 Penstock Support - Tierckenkill Falls Hydroelectric Project

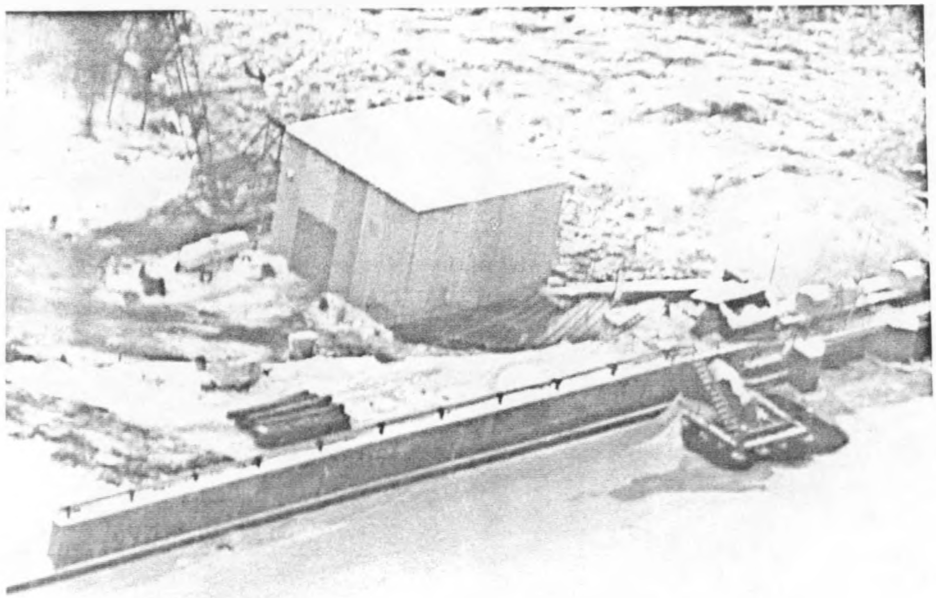


Figure 4-29 Bubbler System in Operation at Jim Falls Minimum Flow Unit Hydro Development Intake

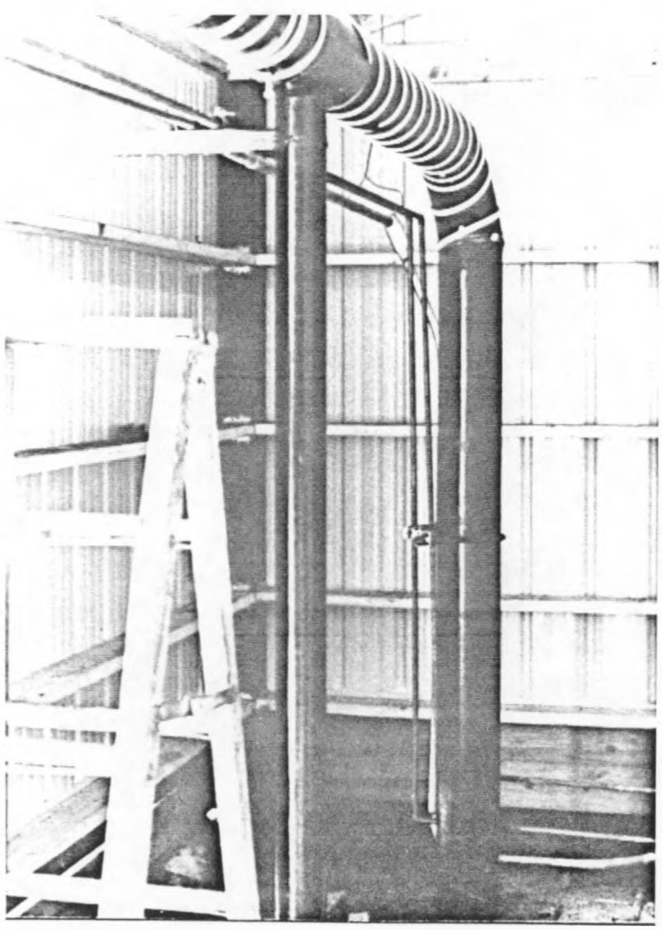


Figure 4-30 Heat Traced Priming Line - Lac Courte Oreilles Hydro Development

- Inserting a bubbler probe in the penstock when the unit is shut down and the siphon is broken, to prevent ice formation at the water surface in the penstock.

Freeze protection of vacuum systems is provided by:

- Enclosing the vacuum pumps and tanks in a heated enclosure;
- Heat tracing exposed vacuum lines, priming valves, vacuum break valves and control valves (Figure 4-30); and
- Providing a heated enclosure around priming valves, vacuum break valves, and control valves (Figure 4-31).

The freeze protection provided at the various plants is summarized on Table 4-7.

REFERENCES

1. Energy Mines and Resources Canada. "Evaluation of Siphon Performance", Phase II Draft Report, March 1987.

2. J.S. Gulliver, A.J. Rindels, K.C. Lindblom. "Designing Intakes to Avoid Free Surface Vortices". Water Power and Dam Construction, September 1986.

3. V. Helden. "ISO Views on Buckling" C188/72.

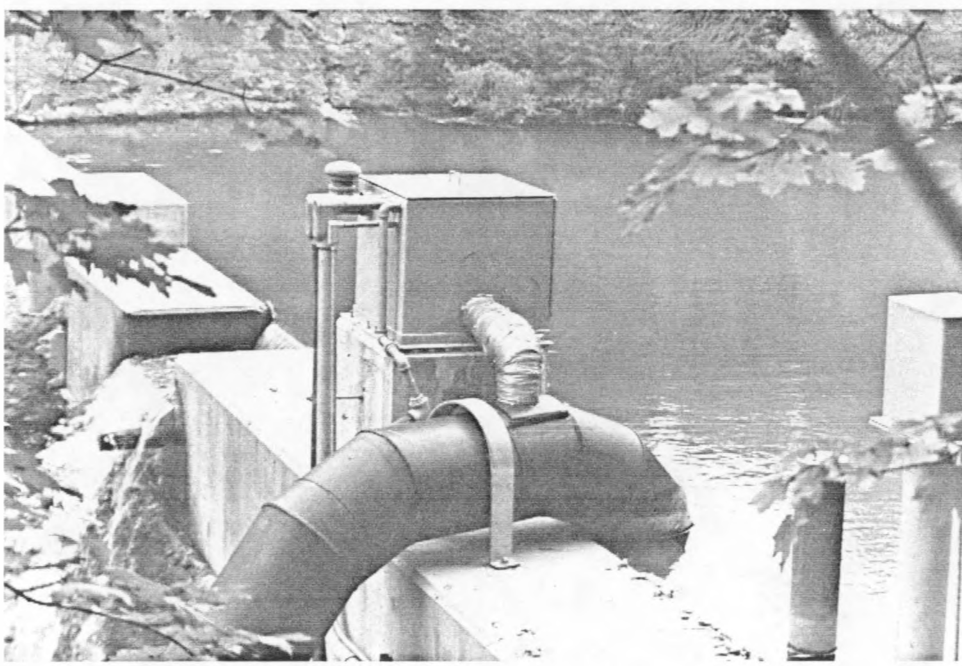


Figure 4-31 Heated Priming Enclosure - Tierckenkill Falls Hydroelectric Project

TABLE 4-7
FREEZE PROTECTION FOR SIPHON PENSTOCK SYSTEMS

Project	Minimum Temperature* °F	Heated Enclosure For Vacuum System	Other Freeze Protection
Columbia Mills	12	yes	-- control valves in heated enclosure
Jim Falls	-15	yes	-- air bubbler for trashracks -- bubbler probe in penstock when shutdown
Lac Courte Oreilles	-21	yes	-- heat traced priming line -- penstock is drained when plant shutdown more than 3 days
Ontelaunee	9	yes	-- water level depressed in penstock when shutdown -- heat tracing
Pine Grove Dam	9	yes	-- air bubbler for intake -- penstock is drained during an extended shutdown -- priming siphon line is heat traced
Pocono Lake	1	no	-- heat tracing of priming valve, vacuum breaker valve, air release valves -- 2-in. bypass line to allow small flow in penstock when units are not operating
Schaads Reservoir	28	NA**	-- penstock is buried
Second Broad River	10	no	-- heat tracing of vacuum breaker valve
Superior Dam	1	yes	-- priming and vacuum breaker valves in heated enclosure

*From ASHRAE Handbook - 1985 Fundamentals Volume
**Not applicable - there is no permanent vacuum system at Schaads Reservoir

TABLE 4-7
FREEZE PROTECTION FOR SIPHON PENSTOCK SYSTEMS
(Cont'd)

Project	Minimum Temperature °F	Heated Enclosure For Vacuum System	Other Freeze Protection
Tierckenkill Falls	-30	yes	-- heat tracing of vacuum piping -- bypass valve to allow small flow in penstock when units are not operating -- penstock is drained during an extended outage, and the water level in the intake depressed with compressed air

Section 5
CONSTRUCTION

5.1 - Arrangement and Type of Contracts

The owner of a siphon penstock site has a wide range of options when establishing contracts for construction of the facility. The project may be constructed on a turnkey basis with one contractor responsible for the complete design, manufacture, and construction of the facility. The turnkey contractor will, however, typically employ several subcontractors who specialize in various aspects of the project work. At the opposite end of the spectrum, the owner may retain the services of one or more engineering organizations for the design and management of the project and may award multiple contracts for the various procurement and construction aspects of the work. These may include equipment supply, civil construction, and mechanical and electrical installation. Other possible contractual arrangements would fall between the two extremes mentioned above.

Contracts may be awarded on the following basis:

- Lump sum (fixed price);
- Cost plus (or time and materials); and
- Not-to-exceed price.

The same contractual options are applicable to the construction of a conventional facility.

The arrangement and type of contract may depend on the following:

- Owner's preference and experience;
- The extent to which owner wishes to become involved with project design and construction;
- Schedule; and
- Method of project financing.

The contractual arrangements for various projects in this report are summarized below. There is no apparent relationship between the number of contracts used and the cost or physical size of the project.

- Columbia Mills (Capital Cost $630,000 (1984); Cost/kW $1,510). The project was designed and constructed as a fixed-price turnkey project with the turnkey contractor employing one major subcontractor, the supplier of the turbine and generator equipment. The contract had a liquidated damages provision for late completion of construction.

- Jim Falls (Capital Cost $2,477,000 (1985); Cost/kW $4,950). There were three major contracts for the project. The first was an engineering contract to prepare specifications, design the facility, and evaluate bids for other contracts. The second contract was for supply of turbine/generator and controls. The third contract was for construction of the plant and installation of equipment.

- Lac Courte Oreilles (Capital Cost $3,803,000 (1985); Cost/kW $1,100). There were two major contracts on the project: an engineering contract for civil design; and a turnkey type contract for construction of the facility including supply and installation of equipment. The turnkey contract was for a fixed price and included the performance guarantees for the plant.

- Ontelaunee (Capital Cost $960,000 (1987); Cost/kW $1,810). An engineer was retained for design of the facility. There were four other major contractors:

  - General and mechanical contractor for construction and equipment installation;

  - Equipment contractor for supply of turbines, generators and controls, and low voltage switchgear;

  - Electrical contractor to supply remaining electrical equipment; and

  - Mechanical contractor to supply vacuum pumps and heating and ventilating equipment.

- Pine Grove Dam (Capital Cost $2,632,000 (1984); Cost/kW $5,510). The project had four main contracts. An engineer was retained for overall facility design. A general contract was awarded for construction of the facility including installation of piping and mechanical equipment except for the turbine and generator equipment. An electrical contractor supplied and installed miscellaneous electrical services. The turbine manufacturer supplied and installed the turbine, generator, and associated equipment and controls.

- Pocono Lake (Capital Cost $560,000 (1985); Cost/kW $1,960). There were four contracts for the project:

  - An engineering services contract with a not-to-exceed price;

  - A fixed price, general contract for civil construction and equipment installation;

- A fixed price turbine and generator contract for supply of turbine and generator equipment; and

- A fixed price contract for supply and installation of electrical controls.

- Schaads Reservoir (Capital Cost $397,000 (1985); Cost/kW $1,650). The project was constructed with three contractors: an engineer for facility design; a civil construction contractor; and an equipment contractor for supply and installation of mechanical and electrical equipment and controls.

- Second Broad River (Capital Cost $272,000 (1985); Cost/kW $940). The project owner designed the facility and did much of the construction. Major contracts were awarded for fabrication and supply of the penstocks, and for supply of the turbine and generator equipment. There were also several small "verbal" contracts which were on a time and materials basis. These included crane service, access road construction, switchgear building construction, installation of high voltage overhead cables, and excavation of the turbine bay.

- Superior Dam (Capital Cost $1,866,000 (1985); Cost/kW $3,270). There were three main contracts for the project:

  - An engineer for overall design;

  - An equipment contractor for supply and installation of turbine and generator equipment; and

  - A general contractor for facility construction.

- Tierckenkill Falls (Capital Cost $285,000 (1986); Cost/kW $4,070). The engineering for the project was performed by the owner. There were two contracts for equipment supply only; one for the turbine and generator equipment, and the other for the vacuum system. There were four construction contracts for the project:

  - A general contractor for civil construction and turbine and generator installation;

  - An electrical contractor to supply and install electrical systems;

  - A contractor to supply and install controls; and

  - A contractor to supply and install the control building.

5.2 - Construction Techniques

General

The construction methods for a siphon penstock installation are, in many ways, similar to those for a conventional plant. Major components are shop fabricated and shipped to the project site. The components are either installed directly or pre-assembled into a larger structure prior to installation. Blasting is typically used for rock excavation, and most of the concrete is cast-in-place, the same as for a conventional penstock arrangement. However, unlike a conventional design, the use of a siphon penstock will, in many cases, allow the upstream cofferdam to be eliminated since the dam, which is the principal water retaining structure, is left basically intact. Without the upstream cofferdam, construction of the intake foundations and supporting structures presents a challenge since the area will not be dewatered. Unconventional and innovative approaches to siphon penstock construction may be required.

Various aspects of siphon penstock construction are discussed in the subsections below.

Shop Fabrication

The extent of shop fabrication of siphon penstock components is typically the same as for conventional penstocks. To minimize the number of field joints, components are usually shop fabricated as large as practical, the limitations being the capabilities of the shop and/or shipping constraints. The largest shipping dimension will depend on the site location and type of access. Typical maximum cross-sectional dimensions are 8 ft wide by 10 ft high, although with special provisions, larger components can be transported. If barge access is available directly to the site, very large assemblies can be transported.

For the physically large installations (e.g., Lac Courte Oreilles), the intakes and penstocks were shop fabricated as separate components. Steel penstocks for the different projects were shop fabricated in lengths from less than 20 ft to 114 ft, the largest being for the Lac Courte Oreilles plant.

At some of the small sites (e.g., Pocono Lake), the intake and siphon crown were shop fabricated in one section. All of the penstock bifurcations were shop fabricated.

Unlike turbines, generators, gates and other mechanical/electrical components, the siphon penstocks are typically not shop assembled.

Individual trashrack panels were usually shop fabricated. The extent of shop fabrication of the structural steel trashrack support structures depended on the structure size.

Vacuum pumps are generally shop assembled and operationally tested in the manufacturer's facility.

Site Fabrication

For most projects, the shop prefabricated siphon penstock components were installed directly in position as part of the installation sequence. However, on some projects, the components were site fabricated into larger assemblies prior to installation.

- At the Second Broad River project, each siphon penstock and intake were fabricated in two sections. The two sections of steel construction were welded together prior to being lowered in place; and

- The intake and penstock for the Tierckenkill Falls plant were made entirely of polyethylene pipe with fusion joints made at the site. Standard pipe lengths and fittings were shipped to the site. The siphon structure was site fabricated prior to being lowered into place.

Installation of Penstock and Intake Sections Upstream of the Dam

- Columbia Mills. The siphon penstock is supported at the top of the dam, on a new concrete cap which was poured over the existing masonry construction. The concrete cap was poured behind a steel and plywood cofferdam/form erected in shallow water. The cofferdam/form was anchored to the dam with epoxy set anchor bolts drilled into the dam along the inside and outside perimeter of the formwork. The area was dewatered by pumping, with leakage controlled by cinders.

  Prefabricated penstock components were assembled by bolting and field welding into two main penstock subassemblies; the upstream section consisted of the intake, transition, and siphon crown; and the downstream section which interconnects the siphon crown with the generating unit. The 15 ton intake and siphon crown section, which was about 30 ft long by 14 ft wide by 13 ft high, was lowered into place on the concrete cap on the dam with a 50 ton mobile crane.

  The trashrack structure, which is located on three sides of the intake, is supported by vertical steel columns which were driven into the overburden upstream of the dam. The downstream portion of the rack structure is supported on the concrete cap on the dam.

- Jim Falls. The siphon intake is cantilevered from and supported on the existing concrete wall. The trashrack structure rests on a tremie concrete pad which was poured underwater without a cofferdam.

  The siphon penstock was shipped to the site in three prefabricated sections. The sections were lowered into place on cradle supports and field welded together. The trashrack structure was lowered into place fully assembled.

- Lac Courte Oreilles. The penstock is installed along the slope of an earth dam. The area of the penstock and intake was first dredged and then bedding material placed in the dredged area.

  The crest of the dam was also excavated including minor demolition of the core. Steel piles were driven at each corner of the intake.

  The intake transition was prefabricated and shipped to the site as a single piece. At the site, the trashrack support structure was assembled into the intake with the overall assembly being about 27 ft by 9 ft by 9 ft (Figure 5-1). The intake and trashrack support structure was then lowered into position and tremie concrete poured between the reservoir floor and the base of the intake. Penstock support cradles were installed, and the sections of penstock placed in position and welded. The entire upstream length of penstock (114 ft) was installed in a single section, which weighed 66,000 lbs and required two mobile cranes for handling.

- Ontelaunee. The siphon intake and trashrack structure is supported from an existing gate structure concrete wall. The supports are anchored to the wall both above and below water level using the Hilti HVA Adhesive Anchoring System. The support arrangement was designed to minimize the number of anchors which had to be installed underwater. The divers were trained for installation of the fasteners by Hilti.

  The penstock was lowered into place in sections, using a mobile crane. The penstock had both field welded and field bolted joints.

- Pine Grove Dam. The siphon intake including concrete support structure was constructed in a conventional manner behind an earthfill cofferdam. The steel penstock was prefabricated in 40 ft lengths which were lowered into place using a mobile crane.

- Pocono Lake. The siphon penstock is cantilevered from an existing concrete dam crest. The trashrack structure is supported on the sloping upstream face of the dam.

  The siphon penstock was prefabricated in the shop in sections and lowered into place at site with a mobile crane. Field joints were bolted. The trashrack structure was fabricated in the shop and shipped to the site in pieces. The trashrack structure was pre-assembled at the site with field welded joints and then lowered into place with a crane. The structure weighed about 22,000 lbs.

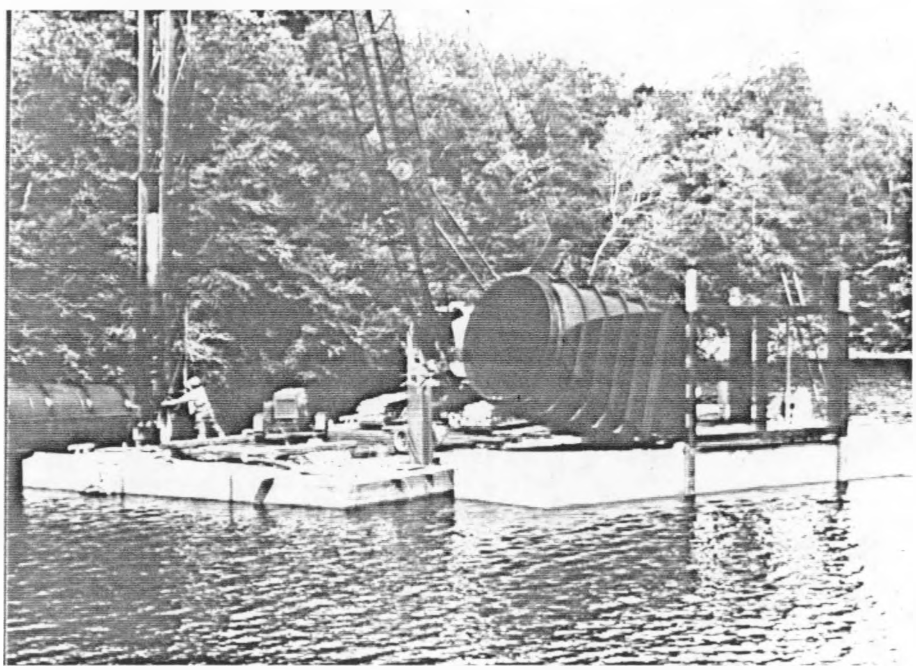


Figure 5-1 Preparing Intake Section for Installation at Lac Courte Oreilles

- Schaads Reservoir. The section of penstock upstream of the apex is about 60 ft long and is installed on the slope of the reservoir embankment. This section of penstock, which weighs about 3000 lbs, was floated at the intake end using a large inflated inner tube placed under the intake box. When the shore end of the penstock was properly located, the inner tube was punctured to allow the intake to sink into place.

- Second Broad River. The siphon penstock is supported by, and cantilevered from, a concrete cap poured over the existing dam. The penstocks were prefabricated in the shop and shipped to the site in two sections. The two sections were field welded together and the complete penstock lowered onto the dam with a 30 ton mobile crane (Figure 5-2). The concrete cap was poured after the three penstocks were in place (Figure 5-3).

- Superior Dam. The siphon penstock and intake structure is installed along the slope of an earthfill dam. A one-foot deep trench was dredged on the upstream slope of the dam for the penstock and intake. Prefabricated concrete anchor blocks, with embedded threaded rods for steel straps, were placed in a trench by a mobile crane. Bedding material was placed and compacted in the trench. The intake and adjacent penstock section were assembled on shore and lowered into the reservoir onto the anchor blocks and bedding. The total weight of this component was 130,000 lbs. Steel tie straps were installed and secured by a diver and bedding material poured around the base of the penstock. The brackets for the intake trashracks were also installed on shore prior to placing the assembly. The trashracks were lowered into place by crane and guided by a diver.

- Tierckenkill Falls. The 24-in diameter siphon intake is supported from the existing concrete dam. The upstream section, including the intake and siphon crown, was site fabricated in one section which weighed approximately 600 lbs, and placed in position by crane.

- Traicao. The siphon intake is integral with the powerhouse substructure and was constructed in the same manner as a conventional concrete powerhouse.

Installation of Penstock Downstream of Dam

The installation of penstock sections downstream of the dam is done generally in the same manner as for a conventional installation. The specific techniques depend on the penstock material and size, the penstock length, and the method of support. Methods of penstock support are discussed in Section 4.11.

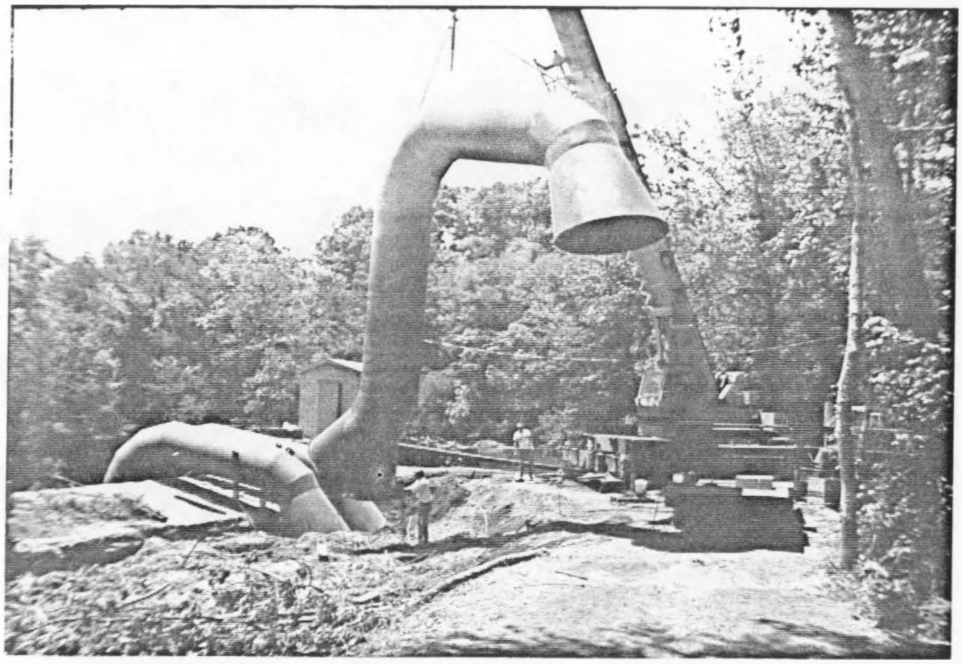


Figure 5-2 Installation of Siphon Penstocks at Second Broad River Hydroelectric Project

Figure 5-3 Placing of Concrete Support for Penstocks at Second Broad River Hydroelectric Project

Construction Equipment

The type of construction equipment depends on the size and configuration of the project. "Conventional" construction equipment is used for land based activities. This will typically include:

- Drilling equipment;
- Earth moving equipment;
- Concrete handling and placing equipment;
- Mobile crane;
- Miscellaneous trucks;
- Compressed air and welding equipment; and
- Miscellaneous equipment, tools, and devices.

For siphon penstock installation, there is an increased use of barges for installation of intake and penstock sections upstream of the siphon crown. This is primarily because of the absence of an upstream cofferdam. Also, there may be added underwater construction requiring increased use of divers and diving equipment.

5.3 - Construction Schedule

The duration of construction for various projects is summarized on Table 5-1. Excluding the larger Traicao project, the duration of construction varied from seven to twenty-one months. In general, the larger projects required a longer construction schedule. Delivery and installation of the turbine and generator equipment was the critical item which governed many of the schedules.

Some projects had delays in the start date. Reasons included:

- Financing;
- Obtaining agency approval; and
- Obtaining a power purchase agreement.

Causes of delay in construction included:

- Generating unit control problems;
- High flows/water levels;
- Construction slow down due to cold weather;
- Difficulties with interfacing of existing structures because of unknown dimensions; and
- Penstock fabrication and erection errors.

On the average, the construction schedule took 2.75 months longer than initially scheduled.

5.4 - Construction Costs

A comparison of construction costs for the various projects is given in Table 5-2. On a cost/kW basis, the facility costs vary from about $940 to $5,510 per kW. Intake and siphon

TABLE 5-1
CONSTRUCTION SCHEDULE DURATION
(Months)

Project	From Award of First Equipment Contract Scheduled	From Award of First Equipment Contract Actual	From Start of Site Construction Scheduled	From Start of Site Construction Actual
Columbia Mills	6	6	4	5
Jim Falls			6.5	8
Lac Courte Oreilles	15	15	21	21
Ontelaunee	13	18	9	14
Pine Grove Dam	12	15	12	15
Pocono Lake	13	16	7	10
Schaads Reservoir			8	11
Second Broad River	8	8	4	5
Superior Dam			6	16
Tierckenkill Falls			7	7

TABLE 5-2
PROJECT CAPITAL COSTS

Project	Completion Date	Plant Capacity (kW)	Plant Flow (cfs)	Intake and Penstock Estimated ($1000)	Intake and Penstock Actual ($1000)	Total Project Estimated ($1000)	Total Project Actual ($1000)	Total Project Actual ($/kW)
Columbia Mills	1985	417	334	--	225	515	630	1510
Jim Falls	1986	500	240	--	--	--	2477	4950
Lac Courte Oreilles	1986	3450	1500	--	--	--	3803	1100
Ontelaunee	1987	530	210	--	--	683	960	1810
Pine Grove Dam	1985	478	175	--	--	2488	2632	5510
Pocono Lake	1986	285	180	--	--	--	560	1960
Schaads Reservoir	1986	240	42	--	131	385	397	1650
Second Broad River	1985	288	246	--	73	--	272	940
Superior Dam	1986	570	567	--	--	1515	1866	3270
Tierckenkill Falls	1986	70	12	79	85	260	285	4070

- Costs are at time of construction and have not been adjusted to a common year dollar.
- Information is not available where none is shown.

penstock costs typically represent 25 to 50 percent of the total project costs. Cost overruns associated with siphon penstocks have been related to:

- Underestimate of the amount of steel required for the siphon/intake structure (at Columbia Mills); and

- Difficulty interfacing new and existing structures because of inaccurate dimensions of the existing structures (at Ontelaunee).

On the average, the actual construction cost exceeded the estimated cost at the start of construction by 17 percent.

Section 6
OPERATION

6.1 - General

The siphon penstock installations may be divided into two categories:

- Those which have a method other than breaking the siphon, for positively stopping flow at the unit. This is done with an intake valve, turbine wicket gates, or both; and
- Those which have no shutoff device at the unit and flow may be stopped only by breaking the siphon.

For plants which fall under the first category (with a shutoff device), starting a unit is accomplished in two separate steps:

- With the shutoff device closed, the penstock is filled and the siphon is primed; and
- The intake valve or turbine wicket gates are opened to start flow of water through the siphon and to start the unit.

During a normal unit shutdown, only the turbine wicket gates or the valve is closed, and the siphon is left primed. The siphon is broken only in an emergency or to dewater the penstock.

For plants with no shutoff device, siphon priming is done as part of each startup operation, and the siphon is broken on each shutdown.

6.2 - Startup Procedures (at Plants with a Shutoff Device)

Siphon priming is normally initiated by an operator at the station. This may simply involve starting the priming operation through a pushbutton or require manually opening or closing specific valves. Manual valve operation is necessary when there is a common priming system for more than one penstock. Where the vacuum system incorporates two vacuum pumps (in lead-lag or main-standby modes), both pumps are used for siphon priming purposes.

The siphon priming operation is normally stopped automatically by pressure and/or level switches associated with vacuum system control.

Some plants have a means of filling the downstream leg of the penstock before starting the vacuum pumps (using pumps or a priming siphon). At these installations, there is manual interface between the initial filling operation and the start of the vacuum pumps.

Because the siphon is normally left primed, there is usually no significant benefit to having an automatic, unattended priming operation.

While the specific startup procedures vary from plant to plant, a typical start-up procedure is as follows:

- Check the following:
  - vacuum breaker valve is closed
  - turbine wicket gates/intake valve is closed
  - power is available to vacuum pumps

- Switch vacuum system to "run". Vacuum pumps start and air is evacuated from the penstock.

- When water level rises to the top of the siphon crown, the float operated valve in the air-vacuum line closes.

- The vacuum pumps continue to operate until shutoff by a pressure switch in the vacuum control tank.

- A signal is sent to the station programmable controller to start the unit.

Once the siphon priming is completed, the unit is started under remote automatic, local automatic, or local manual control.

6.3 - Shutdown Procedures (at Plants with a Shutoff Device)

As mentioned above, for normal shutdown the siphon remains primed. This facilitates unattended automatic restart of the unit. Unit shutdown consists of closing the turbine wicket gates or intake valve, and opening the generator breaker through an automatic or manual shutdown sequence in the same manner as for a conventional installation.

When it is necessary to dewater the penstock, the siphon is broken by manually initiating the opening of the vacuum breaker valve.

In an emergency or unusual situation, the siphon may be broken to stop flow of water through the turbine by protective devices associated with the generating unit. The protective devices will signal the vacuum breaker valve to open. The following conditions will typically initiate breaking the siphon:

- Unit overspeed;
- Loss of hydraulic pressure in the governor, gate positioner, or intake valve operator; and
- Unit creep.

6.4 - Startup Procedures (at Plants without a Shutoff Device)

The siphon priming operation is integral with unit startup and can be done through one or more of the following:

- Remote initiation and automatic sequencing;
- Local manual initiation and automatic sequencing; and
- Local manual sequencing.

A programmable controller is used for automatic startup at all plants except for Traicao. Relay type controls are used for the Traicao station which went into operation in 1944.

A typical start sequence is as follows:

- Unit start is initiated.
- Vacuum breaker valve closes.
- Vacuum pump(s) start.
- When water starts to flow over the apex of the penstock, the unit starts to rotate.
- When the unit reaches synchronous speed the generator breaker is closed.
- When the siphon is completely primed, the vacuum system is shutoff by pressure switches and/or level switches.

Except for the Traicao plant, all of the generating units at plants with no shutdown devices have induction generators. These machines are relatively easy to bring on-line since the breaker may be closed any time near synchronous speed (plus or minus about 2 percent).

At the Traicao station, the adjustable runner blades are positioned at a negative angle (-4 degrees) during priming, so that the unit will not rotate. When the air is almost completely evacuated from the siphon, the blades are opened to bring the unit to synchronous speed. When the unit is synchronized to the power system the generator breaker is closed.

6.5 - Shutdown Procedures (at Plants without a Shutoff Device)

Breaking the siphon prime is part of both normal and emergency shutdown of the unit. A normal shutdown typically involves the following sequence:

- If unit has adjustable blades, reduce load on unit by decreasing blade angle.

- Simultaneously trip generator breaker and open vacuum breaker valve. Alternatively, to minimize unit overspeed, the vacuum breaker valve may be set to open first, followed by tripping of the generator breaker a few seconds later.

Shutdown under emergency conditions is similar to that described in Section 6.3.

6.6 - Removal of Accumulated Air During Operation

Entrained air and air which comes out of solution will tend to accumulate at the crown of the siphon during plant operation. This is removed by automatic operation of the vacuum system through the pressure and/or level controls. It has been found that the flow of water through the penstock removes accumulated air quite well, and at the Columbia Mills and Second Broad River plants automatic air removal was found to be unnecessary.

6.7 - Operational Experience

Experience with operation of siphon penstocks has generally been very good. Most problems have been relatively minor in nature, and these are reviewed in Section 9.

Section 7
MAINTENANCE

7.1 - Maintenance Activities

Siphon penstock systems inherently have low maintenance costs. Inspection and cleaning of the trashracks may be the major maintenance activity, depending on the amount of debris in the river. Trashrack cleaning requirements are essentially the same as for a conventional penstock arrangement. Another activity is preventive maintenance for the siphon priming/vacuum system. The maintenance program for this system is usually based on equipment manufacturer's recommendations as well as operating experience with the facility.

A typical maintenance program for a siphon penstock facility has included:

Item	Frequency
– Inspect trashracks for debris	Site specific
– Clean trashracks	As required
– Inspect penstock interior (including sensors and control devices in penstock interior)	One to five years
– Recoat penstock	As required
– Clean motors, pumps, and miscellaneous equipment	Monthly to yearly
– Lubricate bearings	Monthly to yearly
– Vacuum pump maintenance	As recommended by manufacturer
– Check vacuum system valve operation	Monthly

Unplanned maintenance items at the various plants have included:

- Electrical sensor failure; and
- Expansion joint leakage.

7.2 - Spare Parts

The majority of spare parts at the various projects are for the turbines, generators, and associated equipment. At most plants, there are no spare parts for the siphon penstock system. Where spare parts are provided, they are related to the vacuum system and typically include gaskets, vacuum pump shaft seals, valve components, and pipe fittings.

The most extensive inventory of spare parts for the siphon priming system is at the Pine Grove Dam project, and includes:

- Vacuum pumps
  - shaft seal assembly;
  - slinger;
  - lobe pins;
  - rotor nut, washer, key; and
  - gaskets.

- Ball valves
  - body seat;
  - stem seals; and
  - compression ring.

- Electrical
  - complete solenoid valve;
  - complete vacuum switch;
  - level probe relay package; and
  - one relay, switch and control of each type.

7.3 - Operating and Maintenance Costs

The approximate operating and maintenance costs for the siphon penstock plants presented in this report are summarized on Table 7-1. Present day costs, excluding rent, insurance and interconnection fee, range from $20 per kW of installed capacity to $77 per kW. The costs associated with operation and maintenance of the siphon penstock are relatively low, and would perhaps account for 5 to 10 percent of these total costs. This amounts to about $5 per kW of installed capacity for siphon penstock operating and maintenance costs.

TABLE 7-1
OPERATION AND MAINTENANCE COSTS FOR SIPHON PENSTOCK PLANTS

FERC ACCOUNT NO.	DESCRIPTION	PRESENT DAY COST ($1,000) Columbia Mills	Lac Courte Oreilles	Ontelaunee	Pocono Lake	Second Broad River	Tierckenkill Falls
	Operation Expenses						
535	Operation supervision and engineering	6	--	--	0.5	--	3
536	Water for power	0	--	--	0	--	0
537	Hydraulic expenses	2	--	--	0	--	0
538	Electric expenses	1	--	--	0	6.1	0.5
539	Miscellaneous hydraulic expenses	1	--	--	0	--	0
540	Rents	22	--	--	0		10
	Subtotal Operation Expenses	32	--	--	0.5	6.1	13.5
	Maintenance Expenses						
541	Maintenance supervision and engineering	8	--	--	6	--	0.4
542	Maintenance of structures	2	--	--	0.5	--	0.3
543	Maintenance of reservoirs, dams and and waterways	1	--	--	0.5	1	0.5
544	Maintenance of electric plant	3	--	--	10	5	0.4
545	Maintenance of miscellaneous hydraulic plants	8	--	--	0	3	0.6
	Subtotal Maintenance Expenses	22	--	--	17	9	2.2
	TOTAL O&M COST ($1000)	54	94	31	17.5	15.1	15.7
	TOTAL O&M COST (minus rent, insurance and interconnection fee) ($1000)	32	68		17.5	9	5.2
	PLANT CAPACITY (kW)	417	3450	530	285	288	70
	O&M COST/kW (minus rent, insurance and interconnection fee) ($/kW)	77	20		61	31	74

- Information is not available where none is shown.
- Costs have been adjusted to 1989 dollars using an annual escalation rate of 4 percent.

Section 8
COMPARATIVE COSTS - SIPHON VERSUS CONVENTIONAL DESIGN

8.1 - General

Like most other components of a hydroelectric project, the intake and penstock design is site-specific and must be evaluated for each individual project. When comparing the costs of a siphon penstock versus a conventional pressurized penstock design, the following should be evaluated:

- Capital costs;
- Schedule differences;
- Hydraulic costs (i.e., head losses); and
- Operation and maintenance costs.

8.2 - Capital Costs

The following are examples of capital cost comparisons between siphon penstock installations and projects with conventional penstock designs:

- At the Columbia Mills project, the overall project cost was estimated as 85 percent of that for a conventional design. In estimating the cost of a conventional design, specific consideration had to be given to the safety of the existing loose laid masonry dam. The total project cost (in 1984 $) was $630,000.

- The capital cost comparison for siphon and conventional penstock installations for the Jim Falls project is presented in Table 8-1. The siphon penstock had a capital cost savings of $156,000 (in 1985 $) over the cost of a conventional design.

- At the Lac Courte Oreilles project, it was estimated that a conventional intake and penstock would have additional costs associated with a cellular cofferdam and cutoff wall, increased excavation, and the need for intake control gates. The increase in costs was estimated to be as follows:

– Cofferdam and cutoff wall	$465,000
– Increased excavation	18,900
– Intake gate equipment	139,000
TOTAL (1982 dollars)	$622,900

This savings represents about 20 percent of the total project cost.

TABLE 8-1
JIM FALLS MINIMUM FLOW UNIT HYDRO DEVELOPMENT
COMPARATIVE COSTS FOR CONVENTIONAL AND SIPHON PENSTOCK INSTALLATION

Items	Siphon	Conventional
CAPITAL COSTS		
Powerhouse building	Same	Same
Turbine, generator, controls	Same	Same
Trashracks	Same	Same
Upstream cofferdam	--	$132,000
Downstream cofferdam	Same	Same
Intake structure	--	$ 27,600
Penstock	$ 58,500	$ 43,800
Vacuum system	$ 14,400	--
Upstream stoplog gate	--	$ 12,000
Subtotal (1984)	$ 72,900	$215,400
Escalation at 7.5%	5,500	16,200
AFDC	1,300	3,700
Comparative capital cost (1985)	$ 79,700	$235,300
Differential capital cost (1985)	($155,600)	Base

- On a capital cost per kWh generation basis, a siphon penstock system was estimated to be 12 percent less costly than a conventional intake penstock arrangement at the Ontelaunee project.

- The incremental cost of a conventional penstock over a siphon penstock for the Pocono Lake project was $65,000 in 1984. This is about 12 percent of the total capital cost.

- The penstock options for the Schaads Reservoir project included:

  - Utilization of the existing 24-inch outlet works pipe; and
  - Construction of a new siphon penstock.

  The cost of the siphon-type penstock was marginally higher than the repair costs associated with utilizing the existing outlet works pipe ($77,500 versus $75,000 in 1985). However, a siphon penstock system was selected because of a greater possibility of cost overruns due to the unknown conditions associated with repair of the existing pipe.

- A conventional penstock could not be installed at the Second Broad River plant because of concern for dam safety should penstock openings be cut in the dam. Nevertheless, the theoretical cost increment for a conventional design was estimated to be as follows:

– Excavation through dam	$13,000
– Upstream cofferdam	8,600
– Butterfly valves at turbines including emergency power supply	18,000
– Wood stoplogs for penstock dewatering	7,000
– Additional concrete	12,500
– Deletion of vacuum system	(5,700)
TOTAL INCREMENTAL COSTS (1985 dollars)	$53,400

  This savings is about 19 percent of the total project cost.

- In the feasibility studies for the Superior Dam project, three project configurations were considered:

	Project Capital Cost (1981)
– Three straight flow turbines with siphon penstocks placed over the dam	$1,087,000
– An integral intake and powerhouse with one Kaplan turbine	2,416,000
– An integral intake and powerhouse with two open flume turbines	2,727,000

The siphon penstock option was the most economic and was selected for further design. Eventually, the three-unit concept was replaced with a single-unit design utilizing a siphon penstock.

- At Tierckenkill Falls, a siphon penstock was installed for research/evaluation purposes, although a conventional intake/penstock arrangement was considered slightly more economic.

The foregoing comparisons should not be construed to indicate that siphon penstocks are usually the best choice for a small hydroelectric project. Since the comparisons are for projects where siphon penstocks were actually constructed, it is not surprising that the siphon penstock option was usually most economic. As mentioned previously, a site-specific evaluation of intake and penstock arrangements must be made at each project.

8.3 - Schedule Differences

The use of a siphon penstock rather than a conventional intake/penstock arrangement may offer some improvement in the overall project construction schedule, in that the upstream cofferdam may be eliminated. There may also be a benefit because there will be no required rework of an existing dam.

Of the eleven projects covered in this report, only three required an upstream cofferdam.

8.4 - Hydraulic Costs

A siphon penstock which must go "up and over" the dam will usually have increased head loss when compared to a conventional design primarily because of the increased number of bends in the conduit (at the Lac Courte Oreilles project, turning vanes were installed in the apex of the penstock to minimize bend losses). The added head loss will translate into reduced generation and therefore lost revenue. The difference in head losses is site-specific and must be evaluated on a plant-by-plant basis. As an example, the intake and penstock head losses for the two design options for the Jim Falls project (similar to Figure 2-1) are as follows:

Type of Penstock	Head Loss at Full Flow (ft)	Head Loss/ Gross Head
Conventional	0.95	0.031
Siphon	1.10	0.036

8.5 - Operation and Maintenance Costs

The vacuum system associated with a siphon penstock installation represents an additional operation and maintenance item for the facility. At the plants in this report, operation and maintenance costs associated with the vacuum system and other features of the siphon penstock have been relatively small; present day annual costs may be about $5 per kW of installed capacity. A conventional penstock installation will have maintenance costs associated with the intake gate and hoist; however, these costs are expected to be almost negligible.

In evaluating the siphon penstock concept for the Jim Falls project, an annual levelized cost penalty of $2600 (in 1985 dollars) was assessed to the siphon penstock scheme for operation and maintenance of the vacuum system.

Section 9
SIPHON PENSTOCK PROBLEMS AND SOLUTIONS

The siphon penstock installations on which this report has been based have operated quite satisfactorily. Nevertheless, like most projects, there have been some operating problems, most being relatively minor in nature.

Various problems associated with the design and operation of siphon penstocks, including recommendations for future design, are discussed below.

9.1 - Penstock Location

The intake and penstock section upstream of the dam are usually exposed and vulnerable to damage caused by debris and ice. At the Columbia Mills project, the trashrack structure was destroyed by debris during flood conditions. It is recommended that the location of the intake and siphon penstock be carefully reviewed relative to the possibility of flood and ice damage. An intake and penstock location remote from the center of the flood flow is preferable.

9.2 - Trashracks

At the Superior Dam project, there is no direct access to the trashracks for cleaning. The trash load in the river is higher than initially anticipated and the reverse flow associated with breaking of the siphon is not always satisfactory for rack cleaning. Extensive trash build-up has caused vortex formation.

For projects where trash is expected, a means of access for cleaning the racks should be provided. If it is anticipated that the unit may be required to operate for significant periods with considerable debris on the racks, a conservative submergence criteria should be used to minimize the effect of vortices.

Based on the experience at the Second Broad River project, it is recommended that trashracks be made of steel bar rather than steel grating (Figure 9-1). While the steel grating is less costly and easier to install, it is more difficult to clean.

For very small intakes, wire screening may be suitable; however, a very stiff screening material is recommended. At Tierckenkill Falls, 20 gauge, one-half inch galvanized wire mesh was used on the 12 inch by 35 inch openings (Figure 9-2). Operational experience indicated that this size screen had insufficient stiffness.

9.3 - Vacuum System Controls

A problem which has been common to many of the siphon penstock installations (Columbia Mills, Jim Falls, Lac Courte Oreilles, Pine Grove, Second Broad River) is the tendency of

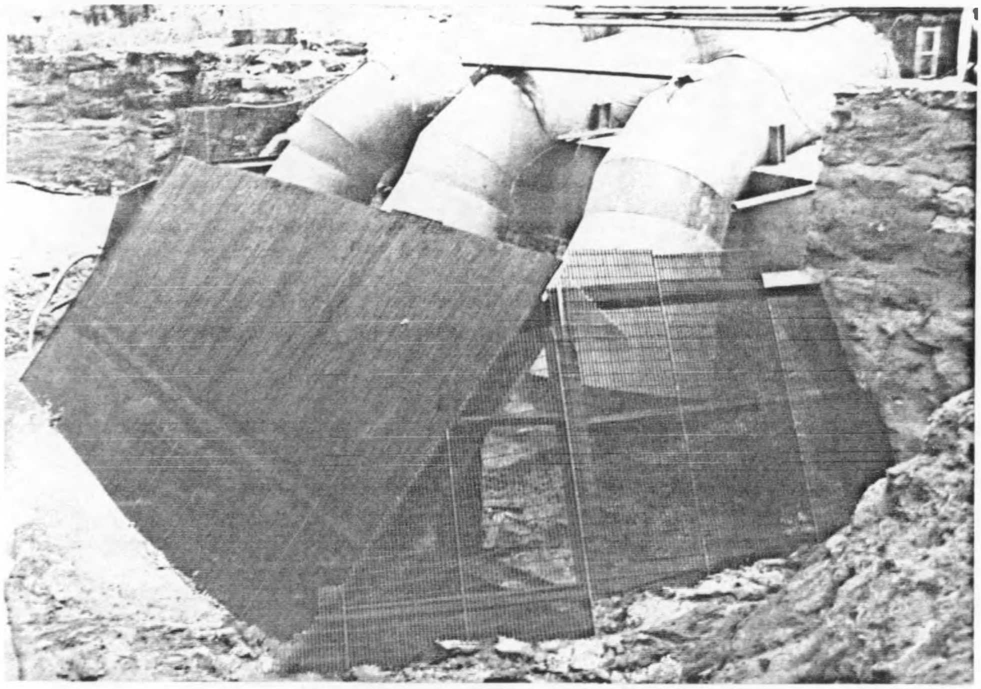


Figure 9-1 Trashracks - Second Broad River Hydroelectric Project

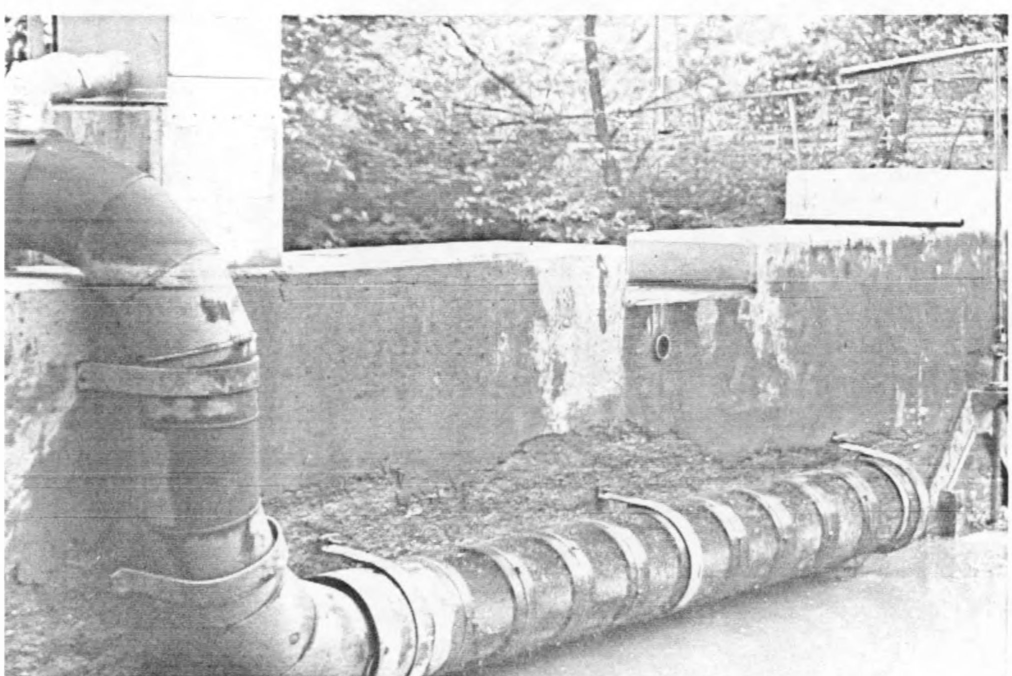


Figure 9-2 Trashracks - Tierckenkill Falls Hydroelectric Project

the system to "overshoot" when the siphon becomes primed resulting in water being drawn into the vacuum system and vacuum pumps. Measures which have been proposed or adopted to prevent this problem include:

- Provision of a relatively high (about 4 ft) siphon control column at the crown of the siphon. The control column should be relatively large in diameter with an orifice at the bottom to prevent rapid water flow;
- Installation of duplicate level sensing devices;
- Setting the vacuum system shutoff level to well inside the penstock and allowing the flow of water through the penstock to remove the remaining air at the crown of the siphon;
- Designing the system to allow water to enter the vacuum tank and having provision to automatically drain the tank;
- Design the vacuum system with a water separator before the vacuum tank and have a second vacuum tank which can be filled with water and has provision for automatic draining when full; and
- Provision of a float operated air vacuum valve at the siphon crown. The rising water level raises the float to close off the vacuum line. Conversely air accumulation at the siphon crown will allow the float to drop and the air will be drawn into the vacuum tanks.

Where level switches are used to control the vacuum system, it is beneficial to have provision for field adjustment of the switch settings.

The pressure switches which control the vacuum pumps on the Superior Dam project are located with the vacuum tank in the powerhouse, about 100 ft from the crown of the siphon. Pressure switches located directly below and above the air vacuum valve at the siphon crown would give a better indication of the vacuum pressure at the siphon.

9.4 - Vacuum Breaker Line

If the vacuum breaker line is too small, the air flow will be insufficient to break the siphon, and the air will be drawn through the unit. This problem was noted at the Pocono Lake and Jim Falls plants which have 2-inch vacuum breaker valves (a 6-inch valve was subsequently installed at Jim Falls). A similar effect was observed with the 3/4 inch air inlet line at the Second Broad River plant. The required size of the air valve is a function of penstock size, water velocity and the magnitude of negative pressure at the siphon crown. From data on projects covered by this report, it appears that the diameter of the vacuum breaker should be at least 4.2 percent of the penstock diameter.

9.5 - Problems with Freezing

Freezing problems were reported at two projects. At Pine Grove Dam, freezing occurred in the 8 inch siphon priming line at the connection to the penstock. This problem was mitigated by applying heat tape and insulation to the line. Depending on the topography, burying of the priming line may also be a suitable method to prevent freezing.

At the Second Broad River plant, in spite of the normally temperate weather, one of the vacuum breaker valves froze on one occasion. The problem was solved by heat tracing the valves and associated piping.

9.6 - Vibration

The apex of each of the siphon penstocks on the Lac Courte Oreilles plant has turning vanes to minimize head losses at the siphon crown. Vortex formation at the intake caused air to be drawn into the penstock, and this resulted in vibration of the turning vanes. Installation of an anti-vortex backstop, as discussed in Section 4.8, eliminated both the vortex formation and the vibration.

Section 10
CONCLUSIONS

The review of design, construction, operation, and maintenance considerations for siphon penstocks, described in the previous sections of this report, has demonstrated that siphon penstocks are viable options for hydroelectric plants. Siphon penstocks are particularly attractive at installations with small units constructed at an existing dam. Cost savings may be significant; nevertheless, the actual economic and technical benefit of using a siphon penstock rather than a conventional design must be evaluated on a site-specific basis.

Present day siphon penstocks are generally custom designed to suit the physical constraints of the project site. The siphon penstocks may have either a horizontal or a vertical intake. Standard off-the-shelf components are used for items such as the vacuum system, and for very small installations standard pipe may be used for the penstock.

Priming of the siphon is usually accomplished with a vacuum system, although a supplementary system (such as pumps) may be used to fill the downstream leg of very long penstocks. The vacuum system consists of one or more vacuum pumps with the size dependent on the penstock volume. Priming systems may be either automatic or manually controlled. The vacuum system can be operated under static conditions when there is no flow through the turbine; and also can be used at installations with no shutoff devices, where turbine flow will start as soon as water flows over the siphon invert.

The design of a siphon penstock is similar to that for a conventional penstock arrangement although appropriate allowance must be made for negative pressure at the siphon crown. Penstock materials have included steel, concrete, and high density polyethylene. Aboveground and buried penstocks have been used and penstock support schemes are comparable to conventional installations.

Site construction may be somewhat different for a siphon penstock because the upstream cofferdam is usually eliminated. This generally results in some cost reduction; however, there may be an increase in underwater construction and a barge may be required for penstock installation. Divers may also be required.

Operation and maintenance costs associated with siphon penstocks are relatively low, and are in the order of $5 per kW installed capacity per year.

Design and operating problems have been relatively minor and generally not unlike those for many conventional installations. The most common problem unique to siphon penstocks is in the controls which stop the vacuum system once siphon priming is complete.

In summary, the principal conclusions of the study are that small hydro plants with siphon penstocks:

- Are a proven technology;
- Operate effectively and efficiently with few operational problems;
- Are a viable economic alternative to a more conventional installation; and
- Are the preferred solution at sites with an existing dam where there is a need to minimize the interference with the existing structures.

APPENDIX A

COLUMBIA MILLS HYDROELECTRIC PLANT

COLUMBIA MILLS HYDROELECTRIC PLANT

The Columbia Mills Hydroelectric Plant is located on the left bank of the Maury River at an existing dam in Buena Vista, Virginia. The power plant, which has a single 417 kW, 17.2 ft head unit, was constructed in 1985.

The plant has an intake, short section of penstock and bulb type generating unit, all of which are exposed and of steel fabrication. Except for foundations for the intake, penstock and generating unit, the powerhouse has no concrete substructure.

The intake is rectangular in shape and has a horizontal opening. Sloped trashracks surround the intake on three sides. The trashracks are manually cleaned.

The rectangular penstock is of fabricated steel construction, 13.8 ft wide by 9.8 ft high. The intake and penstock are made from prefabricated sections with field welded and field bolted joints. The downstream portion of the penstock incorporates a transition to the turbine waterpassages. The penstock is supported at the dam and at turbine foundations. The overall length of the penstock is 83.1 ft, and the distance from the intake to the crown of the siphon is 23.8 ft.

The siphon priming system consists of a positive displacement vacuum pump and associated piping, valves, and controls. The vacuum pump and controls are housed in the control building located near the crown of the siphon. A vacuum breaker valve is also located at the crown of the siphon.

The generating unit has an inclined axis semi-Kaplan bulb turbine, and an induction generator driven through a parallel shaft speed increaser.

The turbine waterpassages are drained by opening the vacuum breaker valve located at the crown of the siphon. Stoplogs are installed downstream of the runner to permit dewatering the runner area.

The plant is operated on a run-of-river basis to maintain the headwater level at the top of the dam. Flows in excess of the turbine discharge pass over the dam. The unit is automatically controlled by a programmable controller.

COLUMBIA MILLS HYDROELECTRIC PLANT

PROJECT OWNER: COLUMBIA MILLS HYDROELECTRIC PARTNERSHIP

FERC NO.: 8005-000

LOCATION: BUENA VISTA, VIRGINIA
MAURY RIVER

ENGINEER: CHI ENGINEERING SERVICES

Year of Initial Operation	1985
Plant Capacity	417 kW
Plant Flow	334 cfs
Rated Head	17.2 ft
Number of Units	One

HYDRAULIC CONDITIONS

- Headwater Level
  - Maximum (for plant operation) .... El 836.9
  - Normal .... El 835.4
  - Minimum (for plant operation) .... El 834.4
- Tailwater Level
  - Maximum (for plant operation) .... El 825.0
  - Normal .... El 818.2
  - Minimum (for plant operation) .... El 817.0
- Gross Head
  - Maximum (for plant operation) .... 18.2 ft
  - Normal .... 17.2 ft
  - Minimum (for plant operation) .... 16.0 ft

GENERATING UNIT DATA

- Turbine
  - Manufacturer .... ESAC
  - Type .... Semi-Kaplan
  - Rated Net Head .... 17.2 ft
  - Rated Power .... 559 hp
  - Speed .... 282 rpm
  - Runner Diameter .... 55.12 in.
  - Number of Blades .... Four

COLUMBIA MILLS HYDROELECTRIC PLANT

- Generator
  - Manufacturer .... Jeaumont Schneider
  - Type .... Induction
  - Rated Output .... 520 kVA
  - Power Factor 0.82
  - Rated Power .... 425 kW
  - Speed .... 912 rpm
  - Voltage .... 480 V

- Speed Increaser
  - Manufacturer .... Comelor Company
  - Type .... Parallel Shaft
  - Rating .... 440 kW
  - Service Factor 1.8

- Blade Positioner
  - Manufacturer .... ESAC

- Controls
  - Manufacturer .... Omron
  - Type .... Programmable Controller

PENSTOCK DATA

- Number of Penstocks .... One

- Size .... 9.8 ft high x 13.8 ft wide (rectangular)

- Length
  - Intake to top of siphon .... 23.8 ft
  - Top of siphon to turbine .... 59.3 ft

- Elevation of Penstock Centerline at Top of Siphon .... El 846.75

- Siphon Lift
  - Maximum (minimum headwater level to penstock centerline at top of siphon) .... 12.4 ft
  - Normal (normal headwater level to penstock centerline at top of siphon) .... 11.4 ft

- Design Flow
  - Maximum .... 374 cfs
  - Normal .... 334 cfs
  - Minimum .... 40 cfs

- Penstock Material .... A36 Carbon Steel

- Material Thickness at Top of Siphon .... 0.25 in.

PENSTOCK INTAKE

- Inlet Flow Direction .... Vertical
- Opening Area .... 210 ft^2
- Material .... A36 Carbon Steel
- Trashracks
  - Gross area .... 624 ft^2
  - Bar clear spacing .... 2.8 in.

SIPHON PRIMING SYSTEM

- Number of Vacuum Pumps .... One

- Vacuum Pump Data
  - Type .... Positive Displacement (Roots)
  - Manufacturer .... Sutorbilt
  - Model Number 7MXB
  - Power .... 15 hp
  - Capacity .... 360 cfm at 10.2 in. Hg

- Air Inlet (Vacuum Breaker) Valve
  - Type .... Butterfly
  - Manufacturer .... Norris
  - Model number R1020-22AA-1A
  - Size .... 6 in.

- Volume of Air to be Removed for Siphon Priming .... 650 ft^3

- Siphon Priming Time .... 5 min.

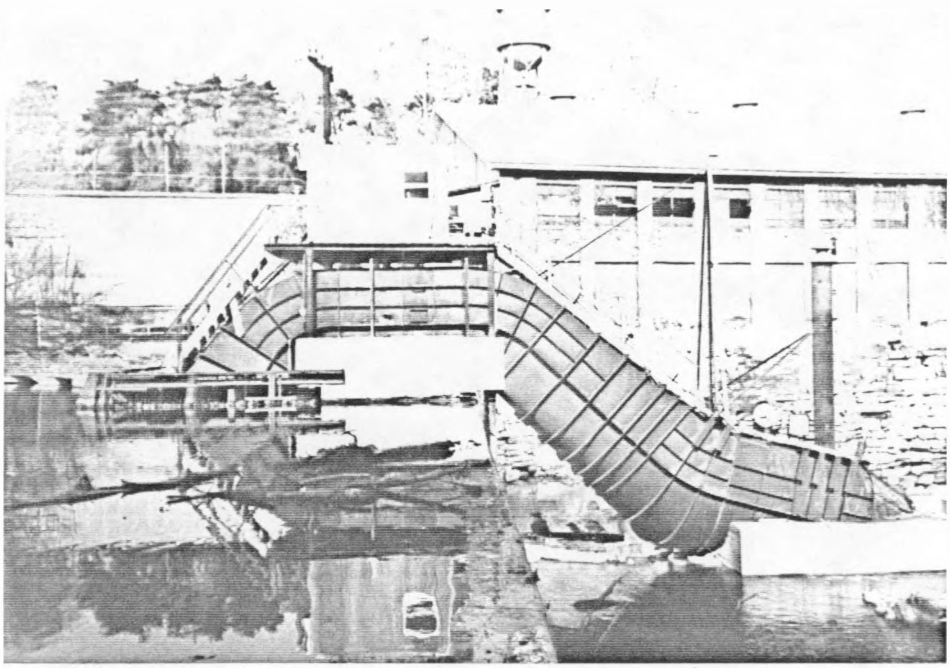


Figure A-1 Columbia Mills Hydroelectric Project

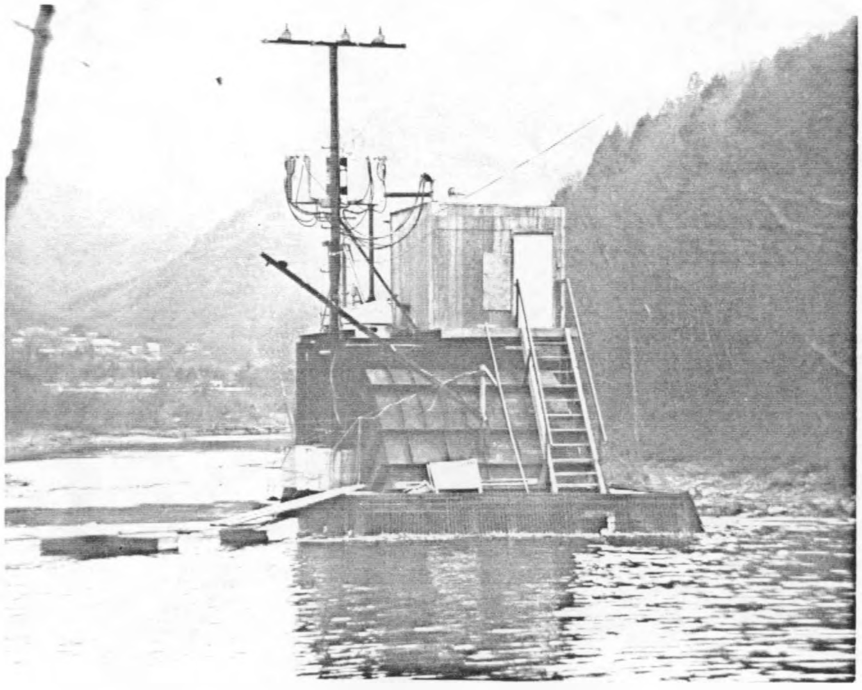
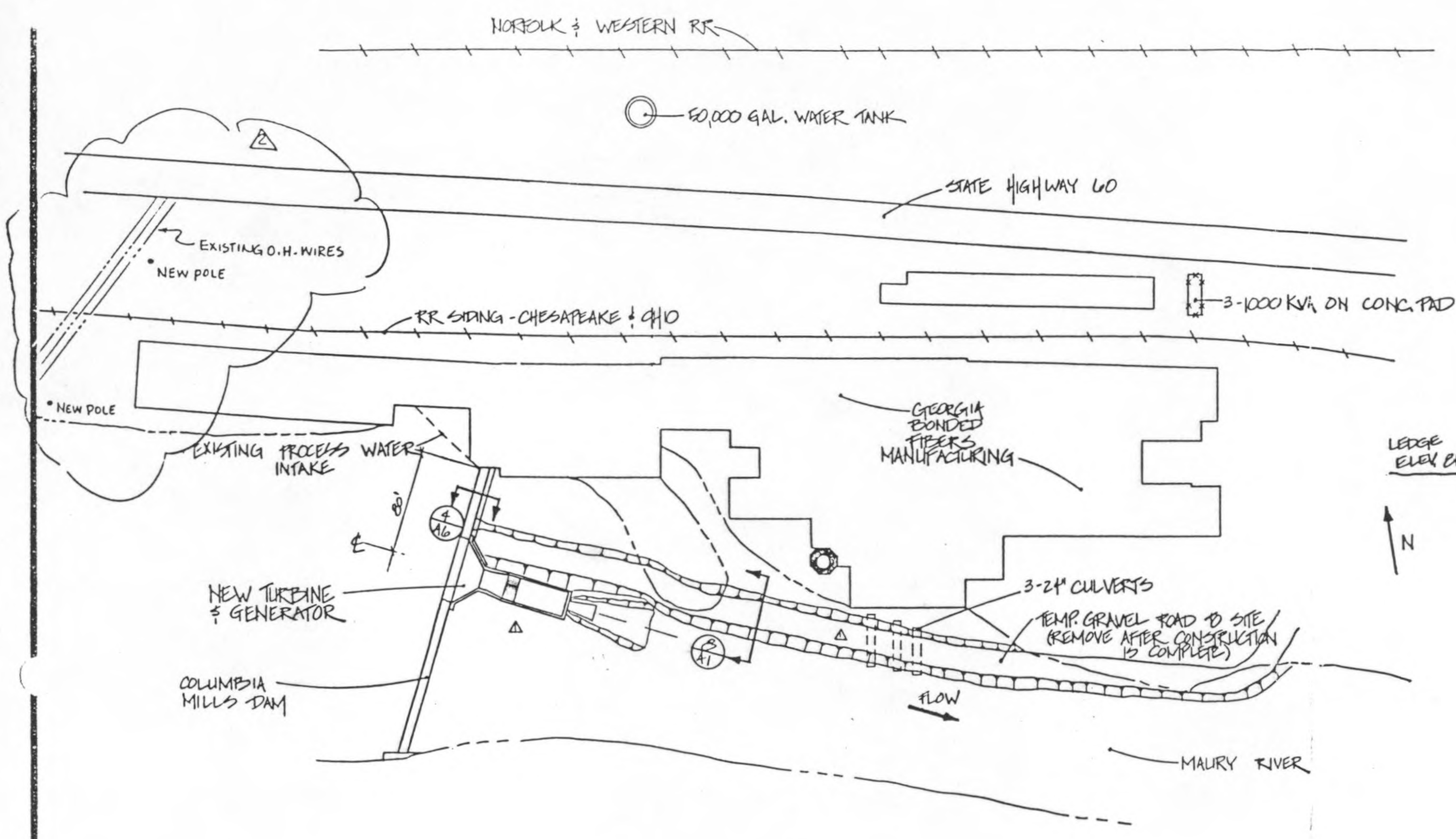
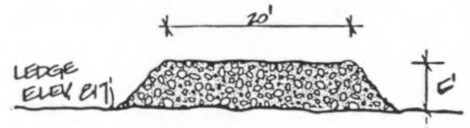


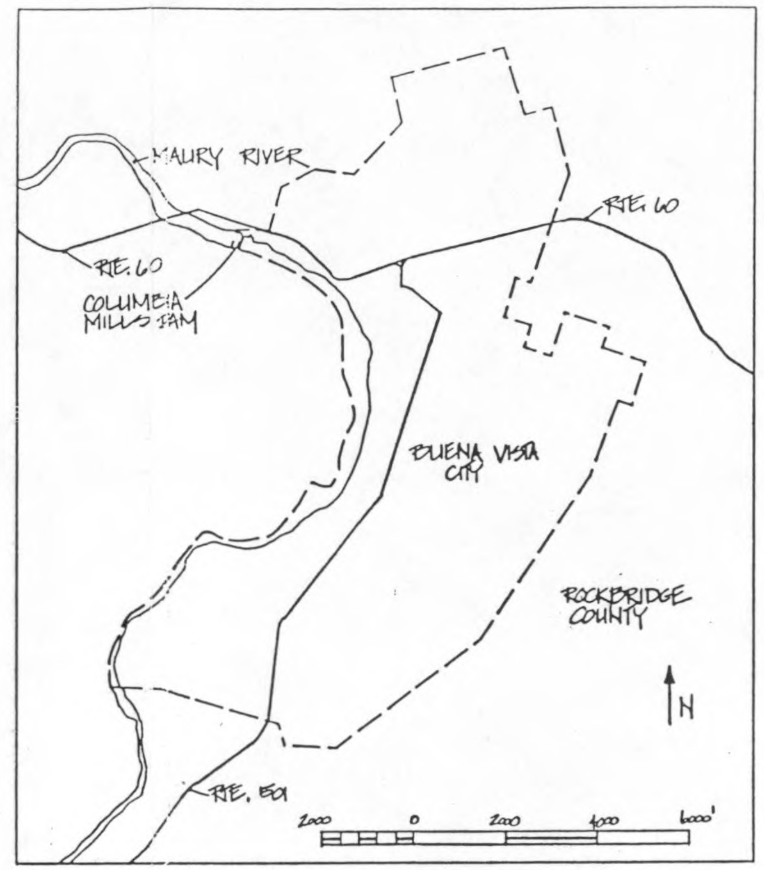
Figure A-2 Columbia Mills - Intake Area



SITE PLAN SCALE - 1" = 60'

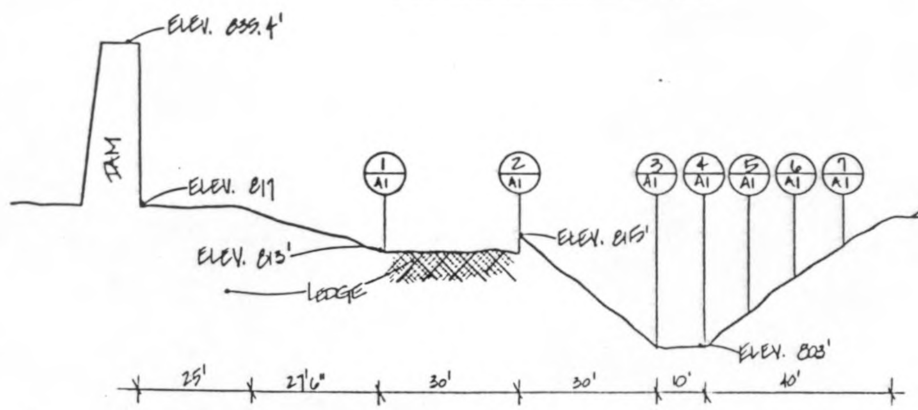


SECTION SCALE - 1" = 10'



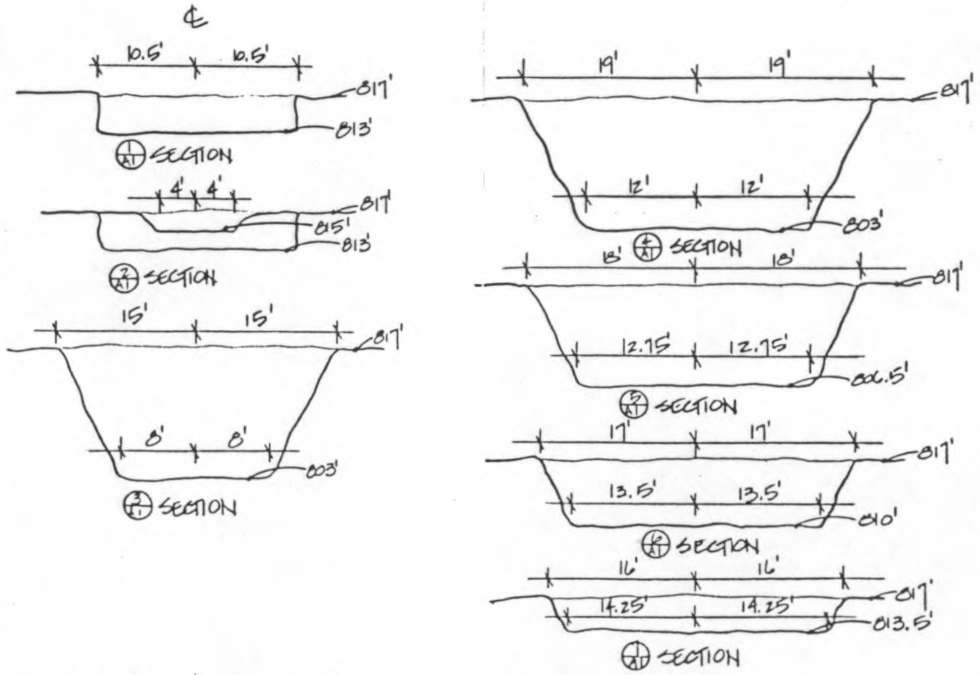
VICINITY MAP SCALE - 1" = 2000'

LOCUS MAP SCALE - 1" = 24 MILES



EXCAVATION PROFILE AT ℄ OF POWER STRUCTURE

VERT. SCALE - 1" = 10' HORZ. SCALE - 1" = 20'



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NO.	DATE	REVISION	BY
2	12/84	NEW ELEV. SHOWN	CH
1	4-27-84	CHNG. STRUCT., ADD CONSTRUCT. ROAD, ADD PROFILE & EXCAV. SECT.	DD

SITE PLAN & LOCI

083-30
AS NOTED
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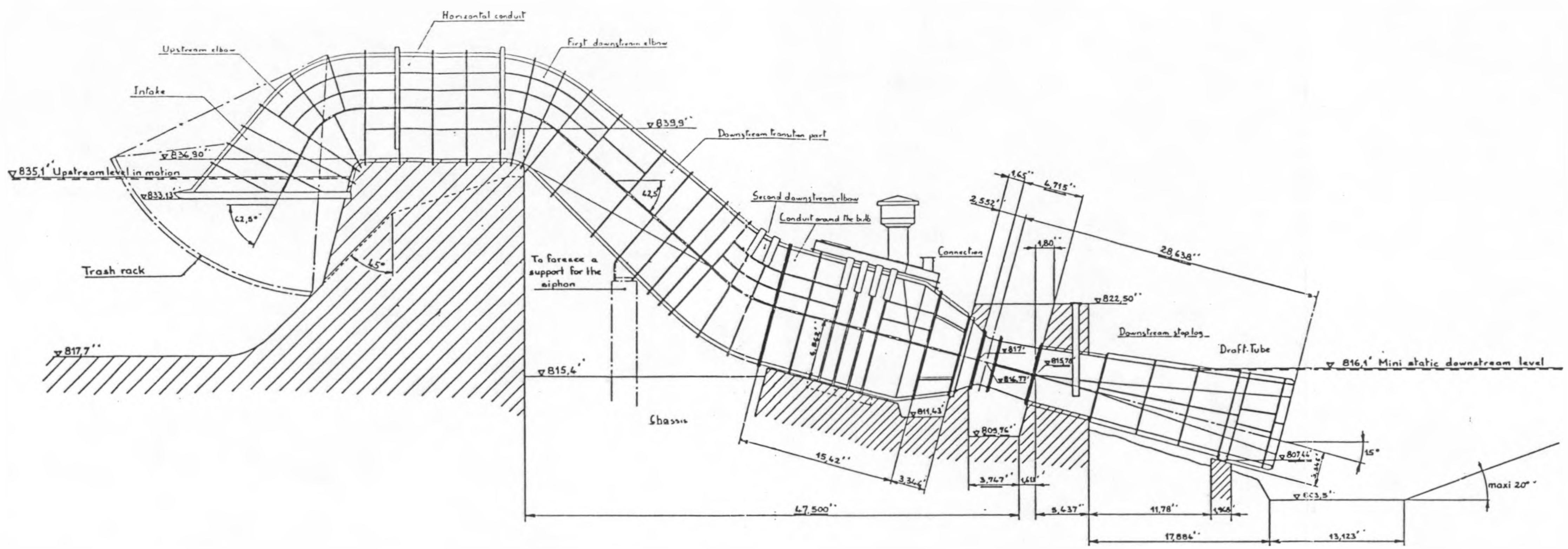
DD

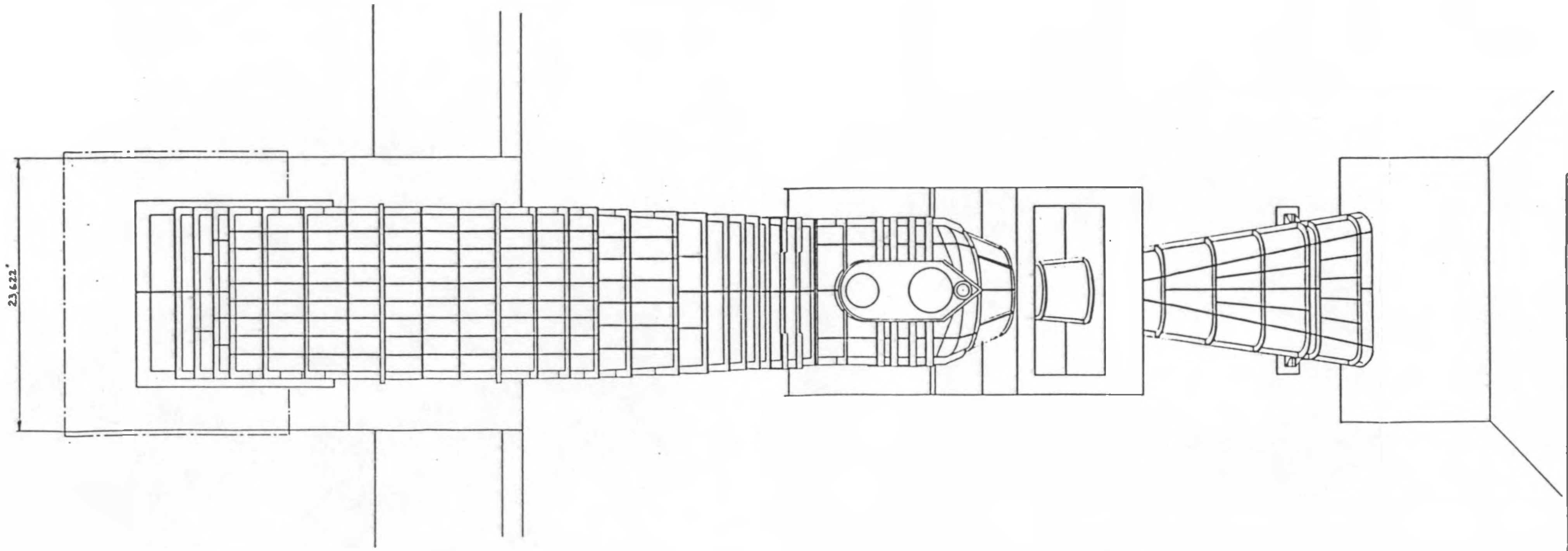
MOOMAWS HYDROELECTRIC
BUENA VISTA, VIRGINIA

CHRIS HOSFORD, INC.
3179 Main Street
BARNSTABLE, MASSACHUSETTS 02630
(617) 362-4561

A1

1 OF 1 SHTS





ESAC S.A. Hydraulic Department

70800 - Saint-Loup-sur-Semouse - FRANCE

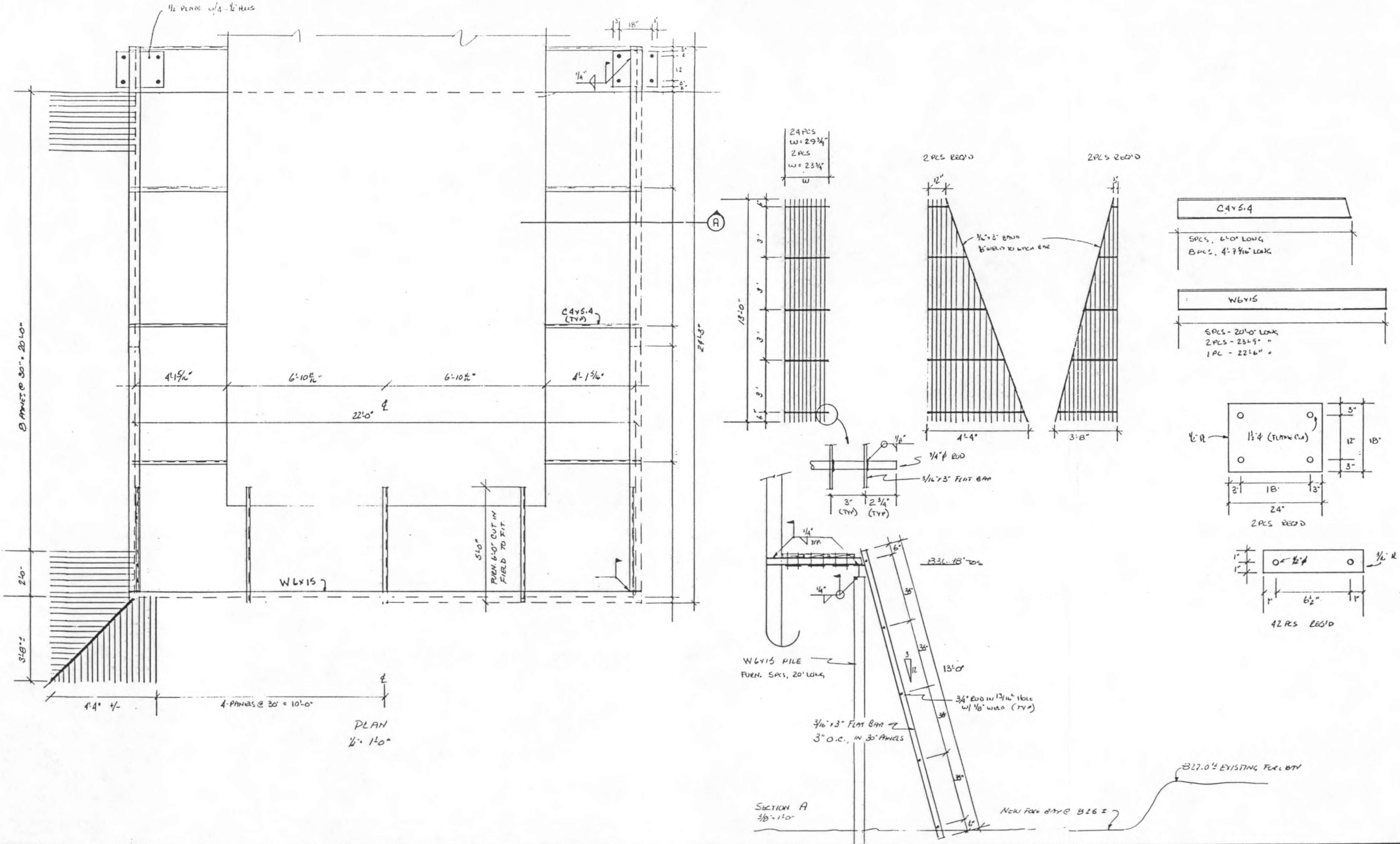
Scale: 1/50 31-07-84

VIRGINIA SITE

Installation

Cde N° 4.5/727

84-510-H4/1



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3				8			
4				5			

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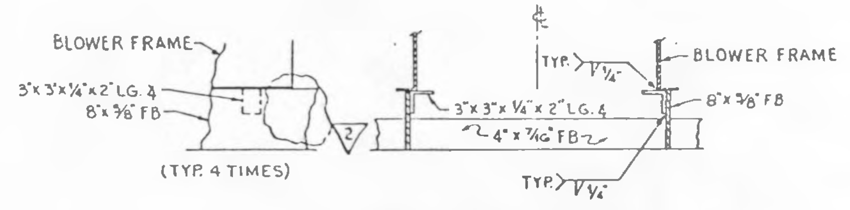
TRASHRACK
FABRICATION DETAILS

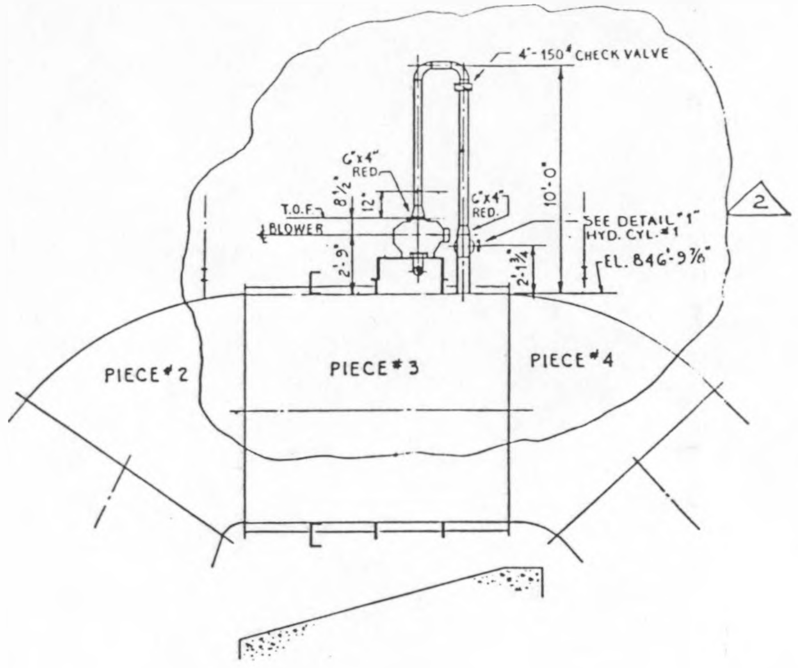
Drawn By: CSH
Checked By: LMD
Scale: AS NOTED

COLUMBIA MILLS HYDRO
BUENA VISTA, VIRGINIA

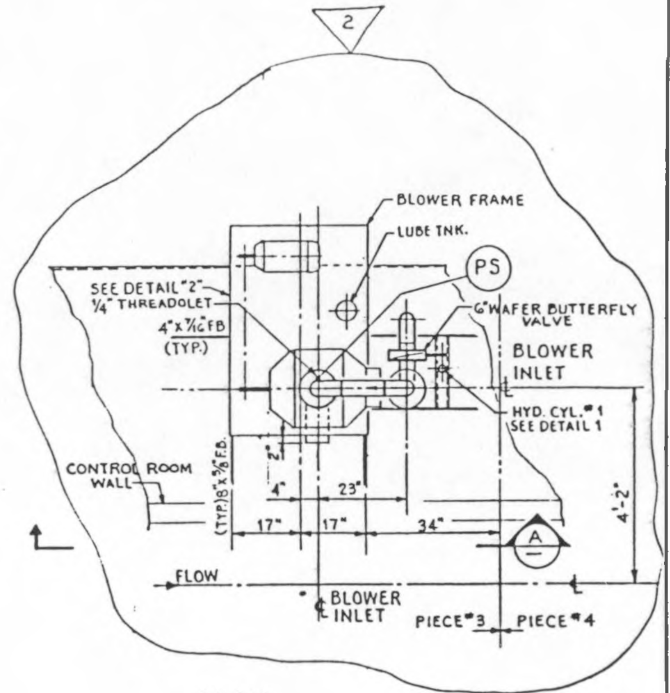
Date: 10/18/84
Job No.: 083-30
Dwg No.: S11



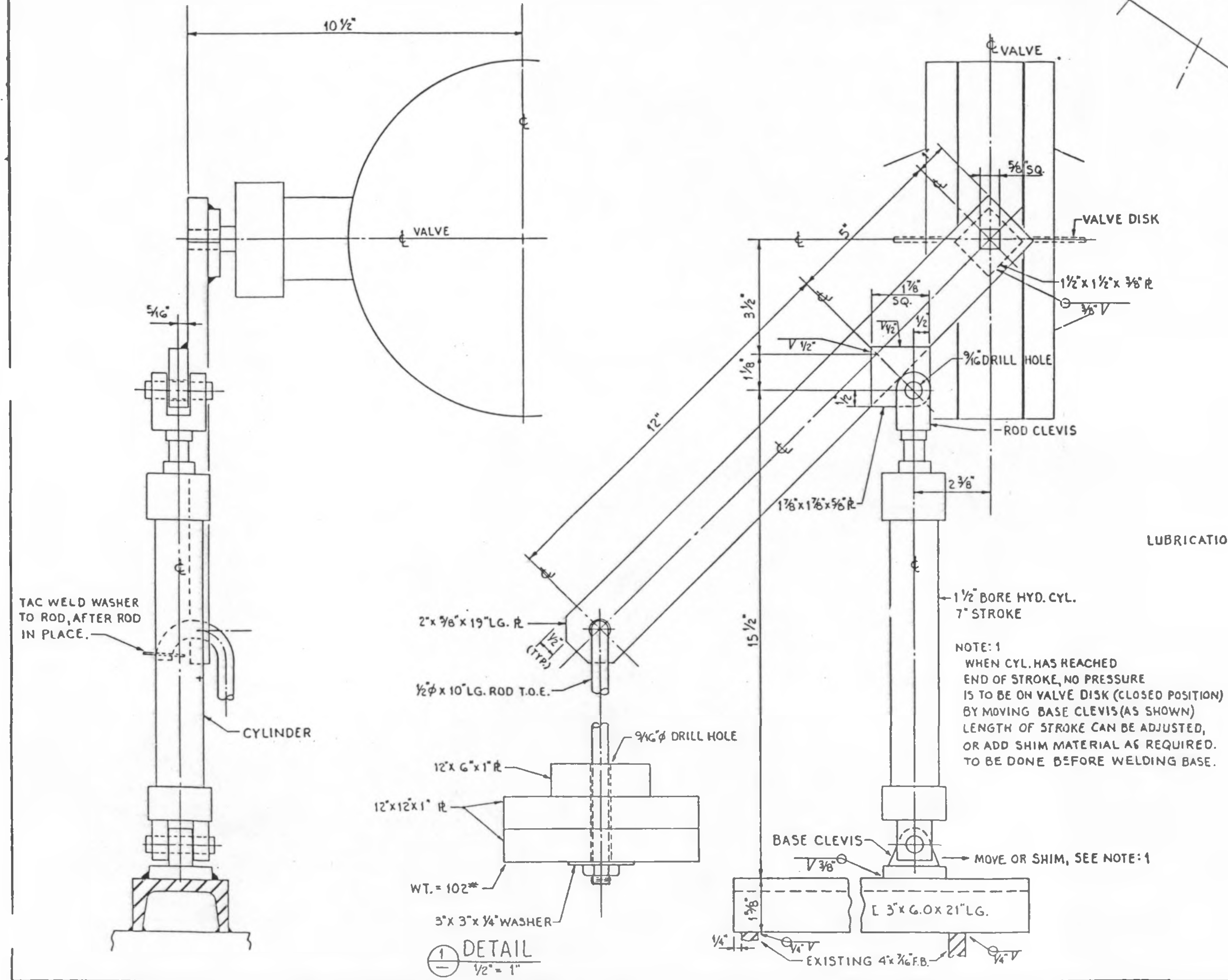
2 BLOWER FRAME DETAIL
NO SCALE



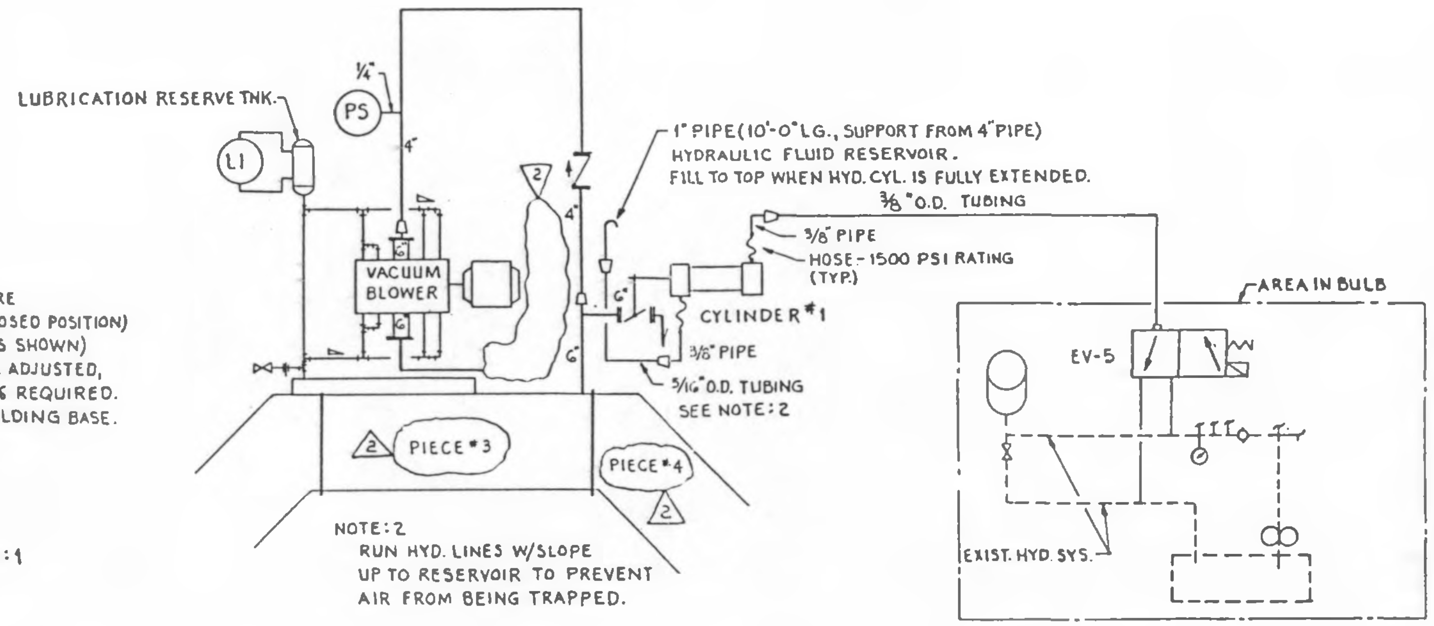
A SECTION
1/4" = 1'-0"



PLAN
1/2" = 1'-0"



1 DETAIL
1/2" = 1"



PIPING DIAGRAM
NO SCALE

REVISIONS		DATE	BY			DATE	BY
1	CHANGED DRAWING NUMBER → M-4 WAS M-1	11-4-84	WVH	8			
2	REM. SILENCER FROM DIAG. CHANGE PLAN, SECTION A, & DIM REM. ON DETAIL 2	12-14-84		7			
3				6			
4				5			

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VACUUM BLOWER DETAILS

Drawn By	
Checked By	
Scale	AS SHOWN

COLUMBIA MILLS HYDROELECTRIC
BUENA VISTA, VIRGINIA

Date	OCT. 17, 1984
Job No.	083-30
Dwg No.	M-4

APPENDIX B

JIM FALLS MINIMUM FLOW UNIT HYDRO DEVELOPMENT

JIM FALLS MINIMUM FLOW UNIT HYDRO DEVELOPMENT

The Jim Falls Minimum Flow Unit Hydro Development is located near Jim Falls, Wisconsin on the north bank of the Chippewa River. The power plant was constructed in 1986 and has a single 560 kW, 30.5 ft head unit.

The intake is an inverted morning glory type with a horizontal opening. The intake has vertical trashracks on all four sides. Access is provided for hand raking the trashracks.

The penstock is of steel construction with a nominal diameter of 6.5 ft. The penstock is made from prefabricated sections with field welded joints. The upstream portion of the penstock bends 90 degrees from the intake to cross the dam. On the downstream side of the dam the penstock bends downward and runs to the powerhouse. The penstock is supported by three cradle supports; two are located at the ends of the siphon crown and one is located at the upstream powerhouse wall. A bridge for the access road passes over the crown of the siphon.

The overall length of the penstock is 89 ft and the distance from the intake to the crown of the siphon is 27 ft.

The siphon priming system consists of two liquid ring seal vacuum pumps, a vacuum tank, an air/water separator with a water accumulator tank, and associated piping, valves, and controls. The vacuum pumps, tanks, separator, and controls are located within the powerhouse. The vacuum system is connected to the priming column at the crown of the siphon with a four inch line. A vacuum breaker valve is also located at the crown of the siphon.

The powerhouse has a reinforced concrete substructure with precast concrete slab walls. A composition roof on a metal deck with steel joist supports is provided. The generating unit has a vertical Francis turbine, with a vertical induction generator driven through a parallel shaft speed increaser. A butterfly type inlet valve is provided at the intake to the turbine.

The turbine is set above tailwater and is dewatered by closing the inlet valve. The penstock can be dewatered by opening the vacuum breaker valve and draining the water through the unit.

The majority of flow in the Chippewa River is directed through a power canal to the Jim Falls main powerhouse which operates as a run-of-river facility. The Jim Falls Minimum Flow Unit provides a continuous flow of 240 cfs in the Chippewa River in the area between the dam and the main powerhouse.

An operator is required to initiate the siphon priming operation and to start the generating unit. The plant has the capability for future remote startup of the unit.

JIM FALLS MINIMUM FLOW UNIT HYDRO DEVELOPMENT

PROJECT OWNER:	NORTHERN STATES POWER COMPANY
FERC NO.:	2491
LOCATION:	WISCONSIN CHIPPEWA RIVER
ENGINEER:	MEAD AND HUNT, INC.

Year of Initial Operation	1986
Plant Capacity	500 kW
Plant Flow	240 cfs
Rated Head	30.4 ft
Number of Units	One

HYDRAULIC CONDITIONS

– Headwater Level	
• Maximum (for plant operation)	El 953.0
• Normal	El 952.5
• Minimum (for plant operation)	El 952.0
– Tailwater Level	
• Maximum (for plant operation)	El 922.8
• Normal	El 922.0
• Minimum (for plant operation)	El 921.8
– Gross Head	
• Maximum (for plant operation)	31.2 ft
• Normal	30.5 ft
• Minimum (for plant operation)	29.2 ft

GENERATING UNIT DATA

– Turbine	
• Manufacturer	Barber Hydraulic Turbine, Inc.
• Type	Vertical Francis
• Rated Net Head	30.5 ft
• Rated Power	751 hp
• Speed	197.36 rpm
• Runner Diameter (throat)	53.0 in.
• Number of Blades	13

- Generator
  - Manufacturer .... Siemens-Allis
  - Type .... Vertical Induction
  - Rated Output .... 708.0 kVA
  - Power Factor (full load) 0.847
  - Rated Power .... 600 kW
  - Speed .... 900 rpm
  - Voltage .... 7200 V

- Speed Increaser
  - Manufacturer .... Dresser-Foote-Jones
  - Type .... Parallel Shaft Helical
  - Rating .... 817 hp
  - Service Factor 1.75

- Gate Positioner
  - Manufacturer .... Barber Hydraulic Turbine, Inc.

- Intake Valve
  - Manufacturer .... Keystone Valve
  - Type .... Butterfly
  - Diameter .... 78 in.
  - Type of Operator .... Hydraulic

- Controls
  - Manufacturer .... PACS Industries, Inc.
  - Type .... Relay Type

PENSTOCK DATA

- Number of Siphon Penstocks .... One

- Diameter
  - Nominal .... 6.5 ft
  - At siphon .... 6.5 ft

- Length
  - Intake to top of siphon .... 27 ft
  - Top of siphon to turbine intake .... 62 ft

- Elevation of Penstock Centerline at Top of Siphon .... El 957.25

- Siphon Lift
  - Maximum (minimum headwater level to penstock centerline at top of siphon) .... 5.25 ft
  - Normal (normal headwater level to penstock centerline at top of siphon) .... 4.75 ft

- Design Flow
  - Maximum .... 240 cfs
  - Normal .... 240 cfs
  - Minimum .... 240 cfs

- Penstock Material .... Steel

- Material Thickness at Top of Siphon .... 1/2 in.

PENSTOCK INTAKE

- Inlet Flow Direction .... Vertical
- Opening Area .... 60.1 ft^2
- Material .... Steel
- Trashracks
  - Gross area .... 137 ft^2
  - Bar clear spacing .... 3 in.

SIPHON PRIMING SYSTEM

- Number of Vacuum Pumps .... Two

- Vacuum Pump Data
  - Type .... Liquid Ring Seal/Tank-mounted System
  - Manufacturer .... Nash
  - Model Number AHC-50
  - Power .... 5 hp
  - Capacity .... 43 cfm at 20 in. Hg

- Priming Valve (Control Valve) - Gross
  - Manufacturer .... Jamesbury
  - Model Number AF30S36TT/ERC800
  - Size .... 3 in.

- Priming Valve (Control Valve) - Fine
  - Manufacturer .... ASCO
  - Model Number MS8030A17
  - Size .... 1/2 in.

- Air Inlet (Vacuum Breaker) Valve
  - Manufacturer .... Jamesbury
  - Model Number 530S-11-2236TT
  - Size .... 6 in.
  - Actuator .... AUMA SAT 12-22B/GS100

- Vacuum Tank Size .... 70.7 ft^3

- Volume of Air to be Removed for Siphon Priming .... 2,664 ft^3

- Siphon Priming Time .... 45 min.

Figure B-1 Jim Falls Minimum Flow Unit Hydro Development

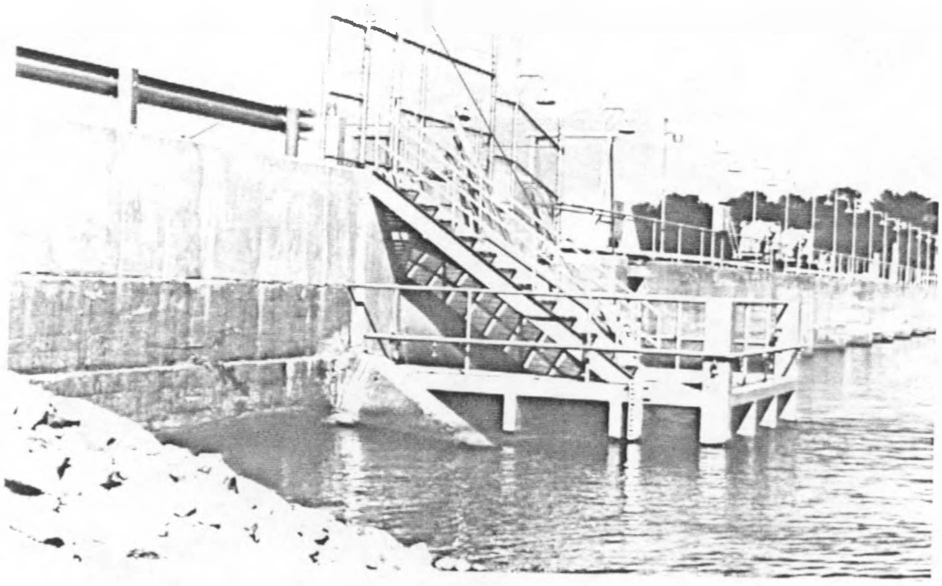
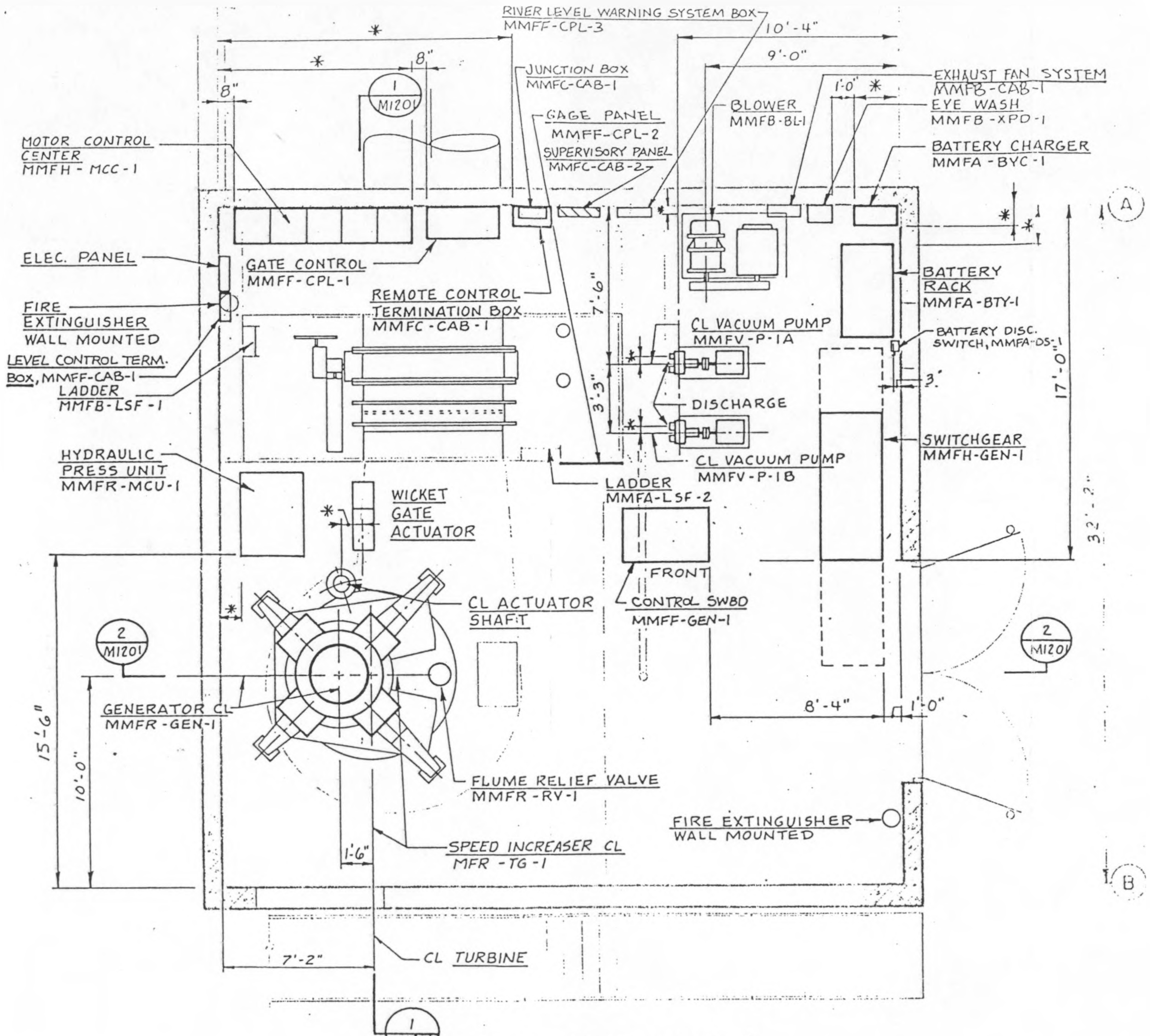


Figure B-2 Jim Falls - Siphon Intake

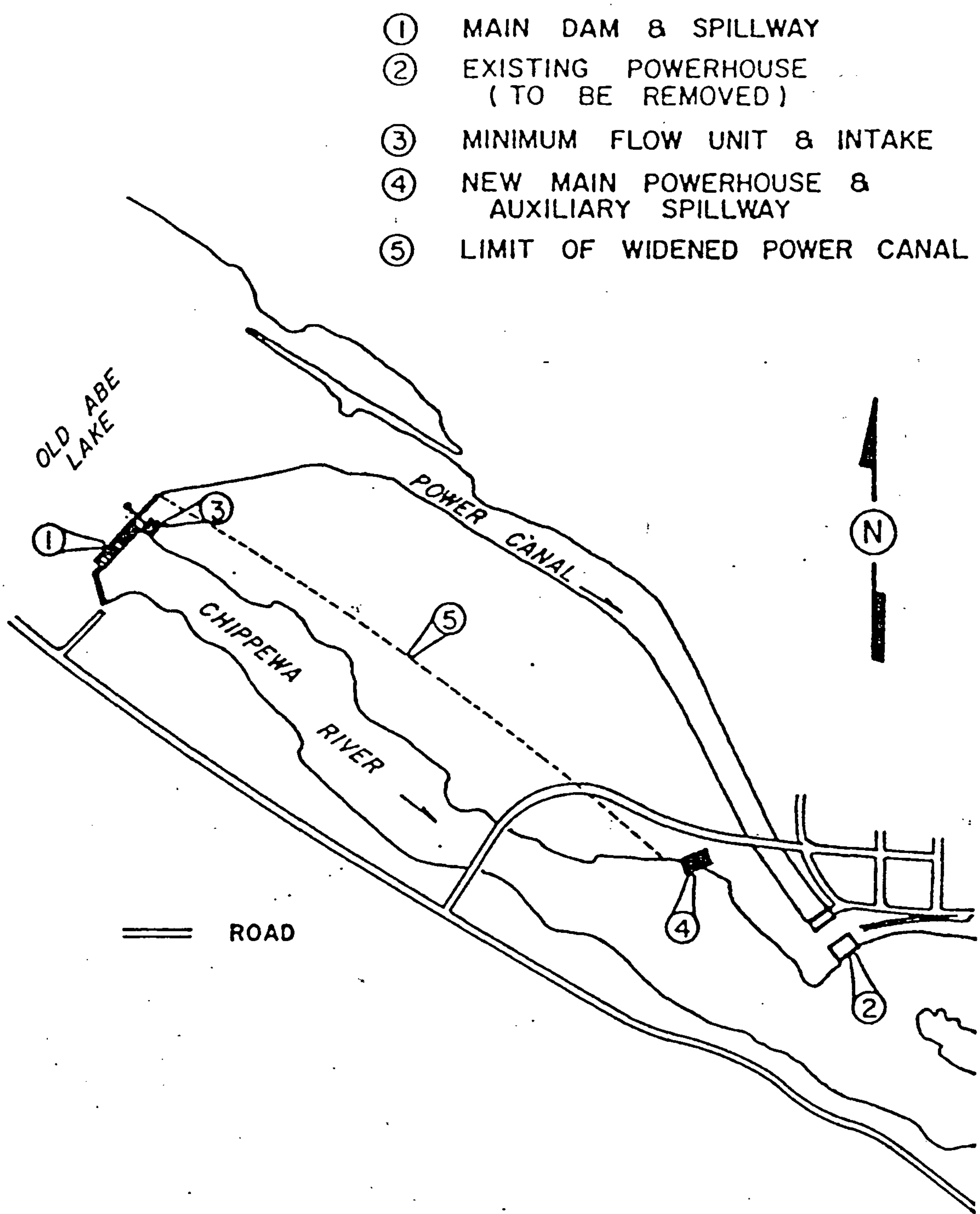
Figure B-3 Jim Falls - Siphon Crown Showing Control Column and Siphon Priming Line



FLOOR PLAN - EL 946'-0"

PLANT ARRANGEMENT PLAN

MEAD & HUNT, Inc.
Consulting Engineers
Madison, Wisconsin



GENERAL LAYOUT (EXISTING)

MEAD & HUNT, Inc.
Consulting Engineers
Madison, Wisconsin

APPENDIX C

LAC COURTE OREILLES HYDRO DEVELOPMENT

LAC COURTE OREILLES HYDRO DEVELOPMENT

The Lac Courte Oreilles Band of Lake Superior Chippewa Indians Hydro Development is located at a water storage dam in Sawyer County near Winter, Wisconsin, on the west bank of the Chippewa River. The 30 ft head power plant, which has two 1767 kW units and one 303 kW unit, was constructed below the existing dam, in 1986. The primary purpose of the dam is to store excess runoff, and then release water during low flow periods for use at downstream hydroelectric facilities.

The three unit project has two parallel 9 ft diameter penstocks. Each penstock supplies water to one of the larger units. One of the penstocks bifurcates at the powerhouse to supply the small unit. Each penstock has a horizontal rectangular intake with vertical trashracks along the two sides and the front. The intake incorporates a transition to the circular penstock. There are no trash handling facilities at the intake.

The penstocks are made from prefabricated steel sections with field welded joints. The upstream portion of the penstocks follows the upstream slope of the dam. An access road, supported by a bridge, passes over the downstream portion of the penstocks. The penstocks are continually supported by compacted, free draining bedding. Concrete cradle supports are provided immediately upstream of the powerhouse and at the crown of the siphon. The penstock diameter increases from 9 ft to 10 ft immediately upstream of the powerhouse.

The overall length of each penstock is 261 ft. The distance from the intake to the crown of the siphon is 121 ft.

The siphon priming system consists of two liquid ring seal vacuum pumps, and associated piping, valves, and controls. In addition, a pump is provided to fill the section of penstock downstream of the siphon crown with water prior to priming the siphon. The water pump, vacuum pumps, and controls are located within the powerhouse. The siphon break valve and vacuum header are located at the crown of the siphon inside a metal sided, woodframe structure.

The powerhouse is of reinforced concrete construction. The generating units have vertical Francis turbines with adjustable wicket gates. The generators are of the vertical induction type driven through parallel shaft speed increasers. The turbines are set above tailwater; therefore, the turbine waterpassages and penstock may be drained by breaking the vacuum in the penstock.

For most of the year, the plant is operated as a run-of-river facility to maintain relatively constant headwater level in Lake Chippewa. During the late winter, the level can be lowered about 15 ft so that the reservoir can store the spring runoff. Flood flows are handled through a spillway with three 20-ft wide tainter gates.

The generating units can be automatically or manually controlled. An operator is required to initiate the siphon priming operation.

LAC COURTE OREILLES HYDRO DEVELOPMENT

PROJECT OWNER:	LAC COURTE OREILLES BAND OF LAKE SUPERIOR CHIPPEWA INDIANS
FERC NO.:	8286
LOCATION:	WISCONSIN CHIPPEWA RIVER
ENGINEER:	MEAD AND HUNT, INC.

Year of Initial Operation 1986

Plant Capacity .... 3,450 kW

Plant Flow .... 1500 cfs

Rated Head .... 30.0 ft

Number of Units .... Three

HYDRAULIC CONDITIONS

- Headwater Level
  - Maximum (for plant operation) .... El 1313.0
  - Normal .... El 1312.0*
  - Minimum (for plant operation) .... El 1297.0

- Tailwater Level
  - Maximum (for plant operation) .... El 1282.0
  - Normal .... El 1280.0
  - Minimum (for plant operation) .... El 1278.25

- Gross Head
  - Maximum (for plant operation) .... 34.75 ft
  - Normal .... 32.0 ft
  - Minimum (for plant operation) .... 18.75 ft

GENERATING UNIT DATA

	1	2 & 3
– Unit No.	1	2 & 3
– Turbine		
• Manufacturer	W. J. Bauer	W.J. Bauer
• Type	Vertical Francis	Vertical Francis
• Rated Net Head	30.0 ft	30.0 ft
• Rated Power	406 hp	2370 hp

*Other than during annual reservoir drawdown.

– Unit No.	1	2 & 3
• Speed	231 rpm	118 rpm
• Runner Diameter	34.0 in.	70.5 in.
• Number of Blades	14	14
– Generator		
• Manufacturer	Siemens-Allis	Siemens-Allis
• Type	Vertical Induction	Vertical Induction
• Rated Output	309.1 kVA	2010.3 kVA
• Power Factor (full load)	0.81	0.83
• Rated Power	250 kW	1600 kW
• Speed	1215 rpm	905 rpm
• Voltage	4160 V	4160 V
– Speed Increaser		
• Manufacturer	Flender	Flender
• Type	Parallel Shaft Helical	Parallel Shaft Helical
• Rating	226 hp	2215 hp
• Service Factor	1.00	1.00

– Gate Positioner
- Manufacturer .... W. J. Bauer

– Controls - Manual
- Manufacturer .... Shef Massey (design)
Panelex Corp. (fabricator)
- Type .... Relay

– Controls - Automatic
- Manufacturer .... Digitek
- Type .... Microprocessor

PENSTOCK DATA

– Number of Siphon Penstocks .... Two
One with single unit; one bifurcated with two units

– Diameter
- Nominal .... 9 ft
- At siphon .... 9 ft

– Length
- Intake to top of siphon (including transition) .... 121 ft
- Top of siphon to turbine intake .... 140 ft*

*Distance to small unit is 149 feet with bifurcation

- Elevation of Penstock Centerline at Top of Siphon .... El 1318
- Siphon Lift
  - Maximum (minimum headwater level to penstock centerline at top of siphon) .... 21.0 ft
  - Normal (normal headwater level to penstock centerline at top of siphon) .... 6.0 ft
- Design Flow
  - Maximum (per penstock) .... 815 cfs
  - Normal .... 650 cfs
  - Minimum .... 90 cfs
- Penstock Material .... Steel
- Material Thickness at Top of Siphon .... 3/8 in.

PENSTOCK INTAKE

- Inlet Flow Direction .... Horizontal
- Opening Area .... 81 ft^2
- Material .... Steel
- Trashracks
  - Gross area .... 369 ft^2
  - Bar clear spacing .... 3 in.

SIPHON PRIMING SYSTEM

- Number of Vacuum Pumps .... Two
- Vacuum Pump Data
  - Type .... Liquid Ring Seal
  - Manufacturer .... Nash
  - Model Number .... CL 202
  - Power .... 10 hp
  - Capacity .... 170 cfm at 20 in. Hg
- Number of Water Pumps .... One
- Pump Data
  - Type .... Vertical
  - Manufacturer .... Johnston Pump Co.
  - Model Number .... 16LS - 1 stage
  - Power .... 75 hp
  - Capacity .... 6000 gpm at 36 ft head
- Priming Valve (Isolation Valve)
  - Type .... Butterfly
  - Manufacturer .... Keystone Valve Co.
  - Model Number .... 150-952-270/EPI-13 INT
  - Size .... 6 in.

– Air Inlet (Vacuum Breaker) Valve

• Manufacturer	DeZurik	
• Model Number	FIG 632-L-B-RS49-2	
• Size	12 in.	
• Actuator	DeZurik KWG5C6	
	Bifurcated	Single
– Volume of Air to be Removed for Siphon Priming		
• High Water	13,203 ft^3	12,603 ft^3
• Low Water	17,433 ft^3	16,833 ft^3
– Siphon Priming Time		
• High Water	30.3 min.	27.9 min.
• Low Water	67.3 min.	64.8 min.

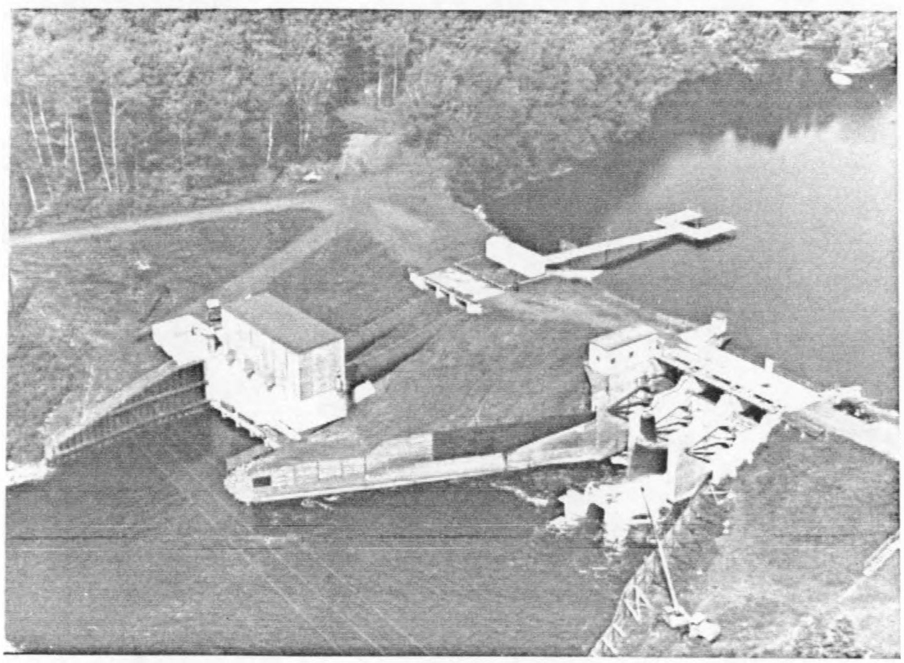
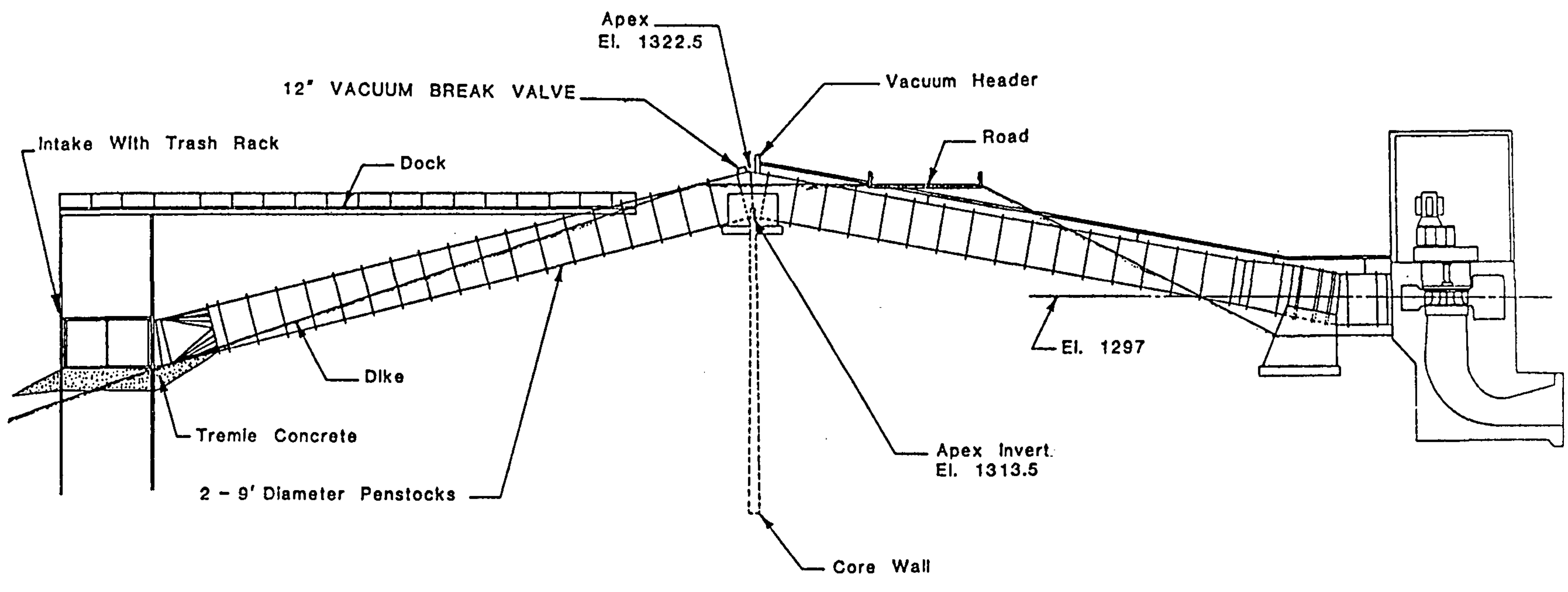


Figure C-1 Lac Courte Oreilles Hydroelectric Project

CHIPPEWA RESERVOIR HYDRO

HEADWATER
Summer Normal -- El. 1312
Winter Low -- El. 1297

TAILWATER :
Summer Normal -- El. 1280
Winter Low -- El. 1278



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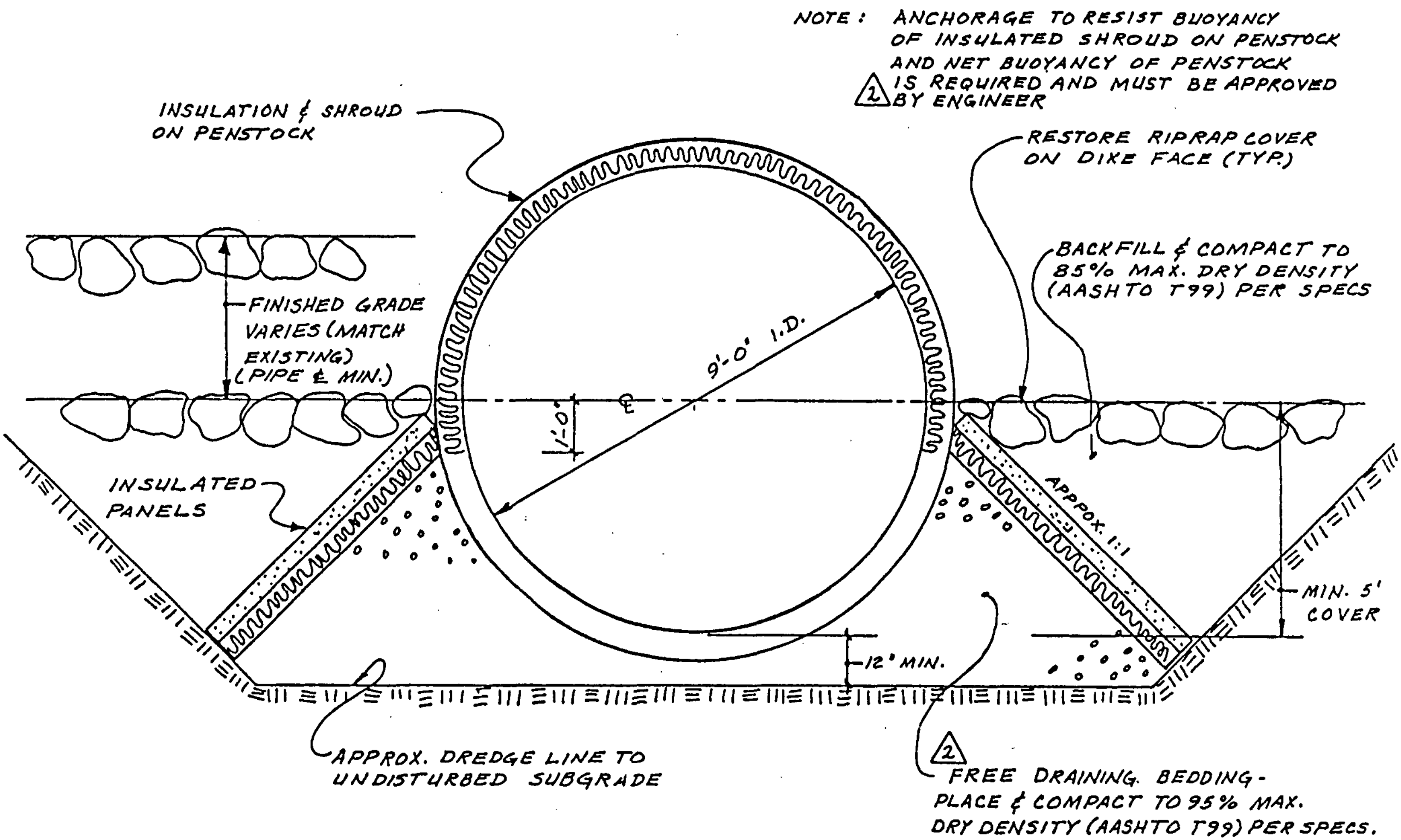
Madison, Wisconsin



A / PS1 SECTION - PENSTOCK

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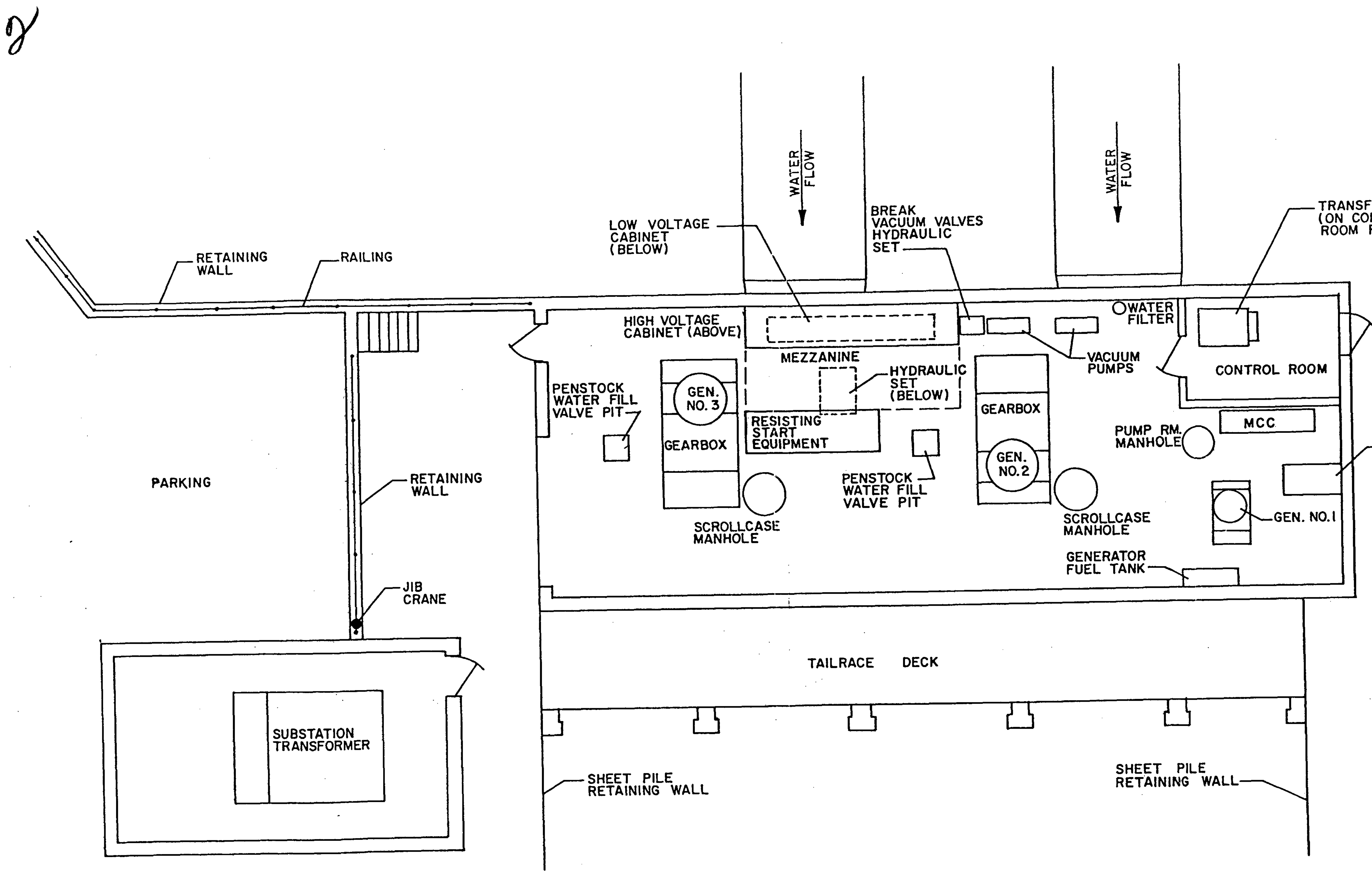

PLANT ARRANGEMENT PLAN

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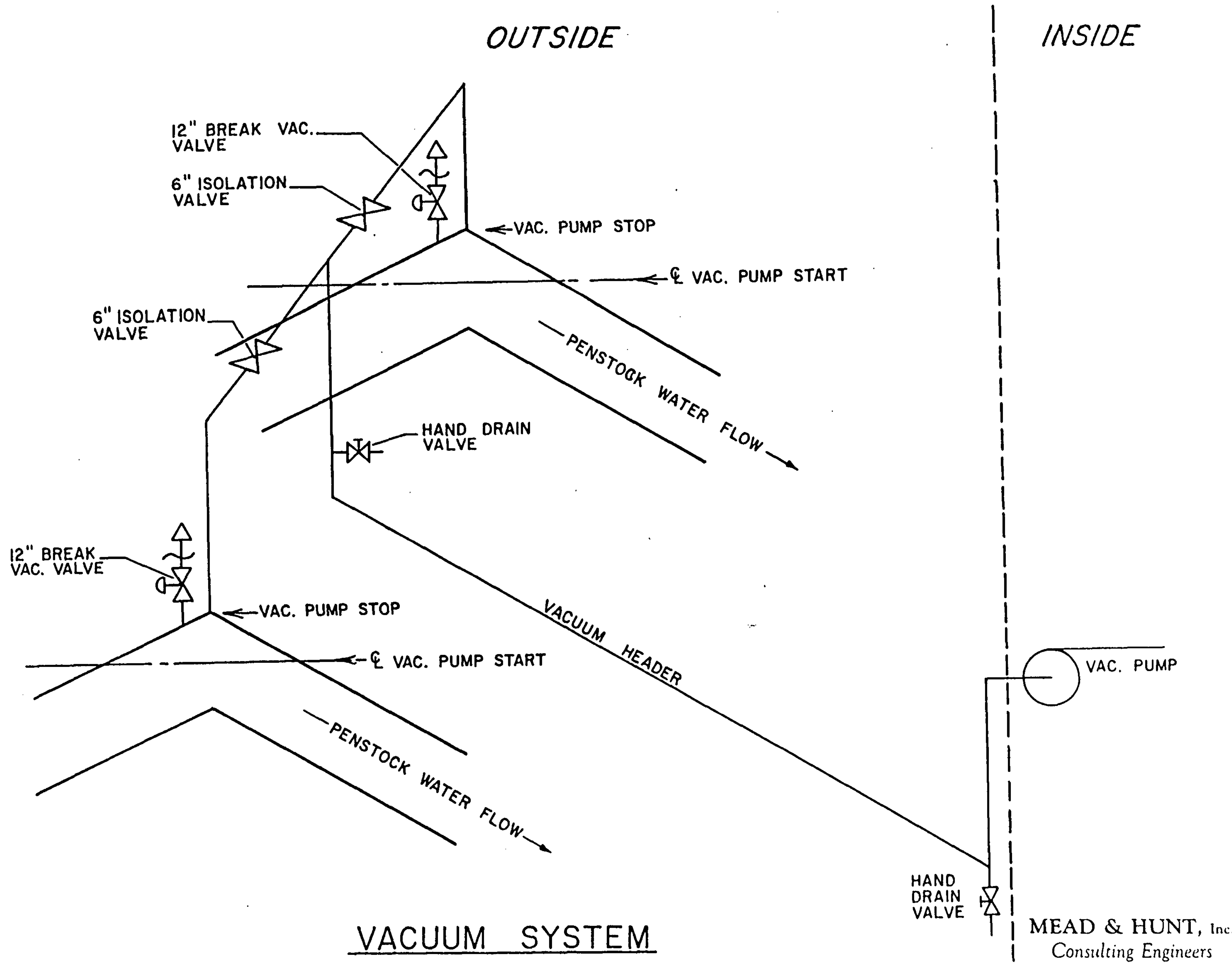

VACUUM SYSTEM

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Madison, Wisconsin

APPENDIX D

ONTELAUNEE HYDROELECTRIC PROJECT

ONTELAUNEE HYDROELECTRIC PROJECT

The Ontelaunee Hydroelectric Project is located in Berks County, Pennsylvania on the west bank of Maiden Creek. The plant was constructed in 1987 at the existing Ontelaunee Dam. The 35 ft head plant has two generating units, a 530 kW unit which has a siphon penstock, and a smaller unit which is supplied from an existing 48 inch blowdown line.

The siphon penstock has a bellmouth intake with an opening inclined at 30 degrees to vertical. Sloping trashracks are installed at the front of the intake, and the trashracks are manually raked.

The penstock is of steel construction with a nominal diameter of 6 ft. The penstock is made from prefabricated sections with both field welded and bolted flanged joints. The upstream portion of the penstock rises vertically from the inclined intake and bends to pass horizontally over the dam. The downstream portion of the penstock slopes down from the dam toward the turbine where it bends to meet the vertical turbine casing.

The overall penstock length is approximately 130 ft, and the distance from the intake to the crown of the siphon is 45 ft. The penstock is supported by steel supports at the intake, 21 ft upstream of the dam crest, and at the dam crest. The penstock is also supported and anchored at the powerhouse. A bridged walkway passes over the penstock at the dam.

The siphon priming system consists of two liquid ring seal vacuum pumps, a receiver tank, a water level tank, and associated piping, valves, and controls. The vacuum pumps, tanks, and controls are located in an existing gate house. A vacuum breaker valve is located on the penstock at the upstream vertical-to-horizontal bend.

The powerhouse is of reinforced concrete construction founded on bedrock. The generating unit is a vertical, submersible type, with a semi-Kaplan turbine, a planetary-type speed increaser and a vertical induction generator. The generator is connected to the utility grid through the switchgear and transformer. The turbine and penstock system is dewatered by opening the vacuum breaker valve.

The plant is operated on a run-of-river basis to maintain a constant headwater level. Flows in excess of the combined capacity of both generating units and an adjacent water supply tunnel pass over the dam.

The unit is controlled by a programmable logic controller located in the gate house. The facility is fully automated and operates unattended.

ONTELAUNEE HYDROELECTRIC PROJECT

PROJECT OWNER:	CITY OF READING, PENNSYLVANIA
FERC NO.:	7662
LOCATION:	PENNSYLVANIA MAIDEN CREEK
ENGINEER:	WILLIAMS AND BROOME, INC.

Year of Initial Operation 1988

Plant Capacity .... 530 kW

Plant Flow .... 210 cfs

Rated Head .... 35.0 ft

Number of Units .... One

HYDRAULIC CONDITIONS

– Headwater Level
- Maximum (for plant operation) .... El 309.0*
- Normal .... El 304.1
- Minimum (for plant operation) .... El 304.1

– Tailwater Level
- Maximum (for plant operation) .... El 274.0
- Normal .... El 267.6
- Minimum (for plant operation) .... El 267.0

– Gross Head
- Maximum (for plant operation) .... 37.1 ft
- Normal .... 36.5 ft
- Minimum (for plant operation) .... 35.0 ft

GENERATING UNIT DATA

– Turbine
- Manufacturer .... Flygt Corporation
- Type .... Semi-Kaplan (Model El 7620R)
- Rated Net Head .... 35.0 ft
- Rated Power .... 720 hp
- Speed .... 346 rpm
- Runner Diameter .... 47.25 in.
- Number of Blades .... Four

*Elevations are based on City of Reading datum. For USGS Elevations add 10.27 ft.

- Generator
  - Manufacturer .... Flygt Corporation
  - Type .... Vertical Induction
  - Rated Output .... 610 kVA
  - Power Factor (full load) 0.87
  - Rated Power .... 530 kW
  - Speed .... 1220 rpm
  - Voltage .... 600 V

- Speed Increaser
  - Manufacturer .... Flygt Corporation
  - Type .... Self-centering Planetary Gear

- Controls
  - Manufacturer .... Electropak
  - Type .... Programmable Controller

PENSTOCK DATA

- Number of Siphon Penstocks .... One

- Diameter
  - Nominal .... 6.0 ft
  - At siphon .... 6.0 ft

- Length
  - Intake to top of siphon .... 45 ft
  - Top of siphon to turbine intake .... 85 ft

- Elevation of Penstock Centerline at Top of Siphon .... El 309.15

- Siphon Lift
  - Maximum (minimum headwater level to penstock centerline at top of siphon) .... 5.05 ft
  - Normal (normal headwater level to penstock centerline at top of siphon) .... 5.05 ft
  - Minimum .... 0 ft (during flood conditions)

- Design Flow
  - Maximum .... 220 cfs
  - Normal .... 210 cfs
  - Minimum .... 125 cfs

- Penstock Material .... Steel

- Material Thickness at Top of Siphon .... 1/2 in.

PENSTOCK INTAKE

- Inlet Flow Direction .... Inclined
- Opening Area .... 50 ft^2
- Material .... Steel

- Trashracks
  - Gross area .... 1550 ft^2
  - Bar clear spacing .... 2 in.

SIPHON PRIMING SYSTEM

- Number of Vacuum Pumps .... Two

- Vacuum Pump Data
  - Type .... Rotary, Liquid Ring Seal, Nonpulsating, Single Stage, Cone Type
  - Manufacturer .... Nash
  - Model Number MHC-130
  - Power .... 7.5 hp
  - Capacity .... 136 cfm at 24 in. Hg

- Priming Valve
  - Manufacturer .... APCO
  - Size .... 3/4 in.

- Air Inlet (Vacuum Breaker) Valve
  - Type .... Butterfly
  - Manufacturer .... Quaker City Valve Actuation
  - Model number .... FIG 660 Resilient Seated
  - Size .... 12 in.

- Vacuum Control Tank Size .... 36 ft^3

- Volume of Air to be Removed for Siphon Priming .... 3024 ft^3

- Siphon Priming Time .... 25 min.

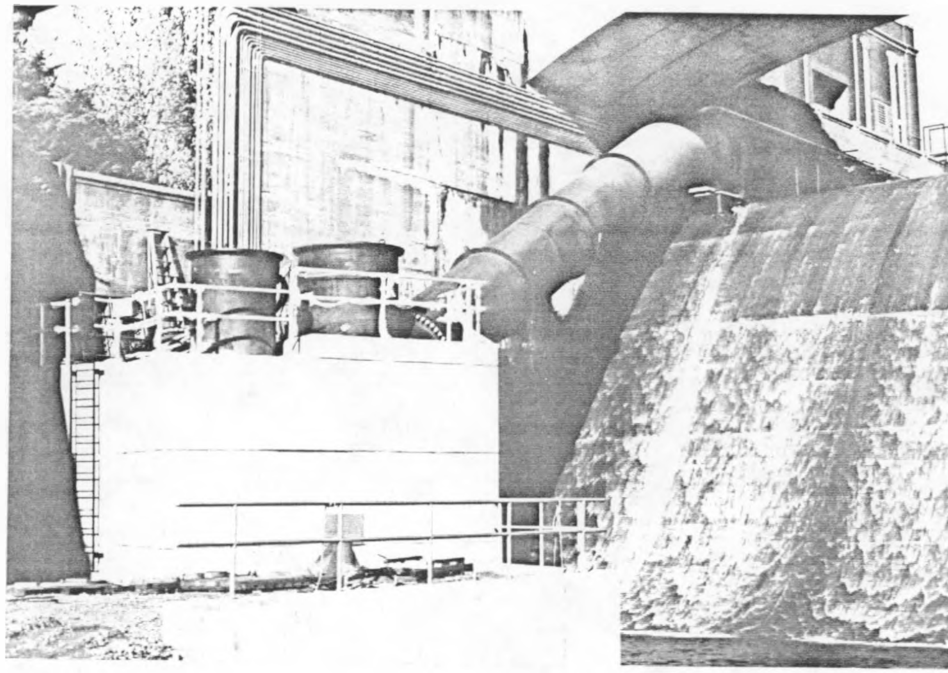


Figure D-1 Ontelaunee - Powerhouse

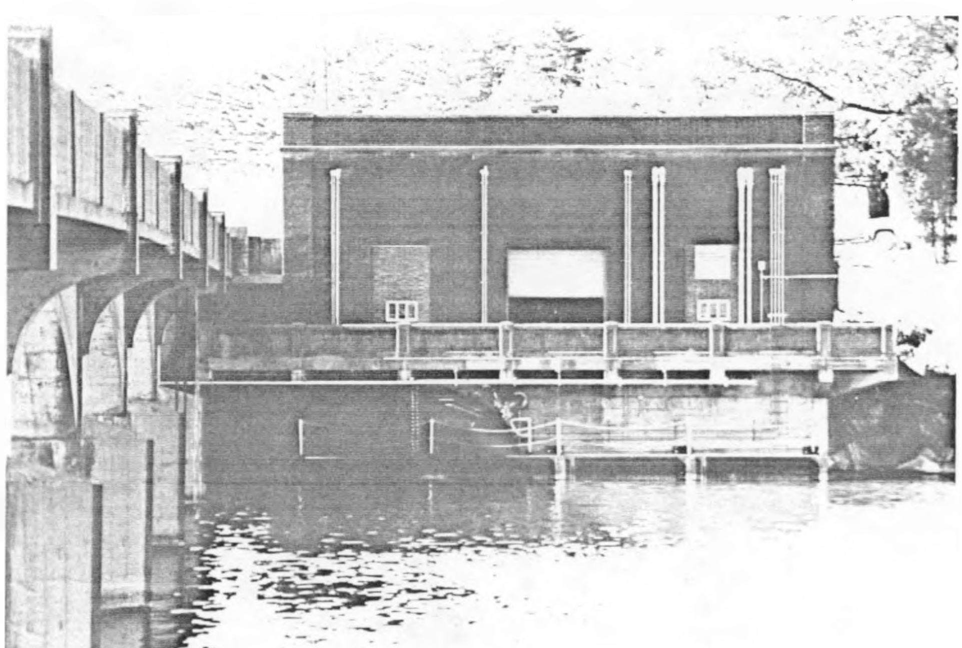


Figure D-2 Ontelaunee - Intake Area

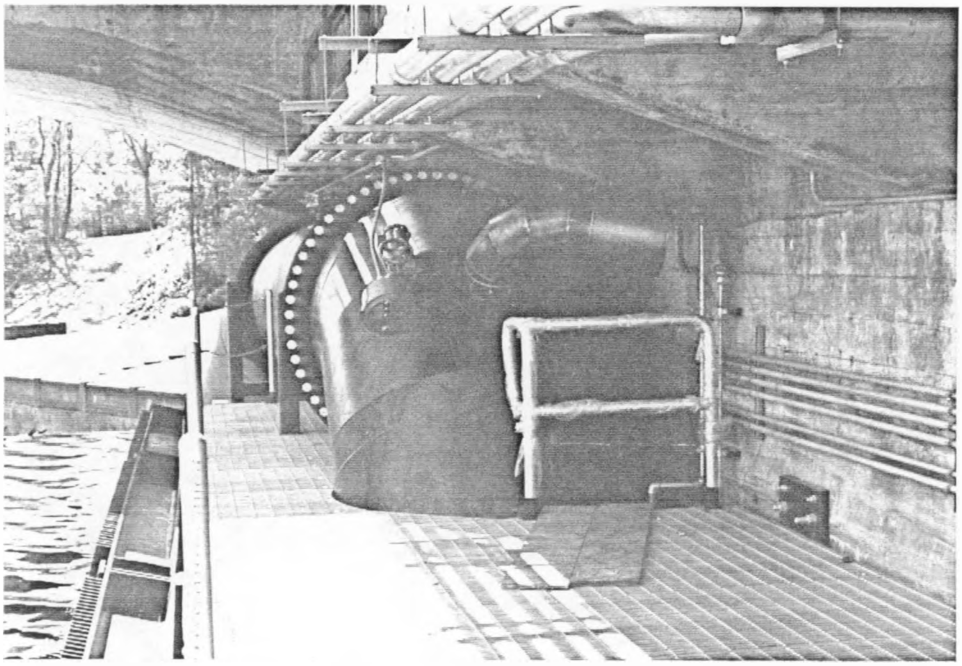
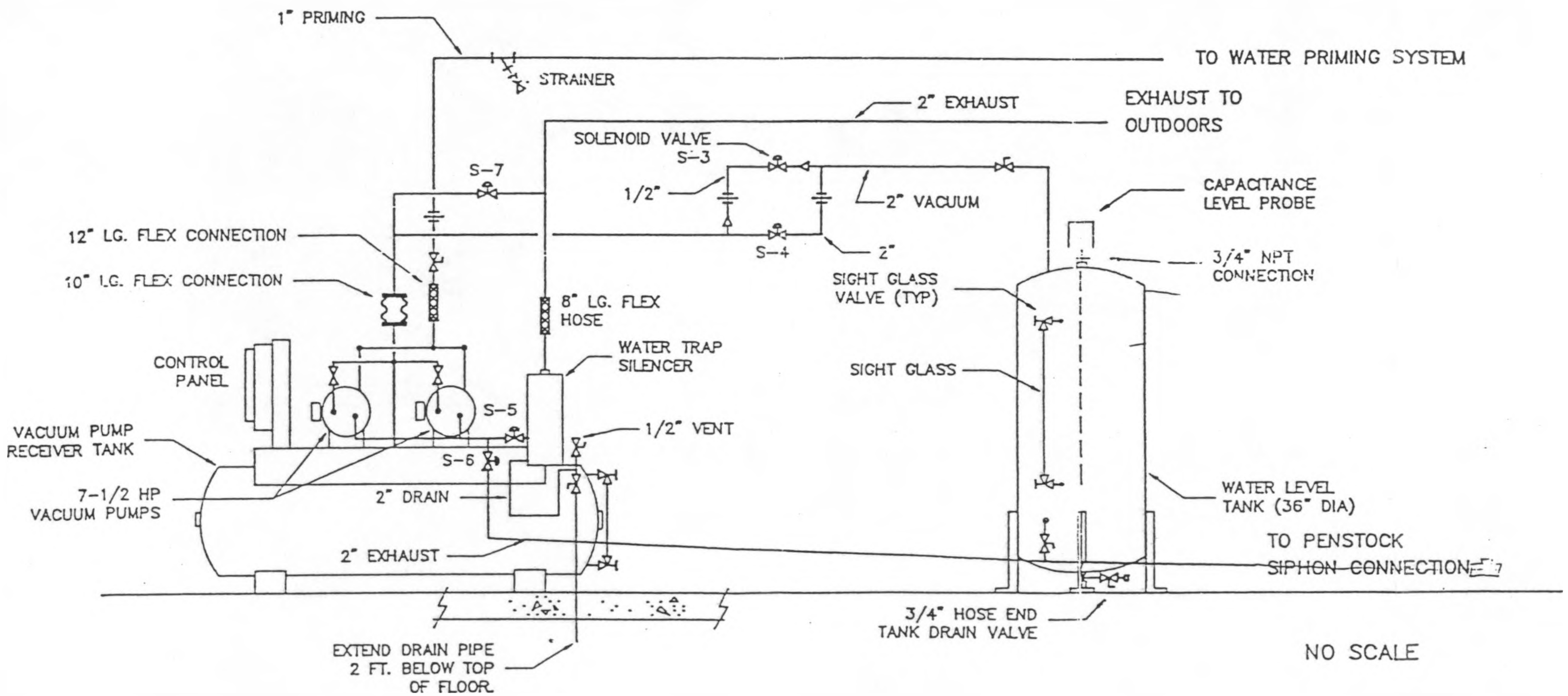


Figure D-3 Ontelaunee - Siphon Crown

SOLENIOD VALVES

	S-3 (N.O.)	S-4 (N.O.)	S-5 (N.O.)	S-6 (N.C.)	S-7 (N.C.)
VACUUM PUMP MODE	OPEN	OPEN	OPEN	CLOSED	CLOSED
COMPRESSOR MODE	CLOSED	CLOSED	CLOSED	OPEN	OPEN
SIZE	1/2 INCH	2 INCH	2 INCH	2 INCH	2 INCH



NO SCALE

NOTES: REVERSE VIEW OF SECTION R-R ON DRAWING MEE002-M003 SHOWING PIPING FOR VACUUM AND COMPRESSOR MODES OF OPERATION.

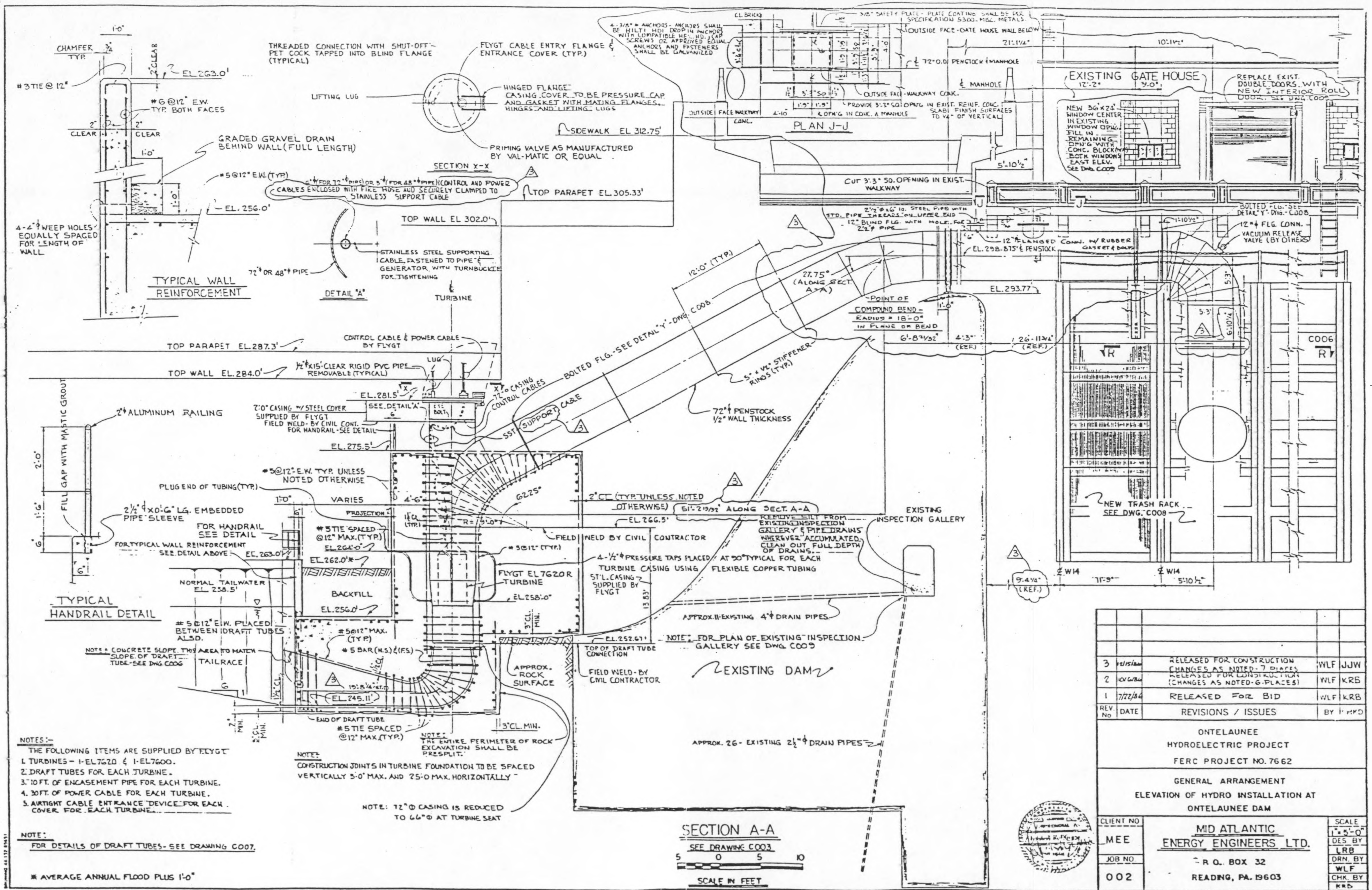
POSITION WATER LEVEL TANK AS CLOSE AS POSSIBLE TO VACUUM PUMP TO ELIMINATE TRIPPING HAZARD.

DIAGRAM # 1

ONTELAUNEE HYDRO PROJECT
VACUUM/ COMPRESSION SYSTEM

PROJECT NUMBER: MEE002

DATE	BY	CHK'D
6/8/87	KAJ	[illegible]



NOTES:-
THE FOLLOWING ITEMS ARE SUPPLIED BY FLYGT
1. TURBINES - 1-EL7620 & 1-EL7600.
2. DRAFT TUBES FOR EACH TURBINE.
3. 10 FT. OF ENCASEMENT PIPE FOR EACH TURBINE.
4. 30 FT. OF POWER CABLE FOR EACH TURBINE.
5. AIRTIGHT CABLE ENTRANCE DEVICE FOR EACH COVER FOR EACH TURBINE.

NOTE:
FOR DETAILS OF DRAFT TUBES - SEE DRAWING C007.

* AVERAGE ANNUAL FLOOD PLUS 1'-0"

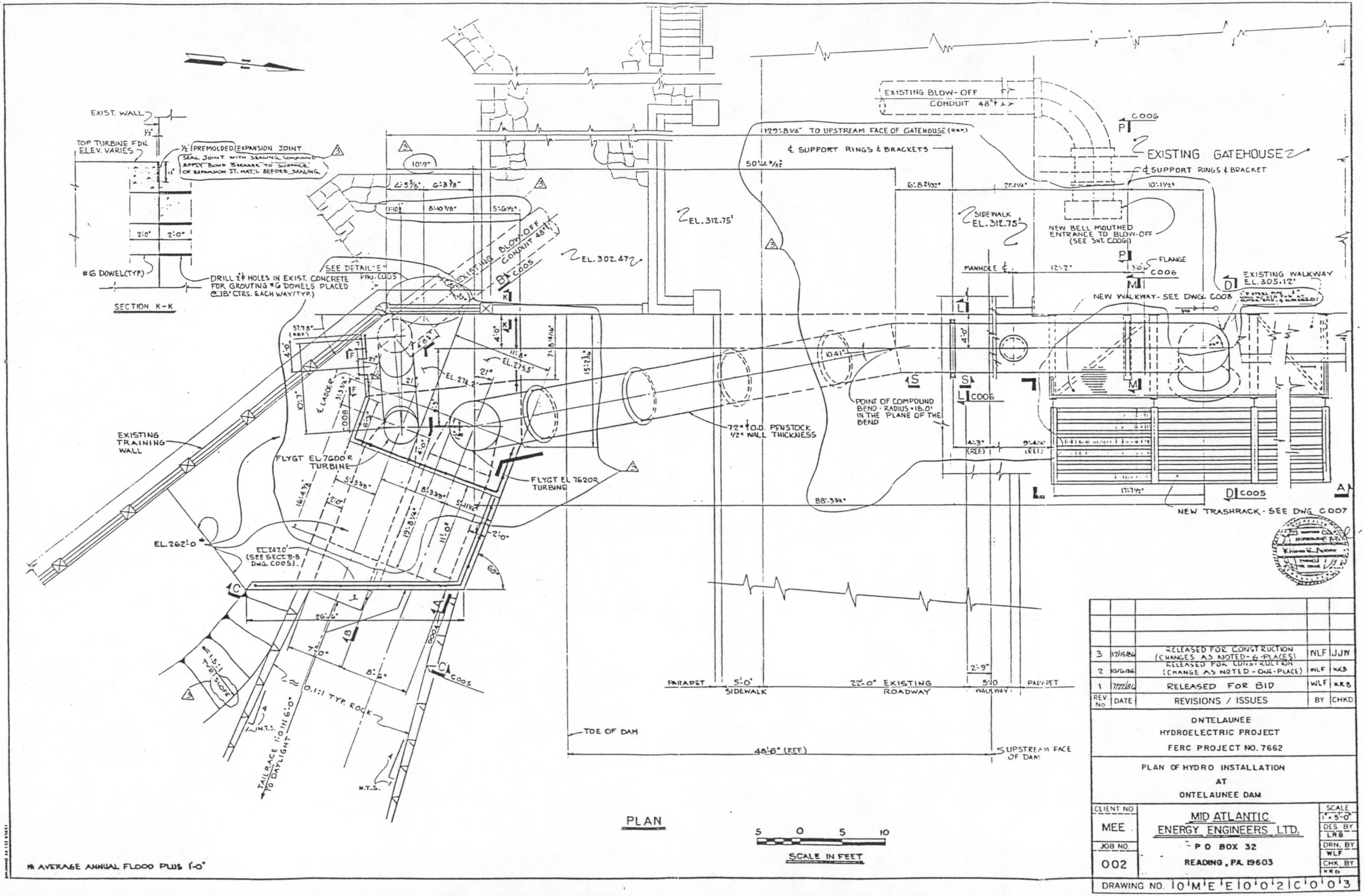
REV. No	DATE	REVISIONS / ISSUES	BY	CHKD
3	12/15/86	RELEASED FOR CONSTRUCTION CHANGES AS NOTED - 7 PLACES	WLF	JJW
2	10/16/86	RELEASED FOR CONSTRUCTION (CHANGES AS NOTED - 6 PLACES)	WLF	KRB
1	7/22/86	RELEASED FOR BID	WLF	KRB

ONTELAUNEE HYDROELECTRIC PROJECT
FERC PROJECT NO. 7662

GENERAL ARRANGEMENT
ELEVATION OF HYDRO INSTALLATION AT ONTELAUNEE DAM

CLIENT NO		SCALE
MEE	MID ATLANTIC ENERGY ENGINEERS LTD.	1" = 5'-0"
JOB NO.	P.O. BOX 32	DES. BY LRB / DRN. BY WLF
002	READING, PA. 19603	CHK. BY KRB

DRAWING NO. 0 M E E 0 0 2 C 0 0 4



REV. No	DATE	REVISIONS / ISSUES	BY	CHKD
3	12/15/86	RELEASED FOR CONSTRUCTION (CHANGES AS NOTED - 6 PLACES)	WLF	JJW
2	10/6/86	RELEASED FOR CONSTRUCTION (CHANGE AS NOTED - ONE PLACE)	WLF	KRB
1	7/22/86	RELEASED FOR BID	WLF	KRB

ONTELAUNEE HYDROELECTRIC PROJECT

FERC PROJECT NO. 7662

PLAN OF HYDRO INSTALLATION AT ONTELAUNEE DAM

CLIENT NO. MEE

JOB NO. 002

MID ATLANTIC ENERGY ENGINEERS LTD.
P O BOX 32
READING, PA 19603

SCALE 1" = 5'-0"
DES. BY LRB
DRN. BY WLF
CHK. BY KRB

DRAWING NO. 0 M E E 0 0 2 C 0 0 3

APPENDIX E

PINE GROVE DAM HYDROELECTRIC STATION

PINE GROVE DAM HYDROELECTRIC STATION

The Pine Grove Dam Hydroelectric Station is located in Little Britain Township, Lancaster County, Pennsylvania, on the north bank of Octoraro Creek. The power plant was constructed at the existing Pine Grove Dam in 1985 and has a single 511 kW, 39 ft head generating unit.

The intake is an inverted morning glory type. Inclined trashracks are provided in the vertical wall of the intake structure on three sides of the intake. The trashracks are manually raked.

The penstock has a nominal diameter of 72 inches, and is of fabricated steel construction in the intake and siphon area. The 1,048 ft section of penstock between the siphon and the powerhouse is constructed of prestressed concrete cylinder pipe. The upstream portion of the penstock is horizontal from the intake structure to the dam embankment where it is buried and follows the upstream slope of the dam. The penstock bends to a horizontal position at the crown of the siphon then enters the siphon priming structure foundation, which is located near the right abutment of the dam. Downstream of the siphon priming structure, the penstock becomes exposed, bends downward, and follows the downstream slope of the embankment.The joint between steel and concrete penstocks, and the remaining downstream concrete penstock, are buried.

The siphon priming system consists of two rotary, liquid ring seal vacuum pumps, a vacuum tank, and associated piping, valves, and controls. An ejector, which operates with water from a nearby water main, provides siphon priming in the event of loss of power supply to the vacuum pumps. Prior to priming the siphon, the long section of penstock downstream of the siphon crown is filled from headwater using an eight-inch priming line, which itself is primed by the main vacuum system. The vacuum pumps, tank, and ejector are located in the siphon priming structure.

The generating unit has a semi-Kaplan tubular turbine with a butterfly valve at the turbine intake. The generator is a horizontal induction type driven through a parallel shaft speed increaser.

The turbine is dewatered by closing the inlet valve and installing stoplogs at the draft tube exit. The penstock system is drained by opening the six-inch vacuum breaker valve on the vent pipe in the siphon priming structure.

The plant is operated on a modified run-of-river basis to meet water supply requirements. Power generation is programmed to vary according to calendar months and reservoir level. The unit is automatically controlled by a programmable controller. An operator is required to initiate the siphon priming operation.

PINE GROVE DAM HYDROELECTRIC STATION

PROJECT OWNER: CHESTER WATER AUTHORITY, CHESTER, PENNSYLVANIA

FERC NO.: 3498-PA

LOCATION: LITTLE BRITAIN TOWNSHIP, LANCASTER COUNTY, PENNSYLVANIA
OCTORARO CREEK

ENGINEER: GANNETT FLEMING WATER RESOURCES ENGINEERS, INC.

Year of Initial Operation 1985

Plant Capacity .... 478 kW

Plant Flow.................... 175 cfs

Rated Head. .... 39 ft

Number of Units .... One

HYDRAULIC CONDITIONS

– Headwater Level
- Maximum (for plant operation) .... El 284.0
- Normal .... El 280.0
- Minimum (for plant operation) .... El 274.0

– Tailwater Level
- Maximum (for plant operation) .... El 254.0
- Normal .... El 235.5
- Minimum (for plant operation) .... El 235.5

– Gross Head
- Maximum (for plant operation) .... 44.5 ft
- Normal .... 38.5 ft
- Minimum (for plant operation) .... 30.0 ft

GENERATING UNIT DATA

– Turbine
- Manufacturer .... Allis-Chalmers
- Type .... Semi-Kaplan (Tubular)
- Rated Net Head .... 39 ft
- Rated Power .... 685.25 hp
- Speed .... 450 rpm
- Runner Diameter .... 39.37 in.
- Number of Blades .... Five

– Generator
- Manufacturer .... Siemens-Allis, Inc.

PINE GROVE DAM HYDROELECTRIC STATION

- Type .... Induction
- Rated Output .... 546 kVA
- Power Factor 0.875
- Rated Power .... 478 kW
- Speed .... 1800 rpm
- Voltage .... 4160 V

– Speed Increaser
- Manufacturer .... Philadelphia Gear Co.
- Type .... Parallel Shaft
- Rating (transmitted power) .... 685 hp
- Service Factor 1.5

– Blade Positioner
- Manufacturer .... Pneumatic and Hydraulic Distributors, Inc.
- Type .... Hydraulic Actuated

– Controls
- Manufacturer .... Powercon Corp.
- Type .... Programmable Controller, Allen Bradley PLC 2

PENSTOCK DATA

– Number of Siphon Penstocks .... One

– Diameter
- Nominal .... 6 ft
- At siphon .... 6 ft

– Length
- Intake to top of siphon .... 149.25 ft
- Top of siphon to turbine runner .... 1240.50 ft

– Elevation of Penstock Centerline at Top of Siphon .... El 293.00

– Siphon Lift (headwater level to penstock centerline at top of siphon)
- Minimum .... 9.0 ft
- Normal .... 13.0 ft
- Maximum .... 19.0 ft

– Design Flow
- Maximum .... 200 cfs
- Normal .... 150 cfs
- Minimum .... 50 cfs

– Penstock Material .... Steel and Prestressed Concrete Cylinder Pipe

– Material Thickness at Top of Siphon .... 0.500 in. (steel)

PENSTOCK INTAKE

- Inlet Flow Direction .... Vertical
- Opening Area .... 78.54 ft^2
- Material .... Steel
- Trashracks
  - Gross area .... 288 ft^2
  - Net area .... 250.3 ft^2
  - Bar clear spacing .... 2.5 in.

SIPHON PRIMING SYSTEM

- Number of Vacuum Pumps .... Two

- Vacuum Pump Data
  - Type .... Rotary, Liquid Ring Seal, Cone Type
  - Manufacturer .... Nash
  - Model Number .... Size OV-6A Duplex System w/Type CL Size MHC-80 Pumps
  - Power .... 5 hp
  - Capacity .... 77 cfm at 20 in. Hg; 68 cfm at 25 in. Hg

- Vacuum Tank Capacity .... 18 ft^3

- Priming Valve
  - Type .... Ball Valve
  - Manufacturer .... Rockwell-McCanna
  - Model Number M502BR-T-RR
  - Size .... 2-in. with Hydraulic Actuator Operated by a 4-way Solenoid Valve

- Air Inlet (Vacuum Breaker) Valve
  - Type .... Ball Valve
  - Manufacturer .... Jamesbury
  - Model Number 5150
  - Size .... 6 in.

- Volume of Air to be Removed for Siphon Priming
  - Turbine inlet valve to reservoir level (filled by an 8-inch priming siphon line) .... 36,000 ft^3
  - Reservoir level to penstock soffit (evacuated by vacuum pumps) .... 5,000 ft^3

- Siphon Priming Time
  - By 8-inch siphon .... 300 min.
  - By vacuum pumps .... 90 min.

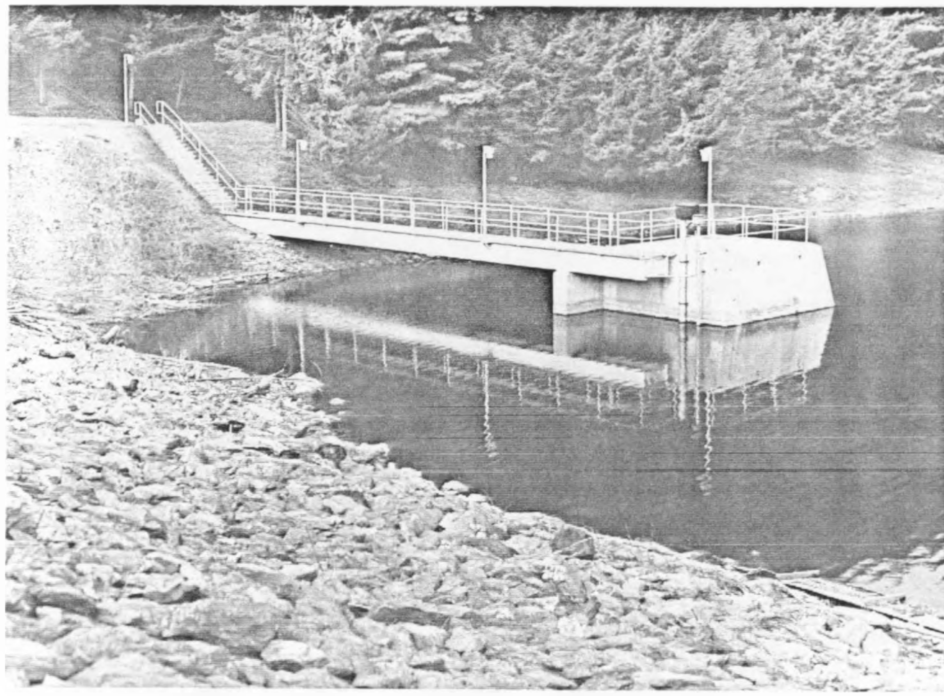


Figure E-1 Pine Grove Dam - Siphon Intake Area

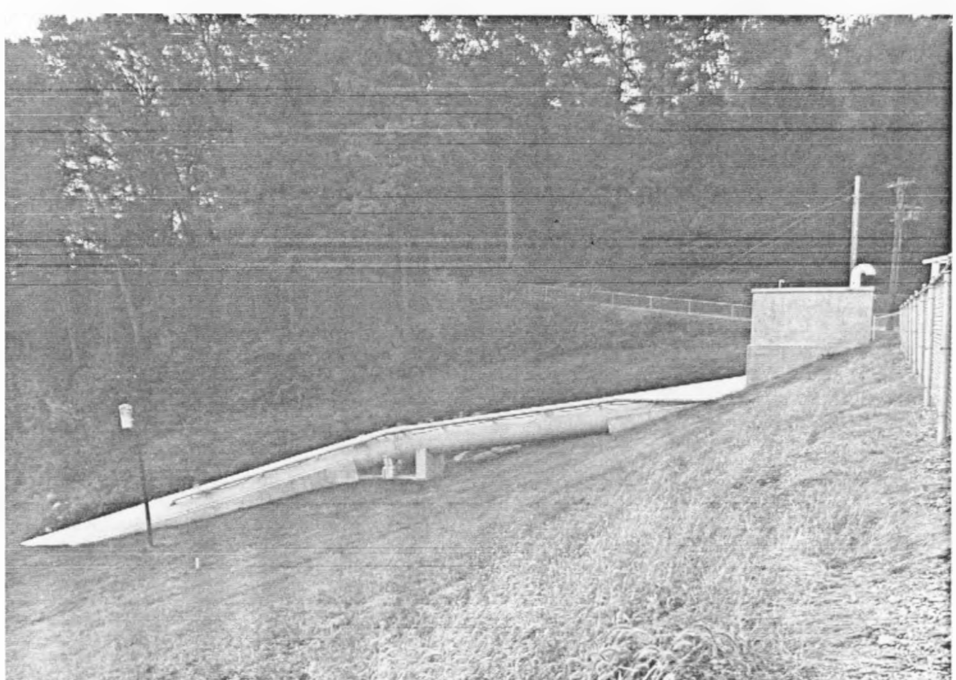


Figure E-2 Pine Grove Dam - Penstock Section Downstream of Siphon Crown

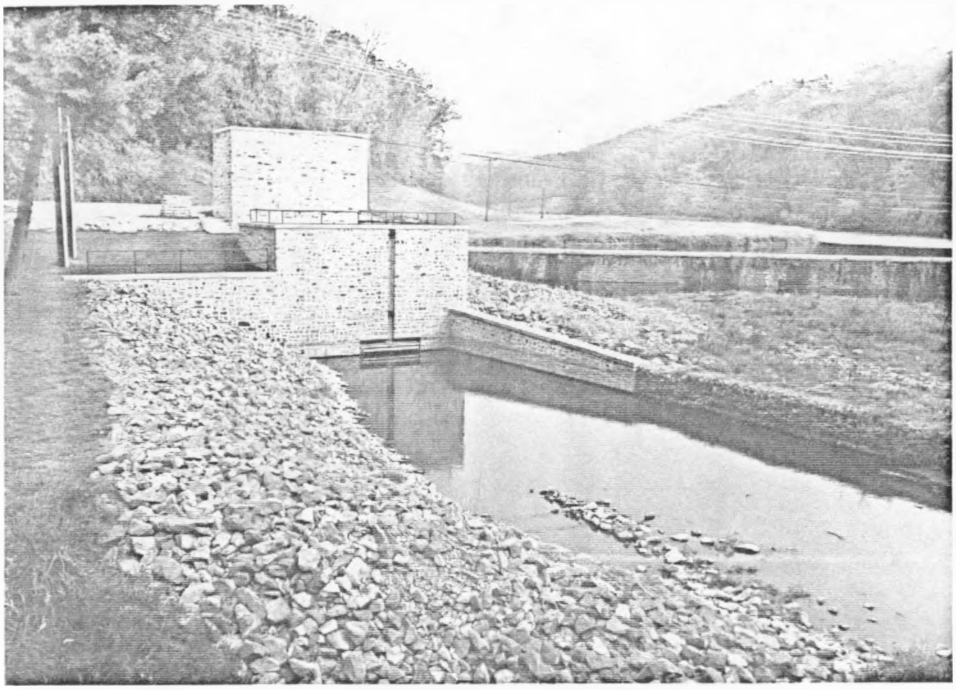


Figure E-3 Pine Grove Dam - Powerhouse and Tailrace Area

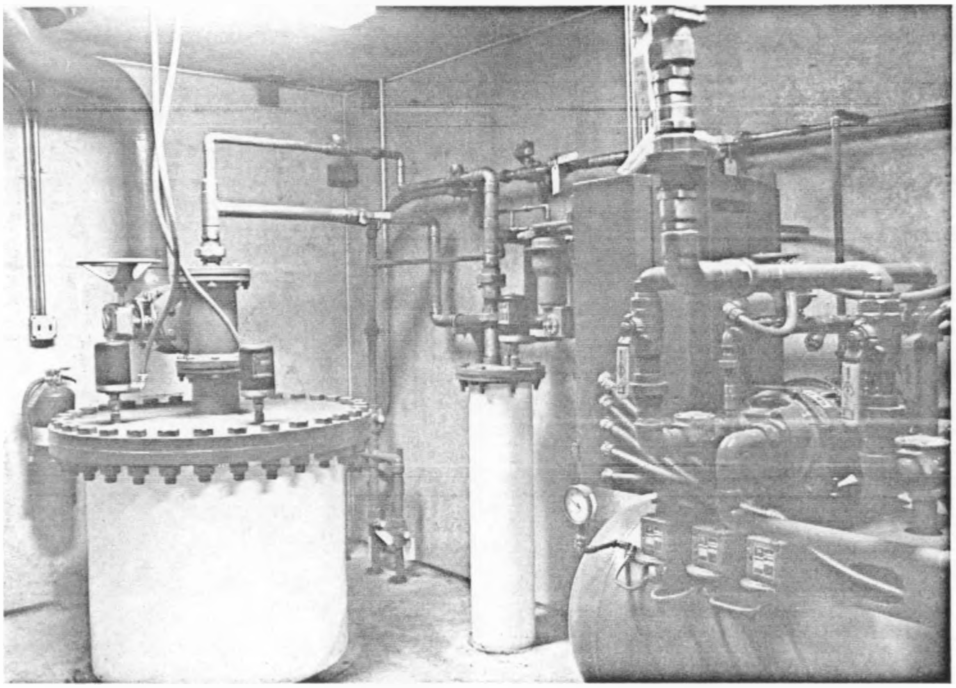
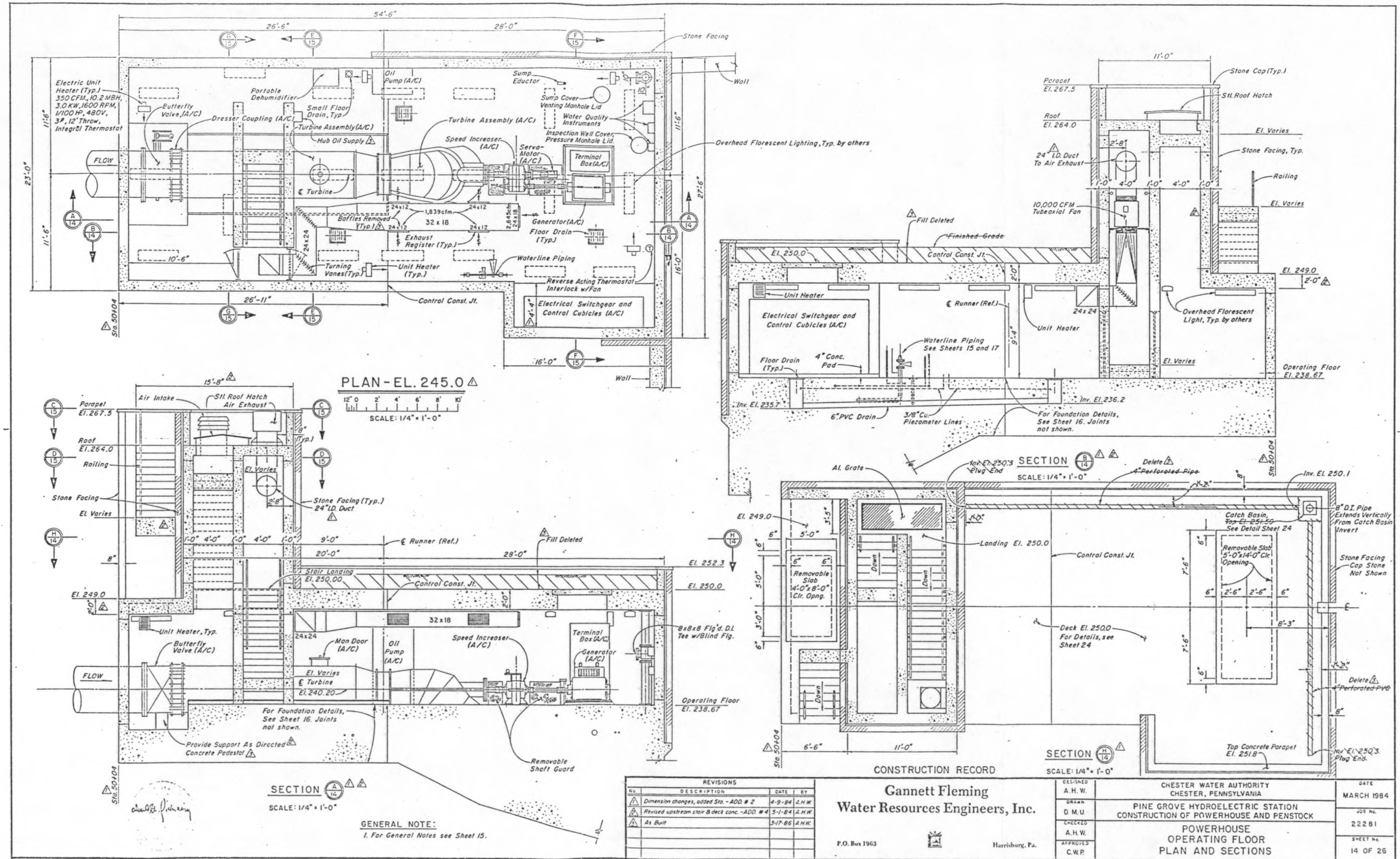
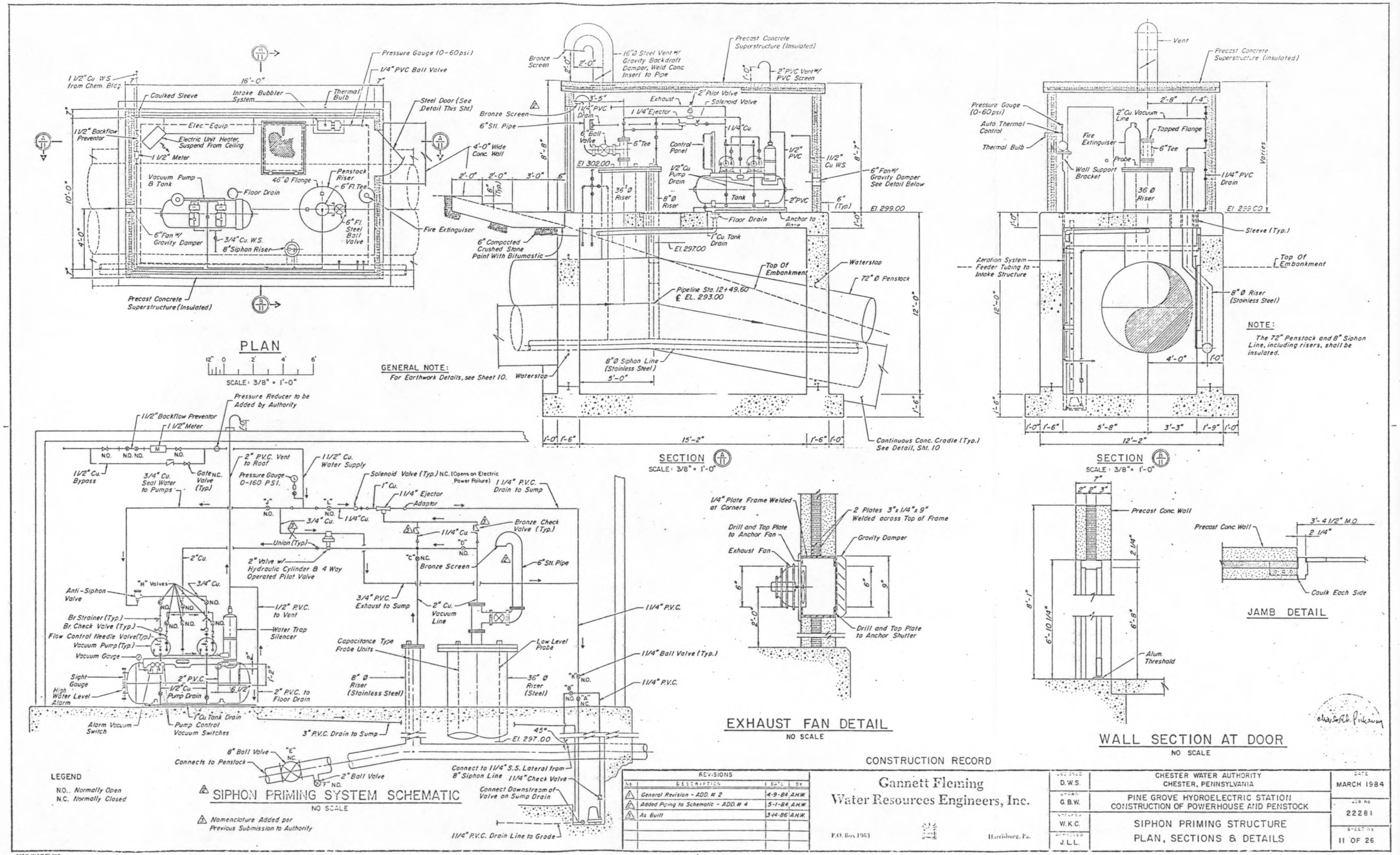


Figure E-4 Pine Grove Dam - Interior of Siphon Priming Structure



PLAN - EL. 245.0
SCALE: 1/4" = 1'-0"
54'-6"
26'-6"
28'-0"
Stone Facing
Wall
Electric Unit Heater (Typ.) 350 CFM., 10.2 MBH, 3.0 KW, 1600 RPM, 1/100 HP, 480V, 3Ø, 12' Throw, Integral Thermostat
Butterfly Valve (A/C)
Dresser Coupling (A/C)
Portable Dehumidifier
Oil Pump (A/C)
Small Floor Drain, Typ.
Turbine Assembly (A/C)
Hub Oil Supply
Sump Eductor
Sump Cover-Venting Manhole Lid
Water Quality Instruments
Inspection Well Cover, Pressure Manhole Lid
Speed Increaser (A/C)
Servo-Motor (A/C)
Terminal Box (A/C)
Overhead Florescent Lighting, Typ. by others
FLOW
℄ Turbine
Baffles Removed (Typ.)
1,839cfm
32 x 18
24x12
Exhaust Register (Typ.)
Generator (A/C)
Floor Drain (Typ.)
Turning Vanes (Typ.)
Unit Heater (Typ.)
Waterline Piping
Reverse Acting Thermostat Interlock w/Fan
Electrical Switchgear and Control Cubicles (A/C)
Control Const. Jt.
Sta. 50+04
SECTION A/14
SCALE: 1/4" = 1'-0"
Parapet El. 267.5
Roof El. 264.0
Railing
Stone Facing
El. Varies
Air Intake
Stl. Roof Hatch
Air Exhaust
Stone Facing (Typ.)
24" I.D. Duct
℄ Runner (Ref.)
Fill Deleted
Stair Landing El. 250.00
El. 252.3
El. 250.0
El. 249.0
Unit Heater, Typ.
Man Door (A/C)
Oil Pump (A/C)
El. Varies
℄ Turbine
El. 240.20
8x8x8 Flg'd. D.I. Tee w/Blind Flg.
Operating Floor El. 238.67
For Foundation Details, See Sheet 16. Joints not shown.
Provide Support As Directed
Concrete Pedestal
Removable Shaft Guard
SECTION B/14
SCALE: 1/4" = 1'-0"
Stone Cap (Typ.)
Stl. Roof Hatch
24" I.D. Duct To Air Exhaust
10,000 CFM Tubeaxial Fan
Finished Grade
Electrical Switchgear and Control Cubicles (A/C)
Floor Drain (Typ.)
4" Conc. Pad
Waterline Piping See Sheets 15 and 17
6" PVC Drain
3/8" Cu. Piezometer Lines
Inv. El. 235.7
Inv. El. 236.2
Overhead Florescent Light, Typ. by others
Operating Floor El. 238.67
SECTION H/14
SCALE: 1/4" = 1'-0"
Al. Grate
Inv. El. 250.3 Plug End
Delete 4" Perforated Pipe
Inv. El. 250.1
8" D.I. Pipe Extends Vertically From Catch Basin Invert
Catch Basin, Top El. 251.50 See Detail Sheet 24
Landing El. 250.0
Removable Slab 4'-0"x8'-0" Clr. Opng.
Removable Slab 5'-0"x14'-0" Clr. Opening
Deck El. 250.0 For Details, see Sheet 24
Stone Facing Cap Stone Not Shown
Delete 4" Perforated PVC
Top Concrete Parapet El. 251.8
GENERAL NOTE:
1. For General Notes see Sheet 15.
CONSTRUCTION RECORD
REVISIONS
No. | DESCRIPTION | DATE | BY
1 | Dimension changes, added Sta. - ADD. # 2 | 4-9-84 | A.H.W.
2 | Revised upstream stair & deck conc. - ADD. # 4 | 5-1-84 | A.H.W.
3 | As Built | 3-17-86 | A.H.W.
Gannett Fleming Water Resources Engineers, Inc.
P.O. Box 1963
Harrisburg, Pa.
DESIGNED A.H.W.
DRAWN D.M.U.
CHECKED A.H.W.
APPROVED C.W.P.
CHESTER WATER AUTHORITY CHESTER, PENNSYLVANIA
PINE GROVE HYDROELECTRIC STATION CONSTRUCTION OF POWERHOUSE AND PENSTOCK
POWERHOUSE OPERATING FLOOR PLAN AND SECTIONS
DATE MARCH 1984
JOB No. 22281
SHEET No. 14 OF 26

1-33600



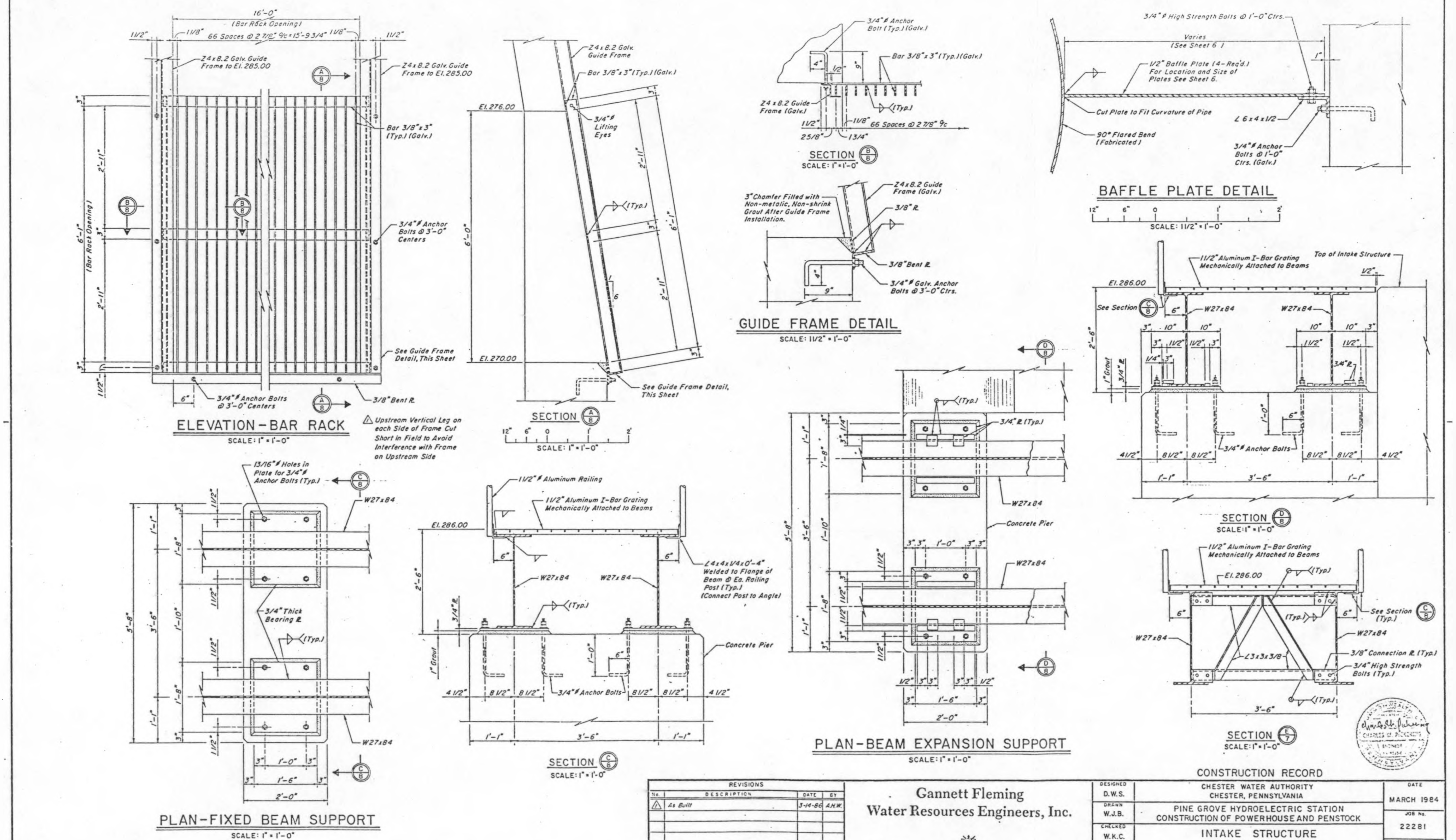
CONSTRUCTION RECORD

REVISIONS

NO.	DESCRIPTION	DATE	BY
1	General Revision - ADD. # 2	4-9-84	A.H.W.
2	Added Piping to Schematic - ADD. # 4	5-1-84	A.H.W.
3	As Built	3-14-86	A.H.W.

Gannett Fleming
Water Resources Engineers, Inc.
P.O. Box 1963 — Harrisburg, Pa.

DESIGNED D.W.S.	CHESTER WATER AUTHORITY CHESTER, PENNSYLVANIA	DATE	MARCH 1984
DRAWN G.B.W.	PINE GROVE HYDROELECTRIC STATION CONSTRUCTION OF POWERHOUSE AND PENSTOCK	JOB NO.	22281
CHECKED W.K.C.	SIPHON PRIMING STRUCTURE	SHEET NO.	11 OF 26
APPROVED J.L.L.	PLAN, SECTIONS & DETAILS		



CONSTRUCTION RECORD

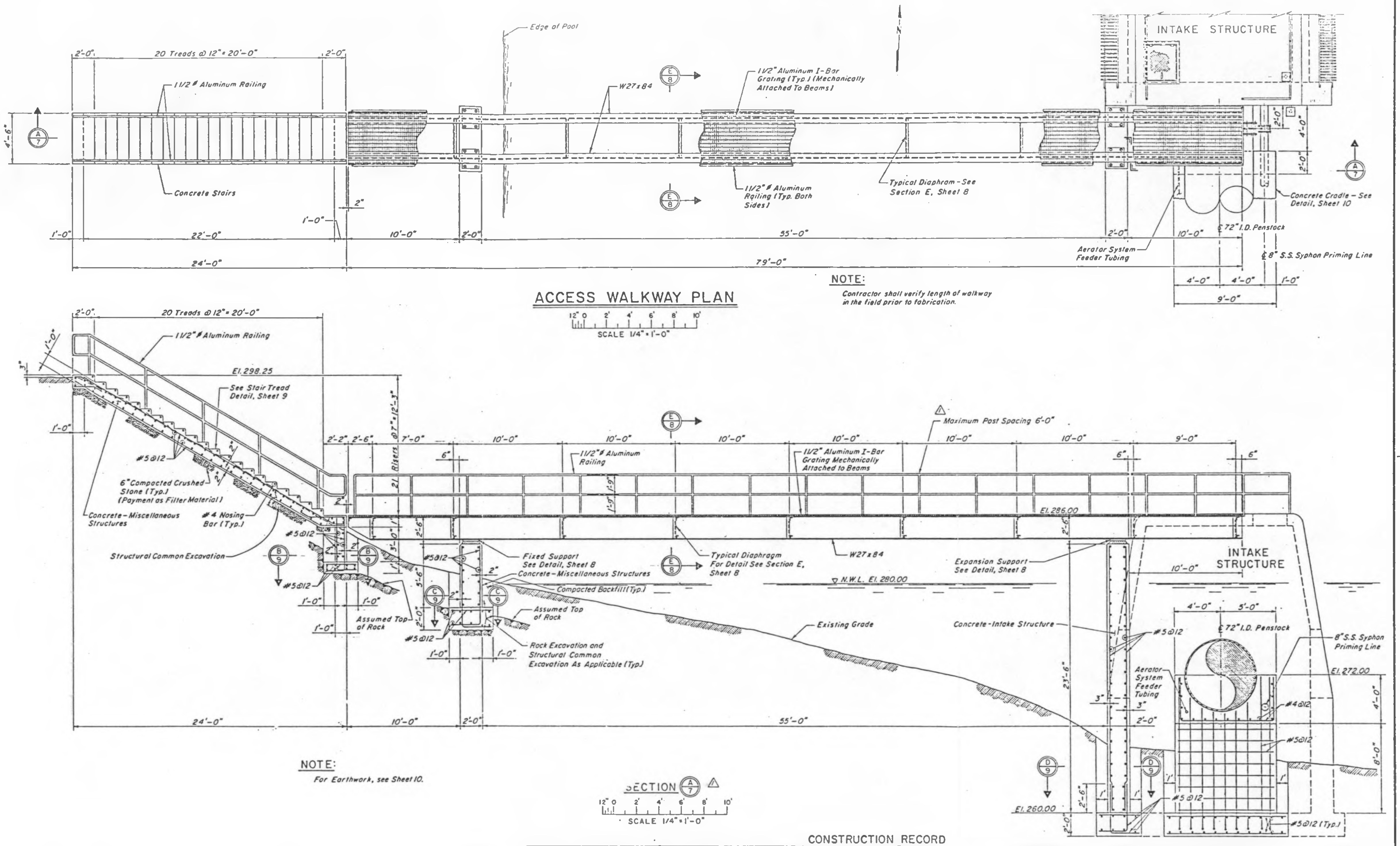
REVISIONS			
No.	DESCRIPTION	DATE	BY
△	As Built	3-14-86	A.H.W.

Gannett Fleming Water Resources Engineers, Inc.

P.O. Box 1963 Harrisburg, Pa.

DESIGNED D.W.S.	CHESTER WATER AUTHORITY CHESTER, PENNSYLVANIA	DATE MARCH 1984
DRAWN W.J.B.	PINE GROVE HYDROELECTRIC STATION CONSTRUCTION OF POWERHOUSE AND PENSTOCK	JOB No. 22281
CHECKED W.K.C.	INTAKE STRUCTURE ACCESS WALKWAY SECTIONS AND DETAILS	SHEET No. 8 OF 26
APPROVED J.L.L.		

1-33592



CONSTRUCTION RECORD

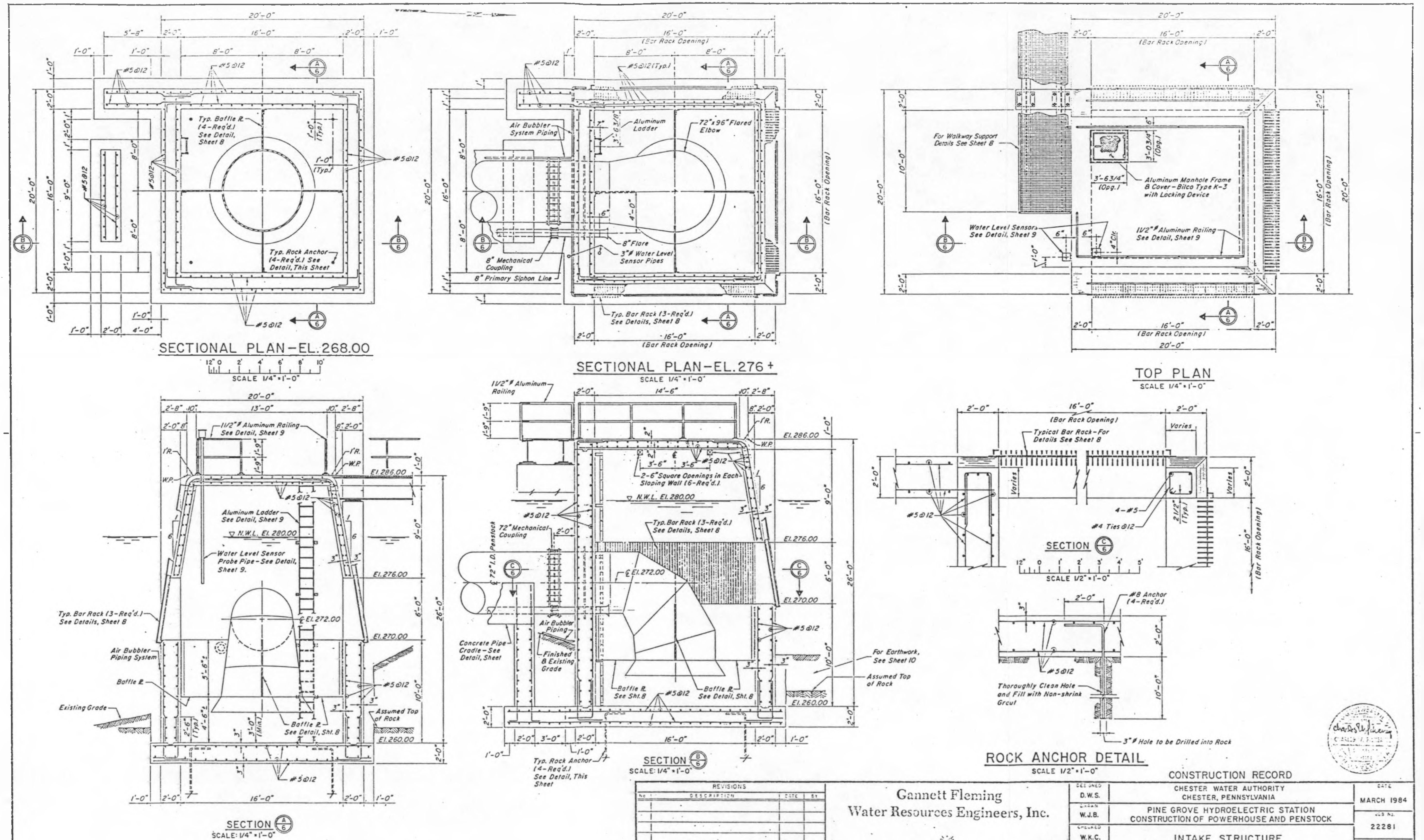
REVISIONS			
No.	DESCRIPTION	DATE	BY
△	Added Max. Post Spacing dimension - ADD #4	5-1-84	A.H.W.

Gannett Fleming Water Resources Engineers, Inc.

P.O. Box 1963 Harrisburg, Pa.

DESIGNED D.W.S.	CHESTER WATER AUTHORITY CHESTER, PENNSYLVANIA	DATE MARCH 1984
DRAWN W.J.B.	PINE GROVE HYDROELECTRIC STATION CONSTRUCTION OF POWERHOUSE AND PENSTOCK	JOB No. 22281
CHECKED W.K.C.	INTAKE STRUCTURE ACCESS WALKWAY PLAN AND SECTION	SHEET No. 7 OF 26
APPROVED J.L.L.		

1-33592

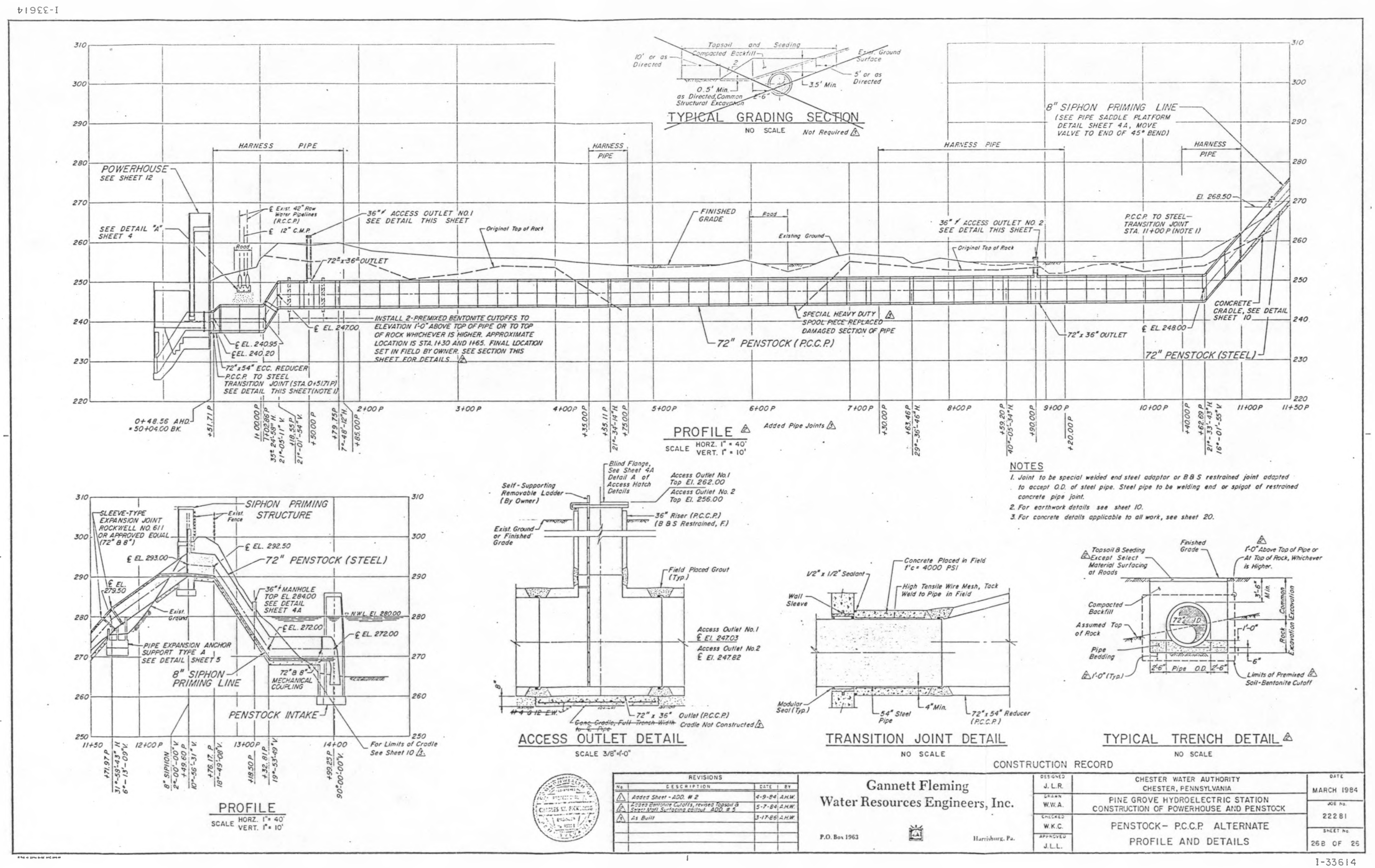


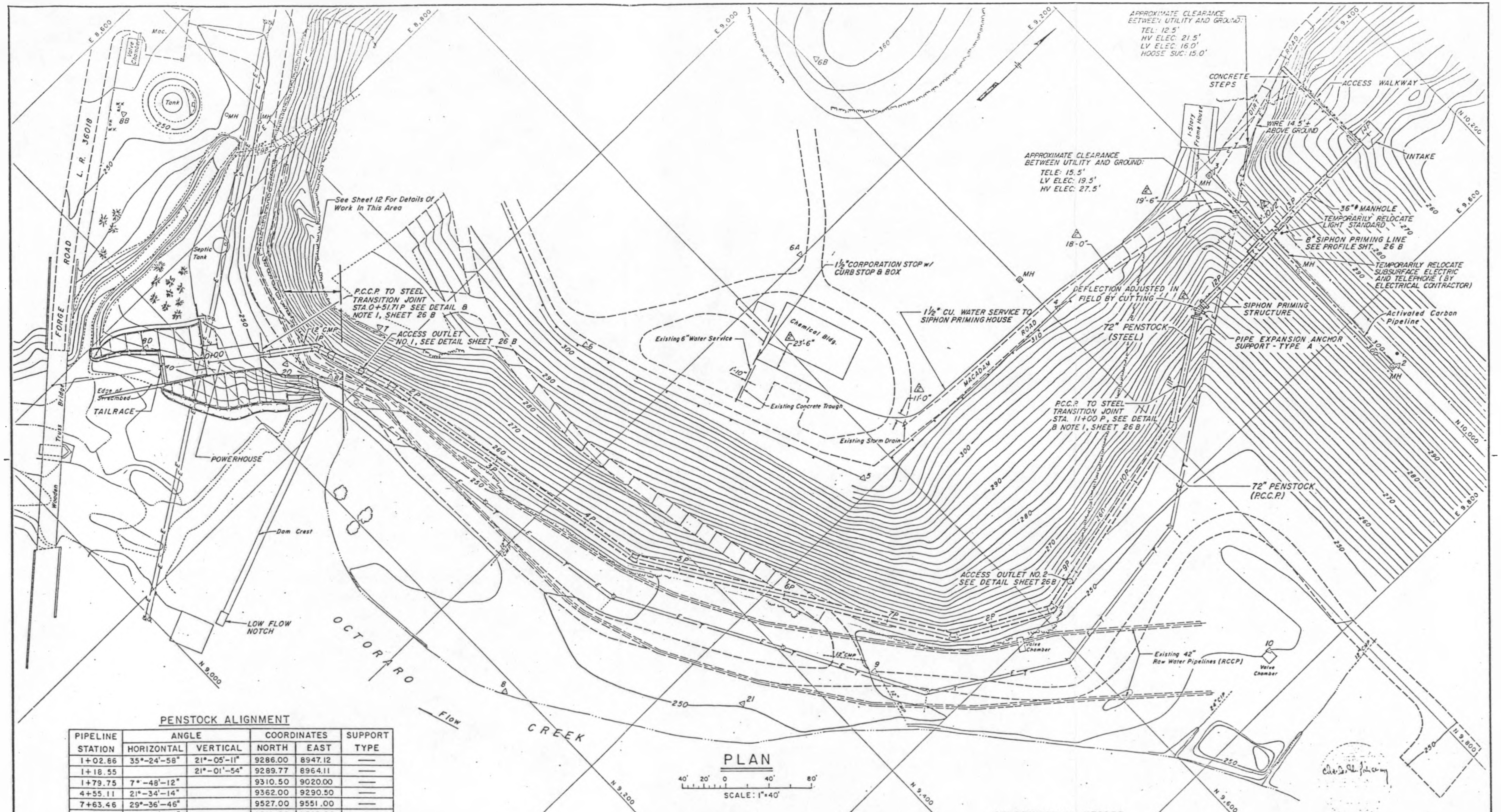
CONSTRUCTION RECORD

REVISIONS			
No.	DESCRIPTION	DATE	BY

Gannett Fleming
Water Resources Engineers, Inc.
P.O. Box 1963 Harrisburg, Pa.

DESIGNED D.W.S.	CHESTER WATER AUTHORITY CHESTER, PENNSYLVANIA	DATE MARCH 1984
DRAWN W.J.B.	PINE GROVE HYDROELECTRIC STATION CONSTRUCTION OF POWERHOUSE AND PENSTOCK	JOB No. 22281
CHECKED W.K.C.	INTAKE STRUCTURE	SHEET No. 6 OF 26
APPROVED J.L.L.	PLANS, SECTIONS AND DETAILS	


I-33614
TYPICAL GRADING SECTION
NO SCALE
Not Required
Topsoil and Seeding
Compacted Backfill
Exist. Ground Surface
10' or as Directed
0.5' Min. as Directed, Common Structural Excavation
3.5' Min.
5' or as Directed
8" SIPHON PRIMING LINE
(SEE PIPE SADDLE PLATFORM DETAIL SHEET 4A, MOVE VALVE TO END OF 45° BEND)
HARNESS PIPE
POWERHOUSE SEE SHEET 12
SEE DETAIL "A" SHEET 4
36"⌀ ACCESS OUTLET NO. 1 SEE DETAIL THIS SHEET
Original Top of Rock
FINISHED GRADE
Road
Existing Ground
36"⌀ ACCESS OUTLET NO. 2 SEE DETAIL THIS SHEET
P.C.C.P. TO STEEL- TRANSITION JOINT STA. 11+00 P (NOTE 1)
El. 268.50
72"x36" OUTLET
INSTALL 2-PREMIXED BENTONITE CUTOFFS TO ELEVATION 1'-0" ABOVE TOP OF PIPE OR TO TOP OF ROCK WHICHEVER IS HIGHER. APPROXIMATE LOCATION IS STA. 1+30 AND 1+65. FINAL LOCATION SET IN FIELD BY OWNER. SEE SECTION THIS SHEET FOR DETAILS
SPECIAL HEAVY DUTY SPOOL PIECE REPLACED DAMAGED SECTION OF PIPE
72" PENSTOCK (P.C.C.P.)
72" PENSTOCK (STEEL)
CONCRETE CRADLE, SEE DETAIL SHEET 10
℄ EL. 248.00
℄ EL. 247.00
℄ EL. 240.95
℄ EL. 240.20
72"x54" ECC. REDUCER
P.C.C.P. TO STEEL TRANSITION JOINT (STA. 0+51.71 P) SEE DETAIL THIS SHEET (NOTE 1)
0+48.56 AHD. = 50+04.00 BK.
PROFILE
SCALE HORZ. 1" = 40' VERT. 1" = 10'
Added Pipe Joints
NOTES
1. Joint to be special welded end steel adaptor or B & S restrained joint adapted to accept O.D. of steel pipe. Steel pipe to be welding end or spigot of restrained concrete pipe joint.
2. For earthwork details see sheet 10.
3. For concrete details applicable to all work, see sheet 20.
SLEEVE-TYPE EXPANSION JOINT ROCKWELL NO. 611 OR APPROVED EQUAL (72" & 8")
SIPHON PRIMING STRUCTURE
Exist. Fence
℄ EL. 292.50
℄ EL. 293.00
℄ EL. 279.50
72" PENSTOCK (STEEL)
36"⌀ MANHOLE TOP EL. 284.00 SEE DETAIL SHEET 4A
N.W.L. EL. 280.00
℄ EL. 272.00
PIPE EXPANSION ANCHOR SUPPORT TYPE A SEE DETAIL SHEET 5
8" SIPHON PRIMING LINE
72" & 8" MECHANICAL COUPLING
PENSTOCK INTAKE
For Limits of Cradle See Sheet 10
PROFILE
SCALE HORZ. 1" = 40' VERT. 1" = 10'
Self-Supporting Removable Ladder (By Owner)
Blind Flange, See Sheet 4A Detail A of Access Hatch Details
Access Outlet No. 1 Top El. 262.00
Access Outlet No. 2 Top El. 256.00
36" Riser (P.C.C.P.) (B & S Restrained, F.)
Exist. Ground or Finished Grade
Field Placed Grout (Typ.)
Access Outlet No. 1 ℄ El. 247.03
Access Outlet No. 2 ℄ El. 247.82
72" x 36" Outlet (P.C.C.P.)
Cradle Not Constructed
ACCESS OUTLET DETAIL
SCALE 3/8" = 1'-0"
1/2" x 1/2" Sealant
Concrete Placed in Field f'c = 4000 PSI
High Tensile Wire Mesh, Tack Weld to Pipe in Field
Wall Sleeve
Modular Seal (Typ.)
54" Steel Pipe
4" Min.
72" x 54" Reducer (P.C.C.P.)
TRANSITION JOINT DETAIL
NO SCALE
Topsoil & Seeding Except Select Material Surfacing at Roads
Finished Grade
1'-0" Above Top of Pipe or At Top of Rock, Whichever is Higher.
Compacted Backfill
Assumed Top of Rock
Pipe Bedding
1'-0" (Typ.)
2'-6" Pipe O.D. 2'-6"
Limits of Premixed Soil-Bentonite Cutoff
Rock Excavation
Common Excavation
TYPICAL TRENCH DETAIL
NO SCALE
CONSTRUCTION RECORD
REVISIONS
Added Sheet - ADD. # 2 4-9-84 A.H.W.
Added Bentonite Cutoffs, revised Topsoil & Select Matl Surfacing callout ADD. # 5 5-7-84 A.H.W.
As Built 3-17-86 A.H.W.
Gannett Fleming Water Resources Engineers, Inc.
P.O. Box 1963 Harrisburg, Pa.
DESIGNED J.L.R.
DRAWN W.W.A.
CHECKED W.K.C.
APPROVED J.L.L.
CHESTER WATER AUTHORITY CHESTER, PENNSYLVANIA
PINE GROVE HYDROELECTRIC STATION CONSTRUCTION OF POWERHOUSE AND PENSTOCK
PENSTOCK- P.C.C.P. ALTERNATE PROFILE AND DETAILS
DATE MARCH 1984
JOB No. 22281
SHEET No. 26B OF 26
I-33614



PLAN

40' 20' 0 40' 80'
SCALE: 1"=40'

PENSTOCK ALIGNMENT

PIPELINE STATION	ANGLE		COORDINATES		SUPPORT TYPE
	HORIZONTAL	VERTICAL	NORTH	EAST	
1+02.86	35°-24'-58"	21°-05'-11"	9286.00	8947.12	—
1+18.55		21°-01'-54"	9289.77	8964.11	—
1+79.75	7°-48'-12"		9310.50	9020.00	—
4+55.11	21°-34'-14"		9362.00	9290.50	—
7+63.46	29°-36'-46"		9527.00	9551.00	—
8+59.20	40°-05'-34"		9611.50	9596.00	
10+62.69	21°-33'-43"	16°-01'-55"	9810.50	9553.50	—
11+71.97	31°-58'-43"	6°-13'-09"	9901.50	9493.00	TYPE A
12+49.60		10°-56'-31"	9979.10	9490.78	—
12+76.17		18°-49'-08"	10005.66	9490.02	—
13+32.81		19°-53'-49"	10062.28	9488.40	—
13+99.25		90°-00'-00"	10128.69	9486.50	

CONSTRUCTION RECORD

REVISIONS			
No.	DESCRIPTION	DATE	BY
1	Added Sheet - ADD. # 2	4-9-84	A.H.W.
2	As Built	3-14-86	A.H.W.

Gannett Fleming
Water Resources Engineers, Inc.
P.O. Box 1963 Harrisburg, Pa.

DESIGNED D.W.S.	CHESTER WATER AUTHORITY CHESTER, PENNSYLVANIA		DATE MARCH 1984
DRAWN B.W.H.	PINE GROVE HYDROELECTRIC STATION CONSTRUCTION OF POWERHOUSE AND PENSTOCK		JOB No. 22281
CHECKED W.K.C.	GENERAL PLAN P.C.C.P. ALTERNATE		SHEET No. 26A OF 26
APPROVED J.L.L.			

APPENDIX F

POCONO LAKE HYDROELECTRIC PROJECT

POCONO LAKE HYDROELECTRIC PROJECT

The Pocono Lake Hydroelectric Project is located in Pocono Lake Preserve, Monroe County, Pennsylvania at the north abutment of the existing dam and bridge on Tobyhanna Creek. The power plant, which has one 59 kW, 24.5 ft head unit and two 113 kW, 23.8 ft head units, went into operation in 1986.

The plant has a single penstock with an inclined bellmouth intake opening. The intake has a steel frame trashrack structure with bar panels on the top, bottom, and three sides. A 12-inch deep timber grid is mounted under the top of the trashrack frame to prevent vortex formation. The top and side panels of the trashrack are cleaned with a hand rake. There is no access for cleaning the bottom trashrack panel.

The penstock has a nominal diameter of 5 ft with a trifurcation to the generating units near the powerhouse. The penstock is made from prefabricated sections with flanged and bolted field joints. The upstream portion of the penstock is angled at approximately 45 degrees and is supported at the apex of the siphon on the existing spillway crest. The portion of the penstock between the spillway crest and the trifurcation is inclined at 20 degrees to horizontal, and has structural steel supports. The branches from the trifurcation also have structural steel supports.

The overall length of the penstock from the intake to the trifurcation is approximately 39 ft, and the distance from the intake to the crown of the siphon is 17 ft. The two 4 ft diameter branches of the trifurcation are approximately 38 ft long, and the 3 ft diameter branch is about 35 ft long.

The siphon priming system consists of a liquid ring seal vacuum pump and associated piping, valves, and controls. The controls are housed in the electrical control building, which is located adjacent to the existing spillway training wall. The vacuum pump is outdoors adjacent to the control building.

The generating units are vertical submersible type with fixed discharge propeller turbines and induction generators. The units are connected to the electrical grid through the switchgear and the transformer.

An inlet butterfly valve is provided upstream of each turbine and is the primary flow control for each unit. The turbines are dewatered and isolated from the penstock by closing the inlet valve. The penstock system is drained by stopping the siphon effect with the vacuum breaker valve.

The plant is operated on a run-of-river basis to maintain a constant headwater level. Flood flows in excess of the capacity of the units pass over the spillway. The units are automatically controlled by a programmable controller located in the control building. An operator is required to initiate the siphon priming operation and for dewatering the siphon penstock.

POCONO LAKE HYDROELECTRIC PROJECT

PROJECT OWNER:	POCONO LAKE PRESERVE
FERC NO.:	7832-0000 PA
LOCATION:	PENNSYLVANIA TOBYHANNA RIVER
ENGINEER:	WILLIAMS AND BROOME, INC.

Year of Initial Operation	1986
Plant Capacity	285 kW
Plant Flow	180 cfs
Rated Head	Units 1 and 3 = 23.8 ft, Unit 2 = 24.5 ft
Number of Units	Three

HYDRAULIC CONDITIONS

– Headwater Level	
• Maximum (for plant operation)	El 1641.0
• Normal	El 1633.31
• Minimum (for plant operation)	El 1633.29
– Tailwater Level	
• Maximum (for plant operation)	El 1621.0
• Normal	El 1607.3
• Minimum (for plant operation)	El 1607.0
– Gross Head	
• Maximum (for plant operation)	26.29 ft
• Normal	26.0 ft
• Minimum (for plant operation)	16.0 ft

GENERATING UNIT DATA

– Unit No.	1 & 3	2
– Turbine		
• Manufacturer	Flygt Corporation	Flygt Corporation
• Type	Fixed Vane Fixed Blade Propeller	Fixed Vane Fixed Blade Propeller
• Rated Net Head	23.8 ft	24.5 ft
• Rated Power	154 hp	85 hp

	1 & 3	2
– Unit No.	1 & 3	2
• Speed	610 rpm	740 rpm
• Runner Diameter	27.5 in.	21.6 in.
• Number of Blades	Four	Four
– Generator		
• Manufacturer	Flygt Corporation	Flygt Corporation
• Type	Vertical Induction	Vertical Induction
• Rated Output	176 kVA	84 kVA
• Power Factor	0.64	0.7
• Rated Power	113 kW	59 kW
• Speed	610 rpm	740 rpm
• Voltage	480 V	480 V

– Intake Valve
- Manufacturer .... McNally
- Type .... Butterfly, Class 25B AWWA C504-80
- Diameter .... 48 in., (Units 1 & 3); 36 in. (Unit 2)
- Type of Operator .... Electric-Limitorque

– Controls
- Manufacturer .... Electropak
- Type .... Programmable Controller

PENSTOCK DATA

– Number of Siphon Penstocks .... One trifurcating into three

– Diameter
- Nominal .... 5.0 ft
- At siphon .... 5.0 ft

– Length
- Intake to top of siphon .... 17 ft
- Top of siphon to turbine intake .... Units 1 & 3 = 60 ft; Unit 2 = 57 ft

– Elevation of Penstock Centerline at Top of Siphon .... El 1636.06

– Siphon Lift
- Maximum (minimum headwater level to penstock centerline at top of siphon) .... 2.77 ft
- Normal (normal headwater level to penstock centerline at top of siphon) .... 2.75 ft

– Design Flow
- Maximum .... 180 cfs
- Normal .... 180 cfs
- Minimum .... 38 cfs

– Penstock Material	Steel
– Material Thickness at Top of Siphon	3/8 in.

PENSTOCK INTAKE

– Inlet Flow Direction	Inclined
– Opening Area	38.48 ft^2
– Material	Steel
– Trashracks	
• Gross area	640 ft^2
• Bar clear spacing	2 in.

SIPHON PRIMING SYSTEM

– Number of Vacuum Pumps	One
– Vacuum Pump Data	
• Type	Positive Displacement Liquid Ring Lateral Portplate Design
• Manufacturer	Sullair Corporation
• Model Number	SL-311-B-01
• Power	3.0 hp
• Capacity	39 cfm at 16 in. Hg.
– Priming Valve	
• Manufacturer	Valmatic Valve and Manufacturing Corp.
• Model Number	38P
• Size	2 in.
– Air Inlet (Vacuum Breaker) Valve	
• Manufacturer	Automatic Switch Company
• Model number	General purpose 2-in. solenoid
• Size	2 in.
– Vacuum Control Tank Size	10.7 ft^3
– Volume of Air to be Removed for Siphon Priming	410 ft^3
– Siphon Priming Time (approx.)	8 min. (valves closed condition)

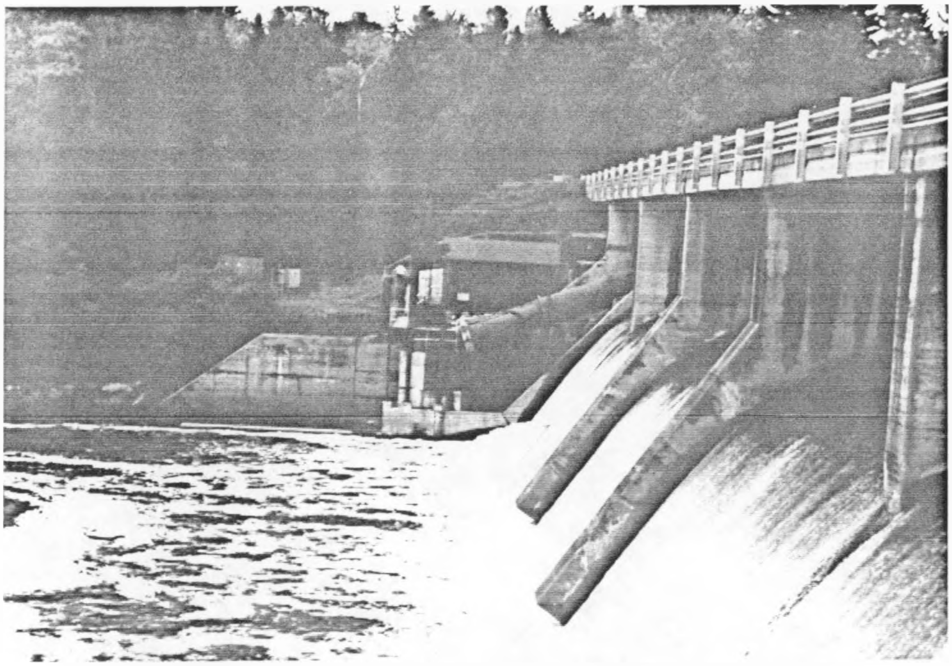


Figure F-1 Pocono Lake - Powerhouse and Downstream Penstock Section

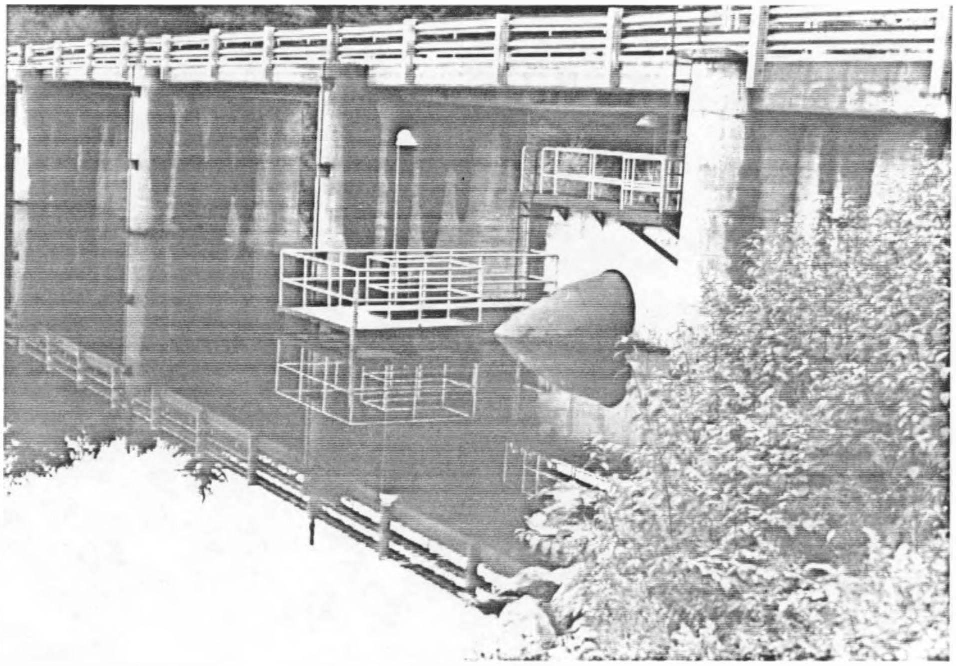


Figure F-2 Pocono Lake - Intake Area

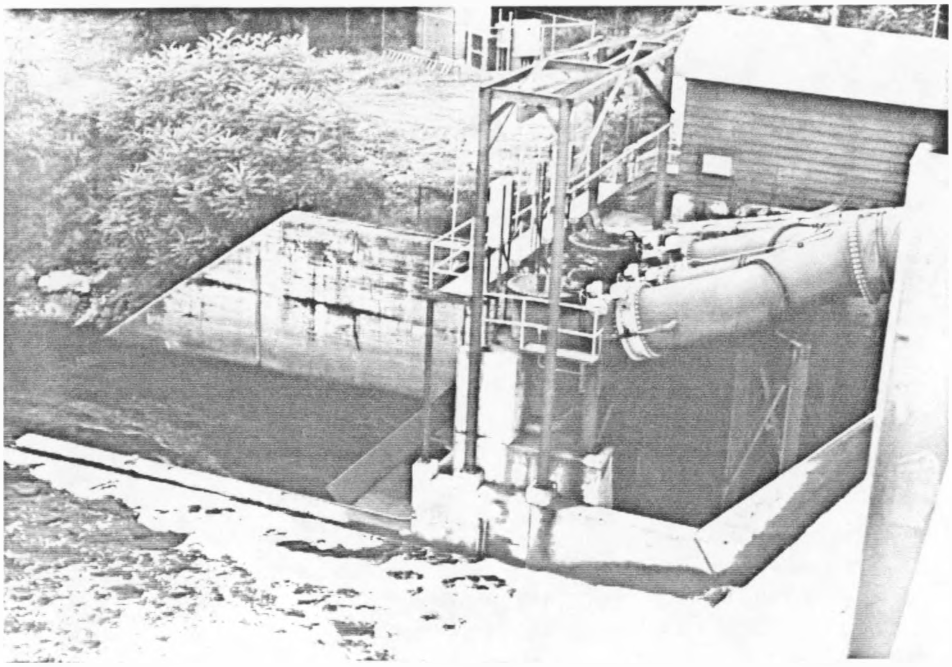
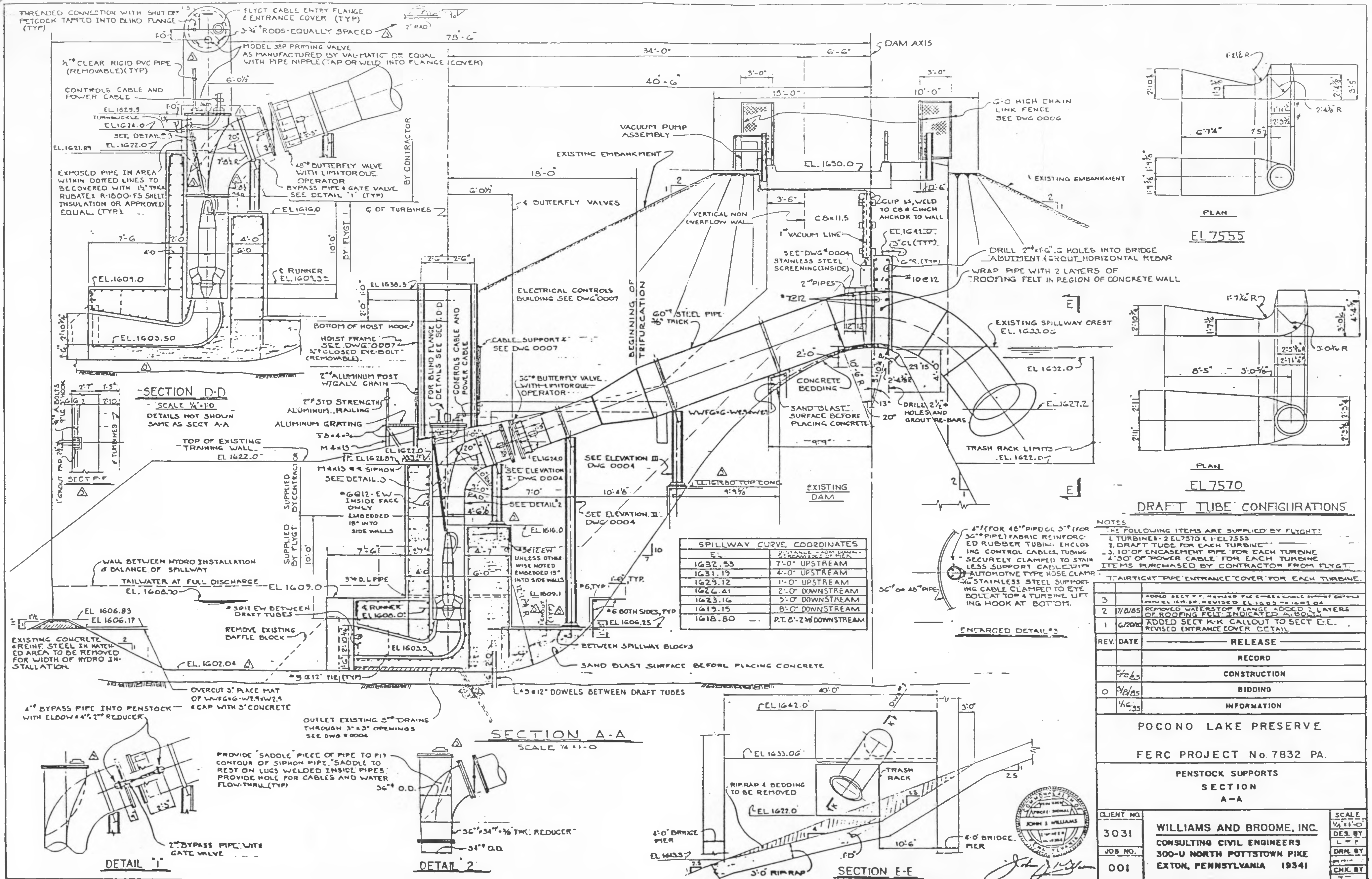


Figure F-3 Pocono Lake - Powerhouse and Penstock Trifurcation

Figure F-4 Pocono Lake - Inlet Valves and Turbine Casings



SPILLWAY CURVE COORDINATES	
EL.	DISTANCE FROM DOWNSTREAM FACE OF PIER
1632.53	7'-0" UPSTREAM
1631.19	4'-0" UPSTREAM
1629.12	1'-0" UPSTREAM
1626.41	2'-0" DOWNSTREAM
1623.16	5'-0" DOWNSTREAM
1619.15	8'-0" DOWNSTREAM
1618.80	P.T. 8'-2⅜" DOWNSTREAM

REV.	DATE	RELEASE
3		ADDED SECT F-F, REVISED PVC PIPE & CABLE SUPPORT DETAILS; REVISED EL 1602.93 TO 1602.04
2	7/8/85	REMOVED WATERSTOP FLANGE ADDED 2 LAYERS OF ROOFING FELT INDICATED A-BOLTS
1	6/20/85	ADDED SECT K-K CALLOUT TO SECT E-E. REVISED ENTRANCE COVER DETAIL
		RECORD
	7/2/85	CONSTRUCTION
0	5/8/85	BIDDING
	1/16/85	INFORMATION

POCONO LAKE PRESERVE

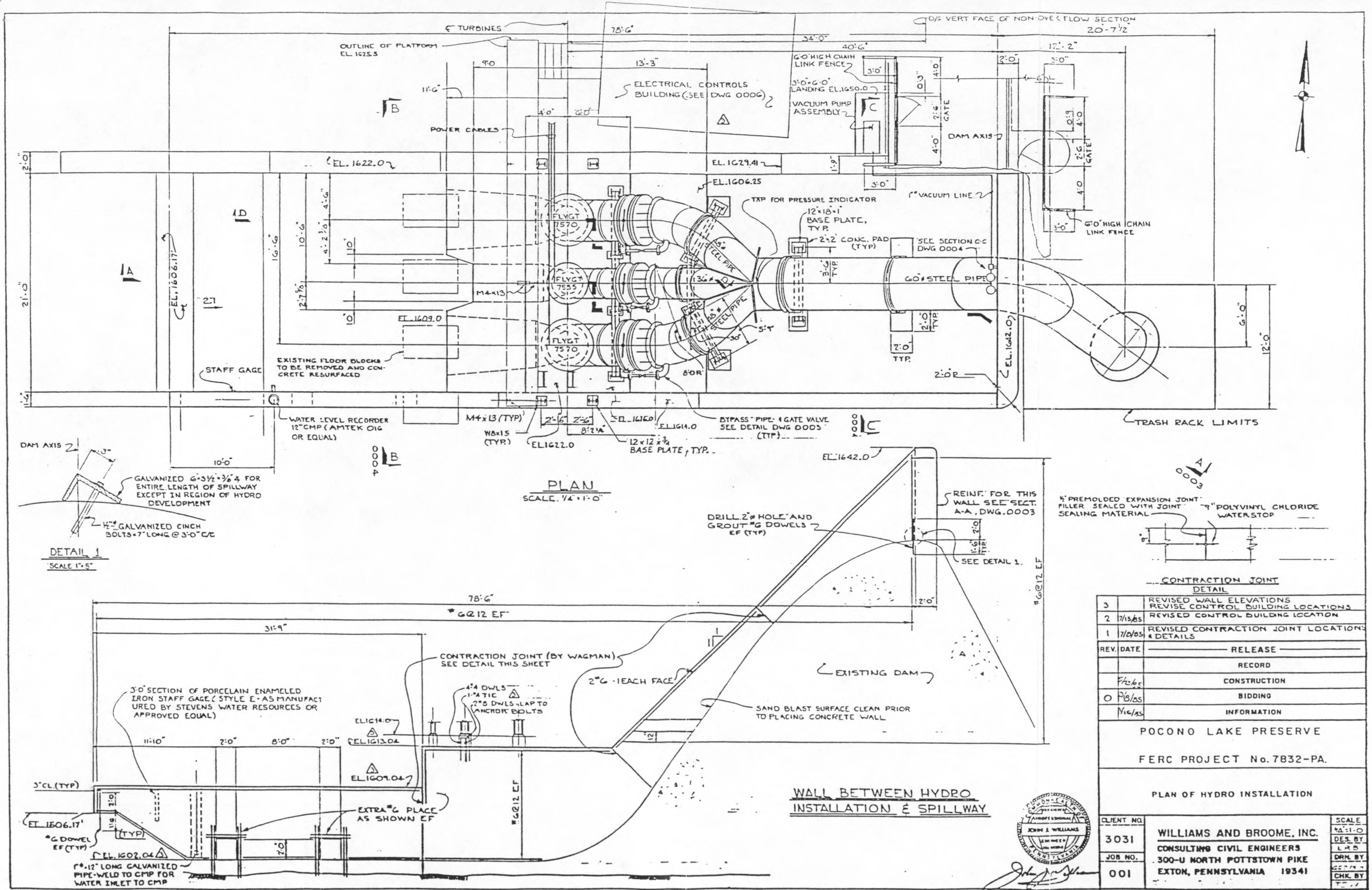
FERC PROJECT No 7832 PA.

PENSTOCK SUPPORTS
SECTION
A-A

CLIENT NO. 3031
JOB NO. 001

WILLIAMS AND BROOME, INC.
CONSULTING CIVIL ENGINEERS
300-U NORTH POTTSTOWN PIKE
EXTON, PENNSYLVANIA 19341

SCALE ¼"=1'-0
DRAWING NO. 3031001003



REV.	DATE	RELEASE
3		REVISED WALL ELEVATIONS REVISE CONTROL BUILDING LOCATIONS
2	7/15/85	REVISED CONTROL BUILDING LOCATION
1	7/10/85	REVISED CONTRACTION JOINT LOCATIONS & DETAILS
		RECORD
	7/12/85	CONSTRUCTION
0	6/8/85	BIDDING
	5/16/85	INFORMATION

POCONO LAKE PRESERVE

FERC PROJECT No. 7832-PA.

PLAN OF HYDRO INSTALLATION

CLIENT NO.		SCALE
3031	WILLIAMS AND BROOME, INC. CONSULTING CIVIL ENGINEERS 300-U NORTH POTTSTOWN PIKE EXTON, PENNSYLVANIA 19341	1/4":1-0
JOB NO.		DES. BY
001		DRN. BY / CHK. BY

DRAWING NO. 3 0 3 1 0 0 1 0 0 0 2

APPENDIX G

SCHAADS RESERVOIR HYDROELECTRIC PROJECT

SCHAADS RESERVOIR HYDROELECTRIC PROJECT

The Schaads Reservoir Hydroelectric Project is located in Calavaras County, California on the Middle Fork of the Mokelumne River. The power plant, which was constructed at the existing Middle Fork Dam, has a capacity of 240 kW and operates at a head of 90 ft. The project was operational in 1986.

The plant has a single penstock with a rectangular box-shaped intake screen.The intake screen is 3 ft wide by 4 ft high by 3 ft deep and is constructed of aluminum bars. The intake is submerged 25 ft below normal water level, and has no provision for cleaning.

The penstock is made from 30 inch steel pipe with butt welded joints. The portion of the penstock upstream of the crest, including the intake, follows the shape of the existing ground. A 152 ft section at the crest of the siphon, which passes through the core of the dam, has a 1 ft thick reinforced concrete encasement. Except for a short section near the powerhouse, the remainder of the penstock is buried.

The overall penstock length is 717 ft, and the distance from the intake to the crown of the siphon is approximately 71 ft. A 30 inch butterfly valve is installed in the penstock immediately upstream of the siphon crown.

Normal static water level is at the crown of the siphon; therefore, the siphon may be filled by gravity by opening the inlet valve upstream of the siphon crown. A portable, gasoline engine-driven vacuum pump is attached to the two-inch air valve at the crown of the siphon to prime the system when the reservoir level is below the invert of the siphon. A vacuum relief valve is provided immediately downstream of the siphon crown to prevent the negative pressure in the penstock from exceeding minus 10 ft of water.

The powerhouse has a concrete substructure, and a woodframe upper level with wood roof trusses and a metal roof. The generating units, controls, transformer, and battery charger are located within the powerhouse. The generating units have horizontal, fixed-discharge "reverse pump" type turbines each with a hydraulic-actuated inlet butterfly valve. One turbine drives a 20 kW induction generator. Two other turbines are connected by a belt-drive system to a common 220 kW induction generator.

The turbines can be dewatered by closing the inlet valves. The penstock system is drained by closing the valve upstream of the siphon crown and opening the air vent at the crown of the siphon.

The plant is operated in a peaking mode. A pressure-operated bypass valve maintains the required minimum releases when all the units are off. The existing outlet works are used to provide the required minimum releases when the siphon is not primed. Flood flows in excess of the capacity of the units pass over the spillway.

The units are automatically controlled by water level sensors, a programmable timer, and relays. The siphon priming operation is initiated by an operator.

SCHAADS RESERVOIR HYDROELECTRIC PROJECT

PROJECT OWNER:	SCHAADS HYDRO PARTNERS
FERC NO.:	7506
LOCATION:	CALAVARAS COUNTY, CA MIDDLE FORK MOKELUMNE RIVER
ENGINEER:	TKO POWER - OTT WATER ENGINEERS, INC.

Year of Initial Installation	1986
Plant Capacity	240 kW
Plant Flow	42 cfs
Net Head	97 ft
Number of Units	Three

HYDRAULIC CONDITIONS

– Headwater Level	
• Maximum	El 3040.0
• Normal	El 3017.5 to El 3020.0
• Minimum	El 3007.5
– Tailwater Level	
• Maximum	El 2925.0
• Normal	El 2923.0
• Minimum	El 2921.0
– Gross Head	
• Maximum	115.0 ft
• Normal	97.0 ft
• Minimum	86.5 ft

GENERATING UNIT DATA

– Unit No.	1	2	3
– Turbine			
• Manufacturer	Hydrolec	Hydrolec	Hydrolec
• Type	Reverse Pump	Reverse Pump	Reverse Pump
• Rated Head	106 ft	89 ft	89 ft
• Rated Power	19 kW	128 kW	109 kW
• Speed	930 rpm	1568 rpm	1220 rpm
• Runner Diameter	12 in.34 in.	36 in.	

– Generator

• Manufacturer	Leroy Somer	Connected	Leroy Somer
• Type	Induction	with Unit 3	Induction
• Rated Power	28 kW		248 kW
• Speed	930 rpm		1220 rpm
• Voltage	480 V		480 V

– Controls - Manual
- Manufacturer .... Hydrolec
- Type .... Relay

– Controls - Automatic
- Manufacturer .... Hydrolec
- Type .... Relay and Programmable Timer

PENSTOCK DATA

– Number of Siphon Penstocks .... One

– Diameter
- Nominal .... 30 in.
- At Siphon .... 30 in.

– Length
- Intake to top of siphon .... 71 ft
- Top of siphon to units .... 646 ft

– Elevation of Penstock Centerline at Top of Siphon .... El 3016.25

– Siphon Lift
- Maximum (minimum headwater level to penstock centerline at top of siphon) .... 8.75 ft

– Design Flow
- Maximum .... 42 cfs
- Normal .... 42 cfs
- Minimum .... 3 cfs

– Penstock Material .... A283 Grade 3 Steel

– Material Thickness at Top of Siphon .... 3/16 in.

PENSTOCK INTAKE

– Intake Flow Direction .... Inclined
– Opening Area .... 4.9 ft^2
– Material .... Steel
– Trashracks
- Gross Area .... 54 ft^2
- Bar Clear Spacing .... 1.06 in.

SIPHON PRIMING SYSTEM

- Priming Valve
  - Size .... 2 in.
- Air Inlet (Vacuum Breaker) Valve
  - Size .... 4 in.
- Volume of Air Removed (approx. max.) .... 2800 ft^3
- Siphon Priming Time (approx.) .... 30 min.

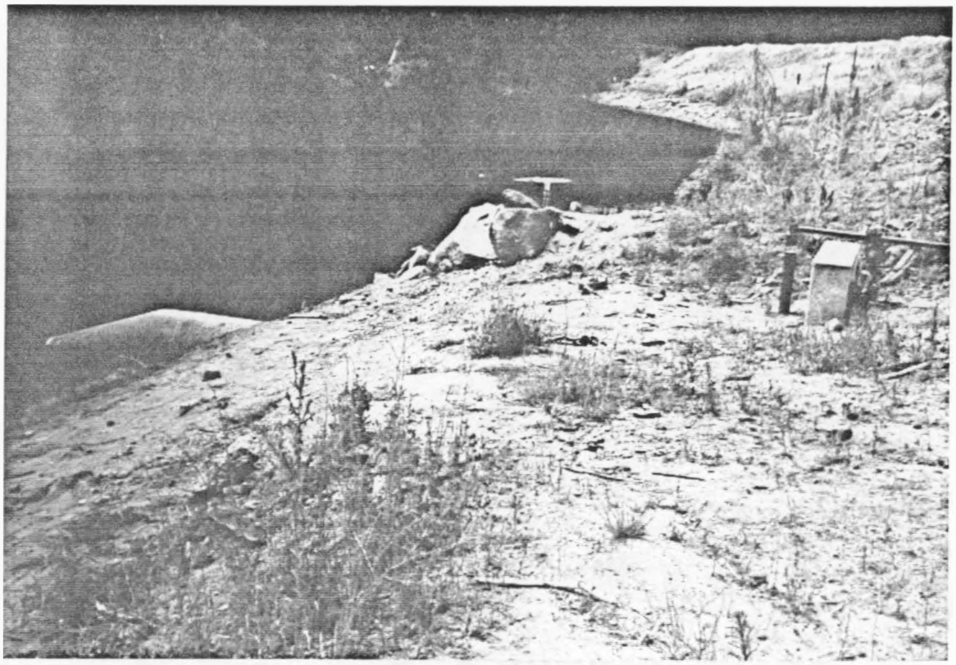


Figure G-1 Schaads Reservoir - Siphon Pipe and Valve Operator

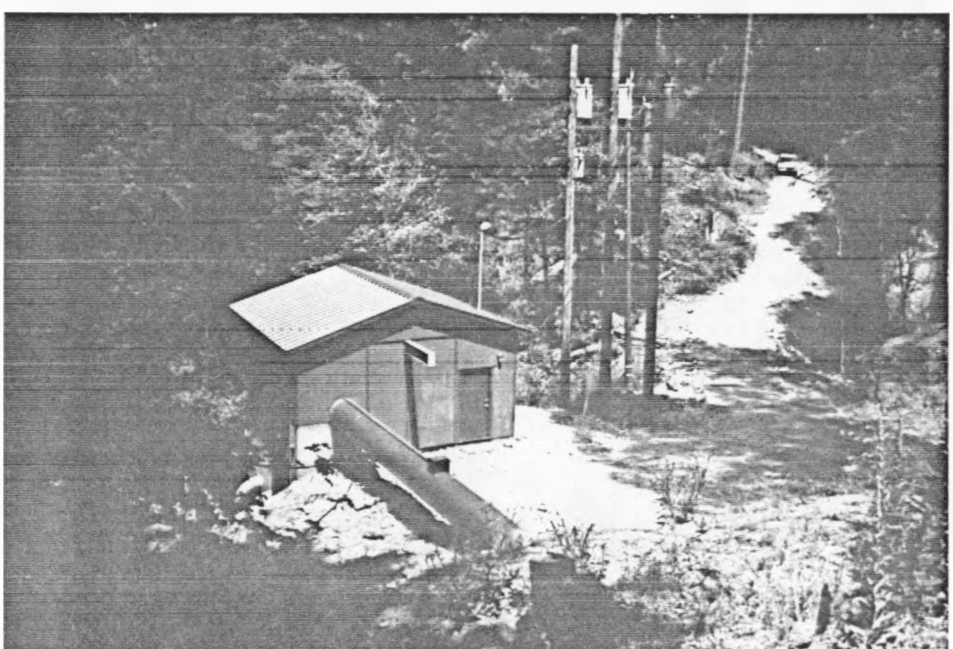


Figure G-2 Schaads Reservoir - Powerhouse

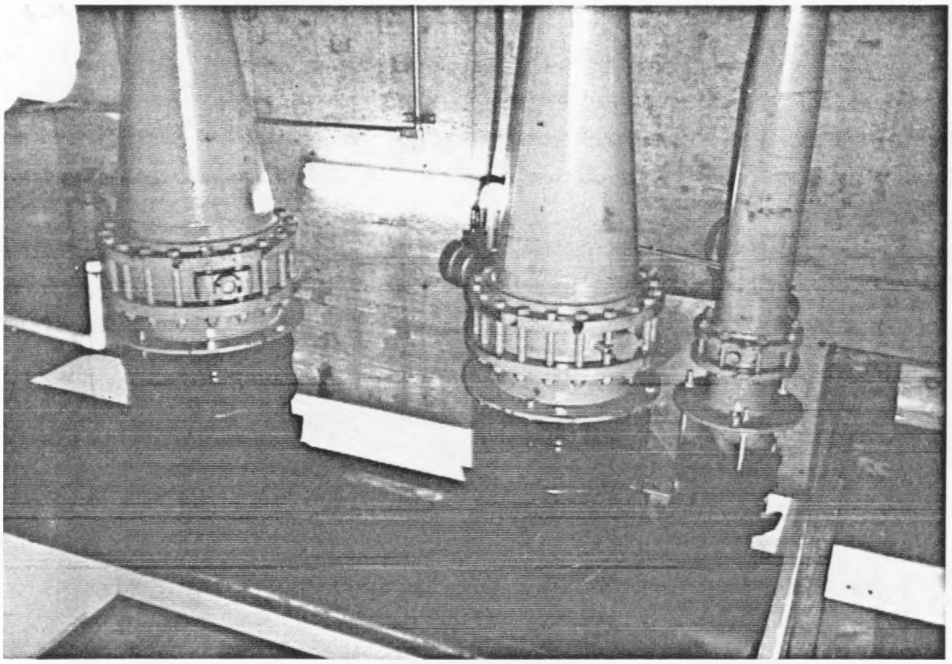


Figure G-3 Schaads Reservoir - Penstock Manifold in Powerhouse

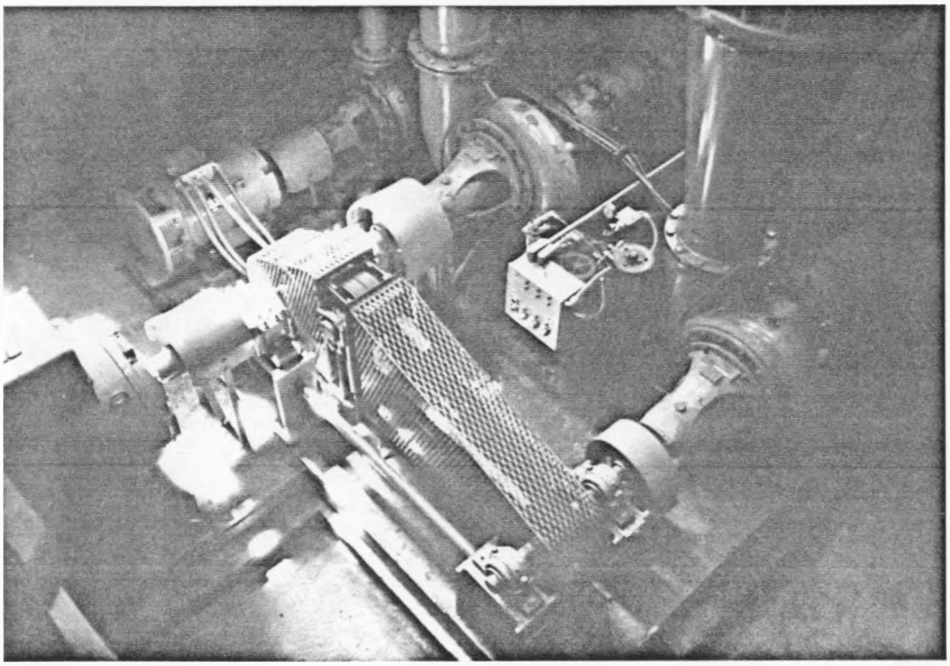
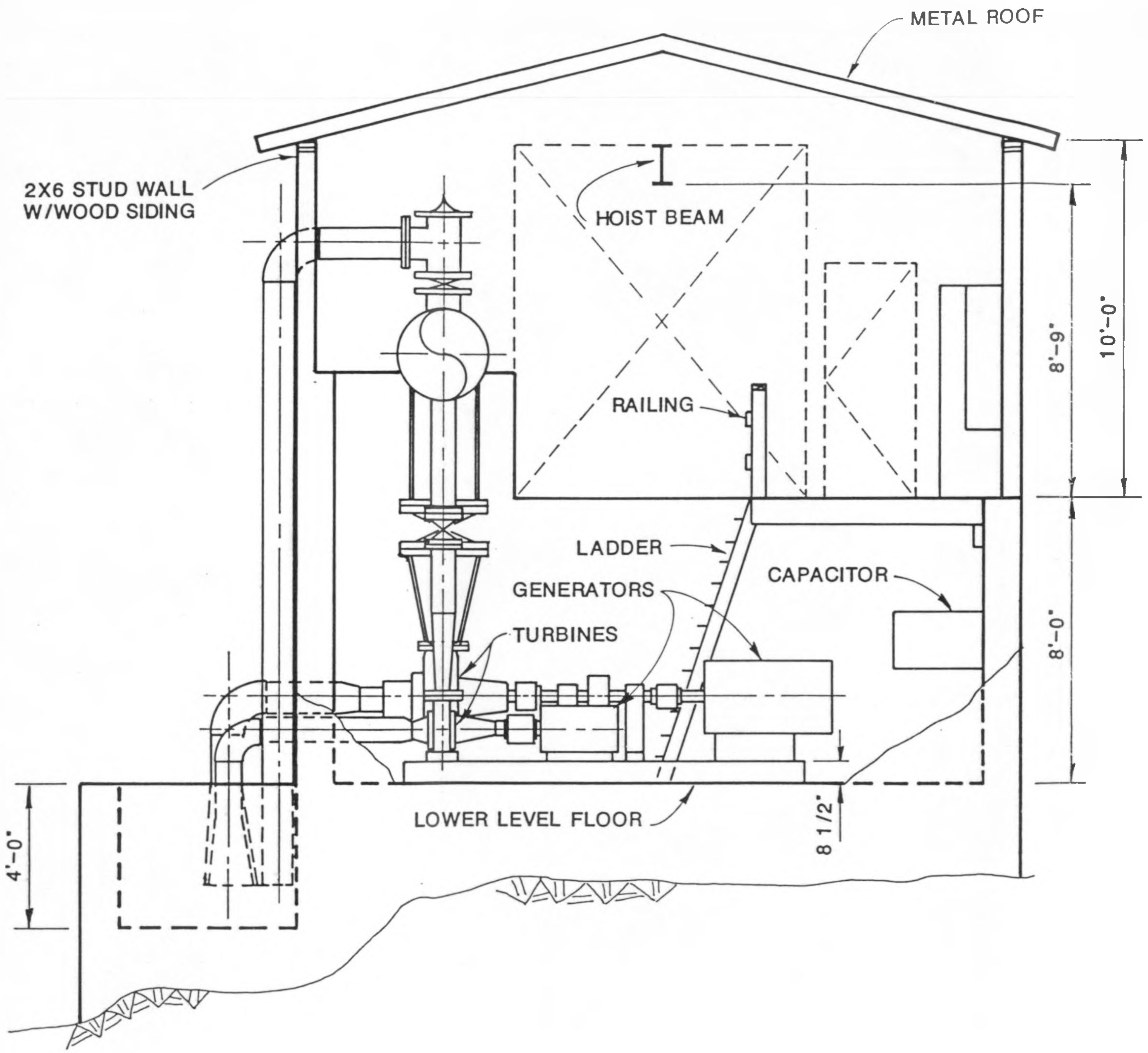


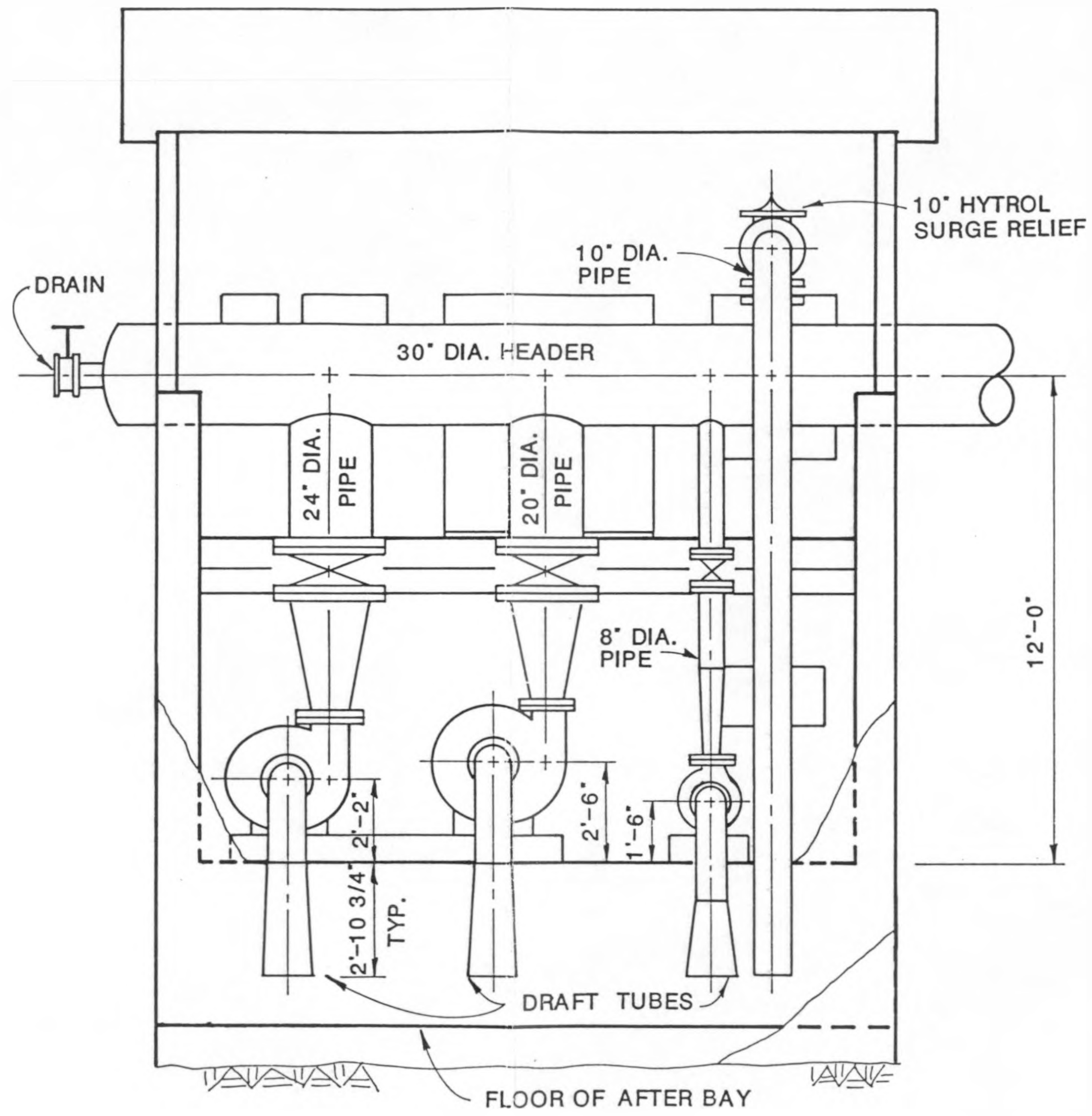
Figure G-4 Schaads Reservoir - Powerhouse Floor

95382



POWERHOUSE ELEVATION

1/4" = 1'-0"



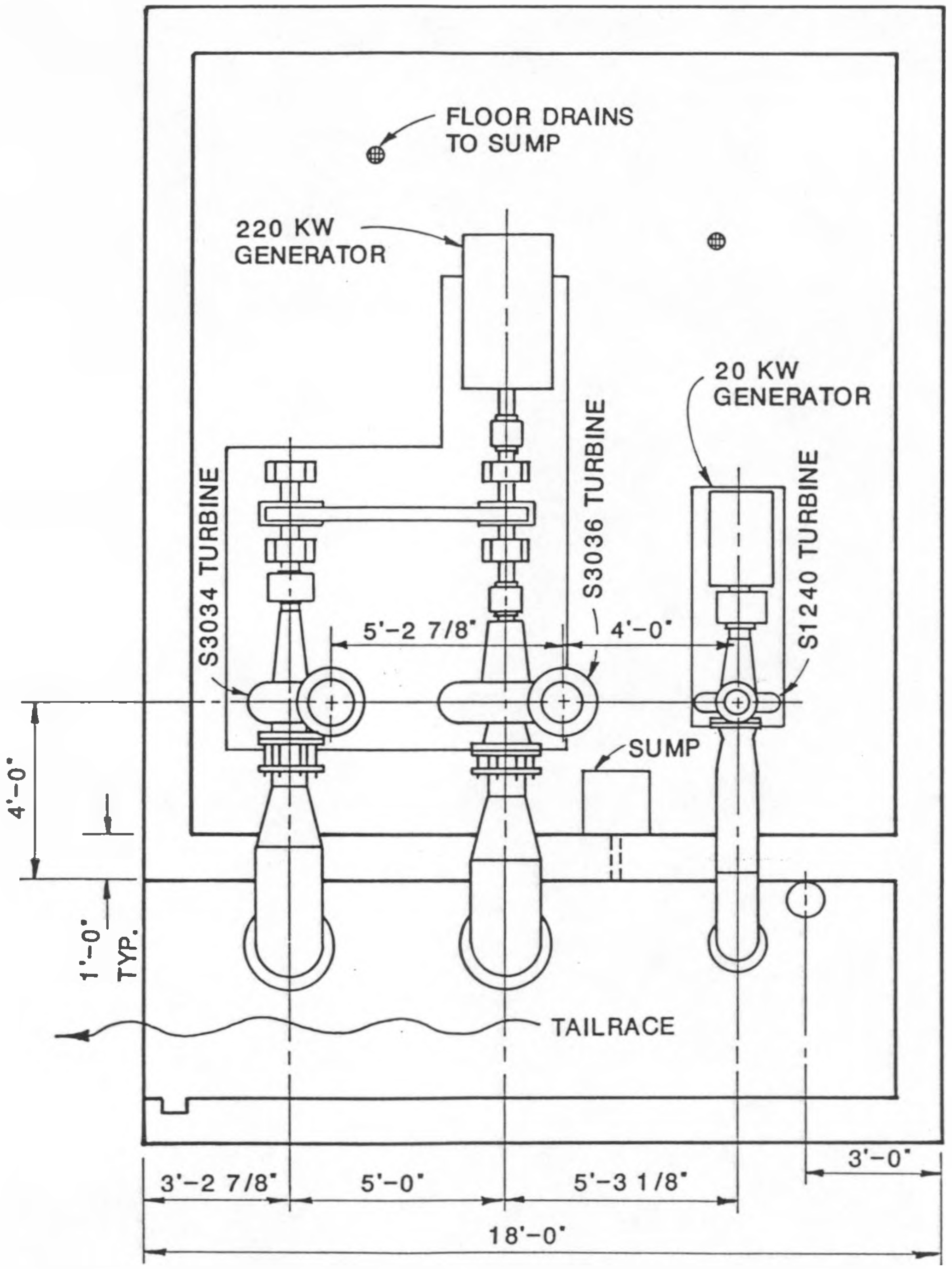
PIPING ELEVATION

1/4" = 1'-0"

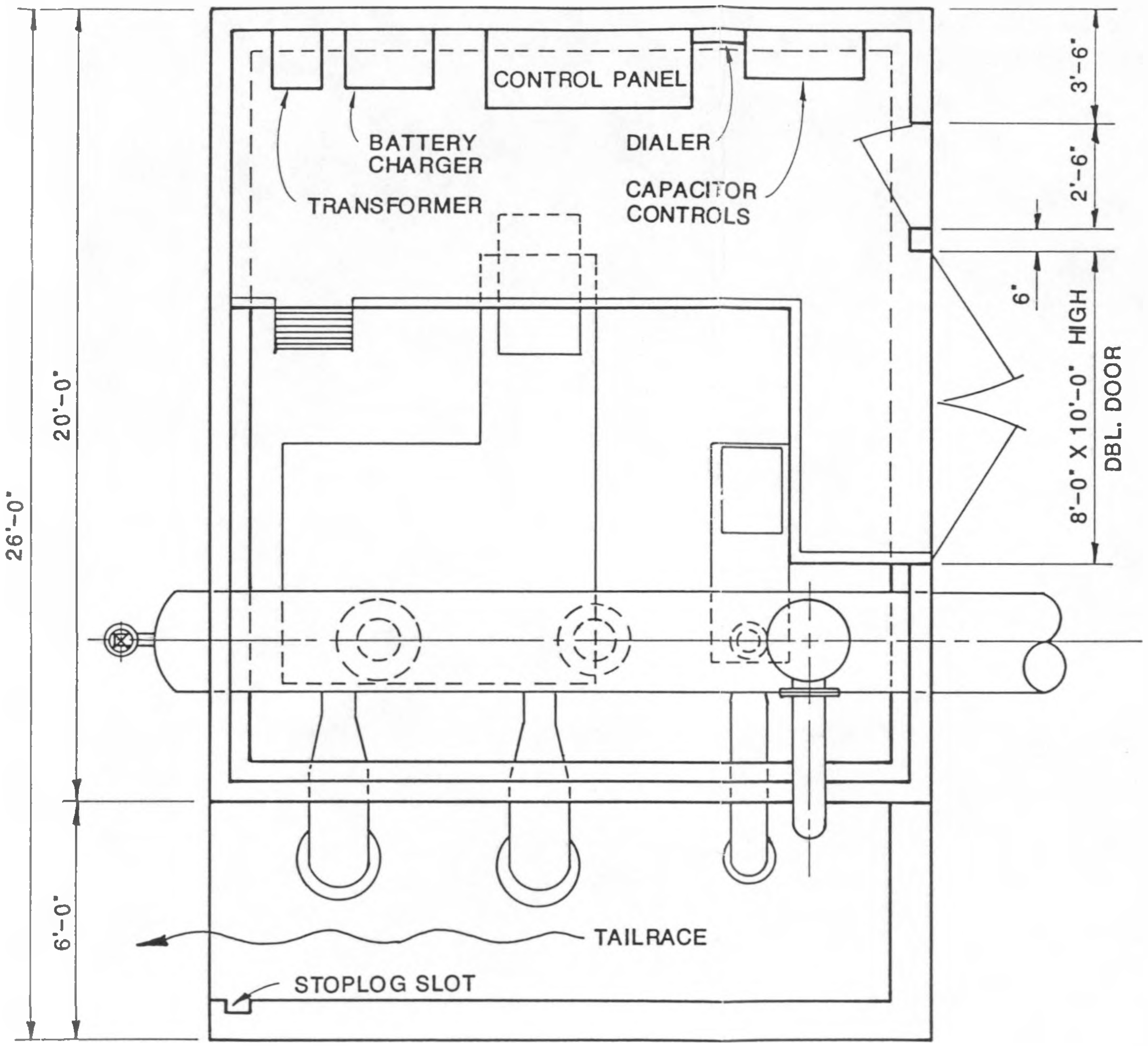
SCHAADS RESERVOIR
HYDROELECTRIC PROJECT

OTT

95382



POWERHOUSE LOWER FLOOR PLAN
1/4" = 1'0"

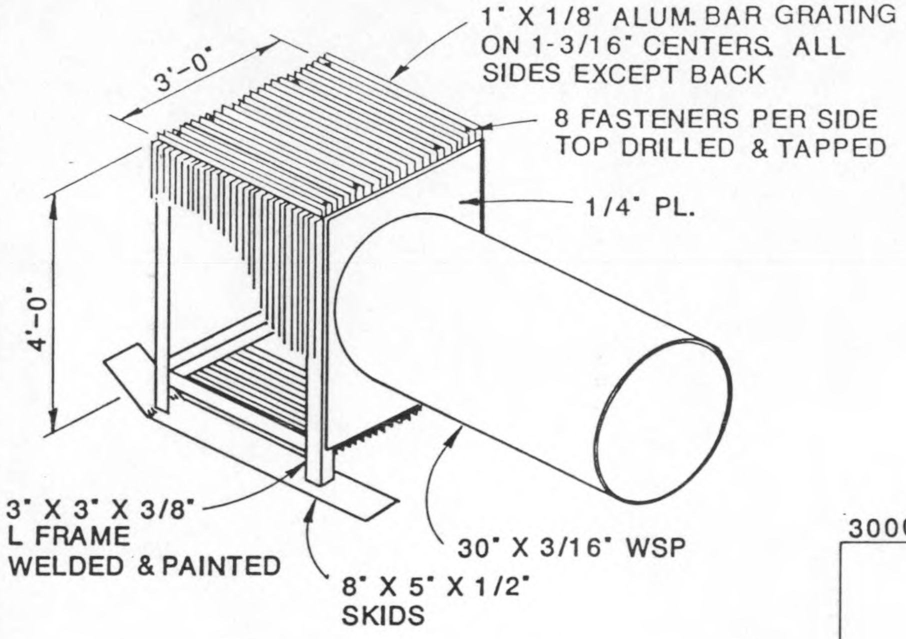


POWERHOUSE UPPER FLOOR PLAN
1/4" = 1'-0"

SCHAADS RESERVOIR
HYDROELECTRIC PROJECT

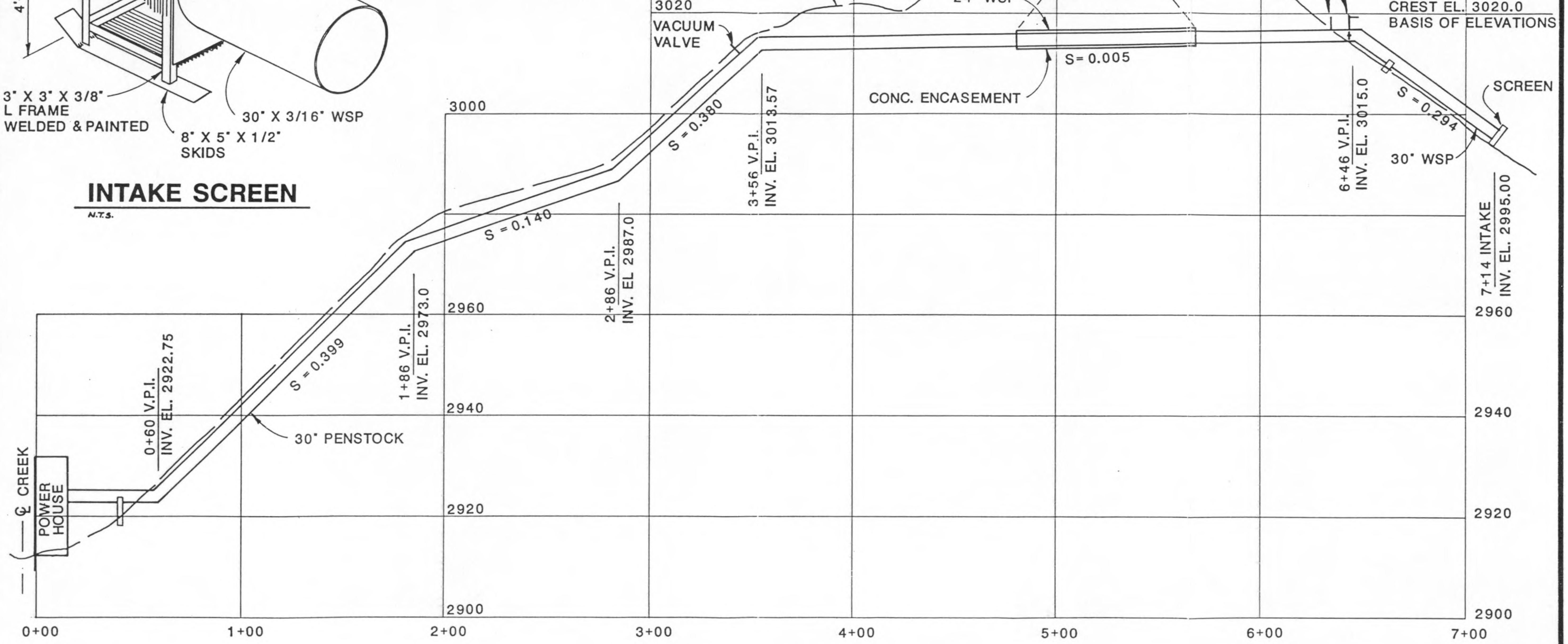
OTT

95382



INTAKE SCREEN

N.T.S.



SIPHON PENSTOCK PROFILE

HORIZ. 1"=50'
VERT. 1"=20'

SCHAADS RESERVOIR
HYDROELECTRIC PROJECT

OTT

APPENDIX H

SECOND BROAD RIVER HYDROELECTRIC PROJECT

SECOND BROAD RIVER HYDROELECTRIC PROJECT

The Second Broad River Hydroelectric Project is located near Forest City, North Carolina at an existing dam on the Second Broad River. The facility went into operation in 1986 and has three 112 kW, 20 ft head units.

Each of the three units has a siphon penstock with a conical intake which extends down into the water at a 55-degree angle. The trashrack structure, which surrounds the three penstocks, is constructed of floor grating with steel supports. The plant has an automatic trash rake; however, an operator is required for trash removal. The penstocks are welded steel construction each with a nominal diameter of 4.33 ft. Each penstock is constructed from two prefabricated sections with a site welded joint. The penstock section downstream of the siphon crown drops vertically to a submersible generating unit which is bolted to the end of the penstock. A concrete slab at the top of the dam supports the penstocks and acts as a thrust block. A concrete support is also provided on the downstream side of the dam at the bottom of the penstocks.

The overall length of each penstock is 44.5 ft, and the distance from the intake to the crown of the siphon is 14.5 ft.

The three penstocks have a common siphon priming system consisting of a positive displacement lobe type vacuum pump and associated piping, valves, and controls. Vacuum breaker valves are located at the crown of the siphon on each penstock.

Each generating unit is integral with and supported by the siphon penstock. A cross beam supported by two concrete piers provides additional support for the generating units. Two of the units have semi-Kaplan turbines, and one has a fixed discharged propeller turbine. The generators are induction type driven through planetary speed increasers. Five-foot long draft tubes, bolted to the end of the turbines, direct discharge back into the river.

Each siphon penstock is dewatered by opening the vacuum breaker valve at the crown of the siphon.

The plant is operated on a run-of-river basis to maintain a constant headwater. Flood flows in excess of the combined capacity of the units pass over the dam.

The units are automatically controlled by a programmable controller located in the switchgear house. The vacuum pump automatically initiates the siphon priming operation during startup.

Because of mechanical difficulties with the three submersible generating units, the three units were subsequently replaced with a single propeller-type hydraulic turbine. However, the three siphon penstocks were retained.

SECOND BROAD RIVER HYDROELECTRIC PROJECT

PROJECT OWNER:	CLEARWATER HYDRO
FERC NO.:	7679
LOCATION:	NORTH CAROLINA SECOND BROAD RIVER
ENGINEER:	CLEARWATER HYDRO

Year of Initial Operation	1985
Plant Capacity	288 kW
Maximum Plant Flow	246 cfs
Minimum Plant Flow	38 cfs
Rated Head	21 ft
Number of Units	Three

HYDRAULIC CONDITIONS

– Headwater Level	
• Maximum (for plant operation)	El 812.0
• Normal	El 811.5
• Minimum (for plant operation)	El 810.8
– Tailwater Level	
• Maximum (for plant operation)	El 797.0
• Normal	El 789.0
• Minimum (for plant operation)	El 788.0
– Gross Head	
• Maximum (for plant operation)	23.0 ft
• Normal	21.0 ft
• Minimum (for plant operation)	14.0 ft

GENERATING UNIT DATA

– Unit No.	1 & 3	2
– Turbine		
• Manufacturer	Leroy Somer	Leroy Somer

– Unit No.	1 & 3	2
• Type	Semi-Kaplan Submersible Hydrolec Model H9H	Fixed Pitch Propeller Submersible Hydrolec Model H9H
• Rated Net Head	20 ft	20 ft
• Rated Power	150 hp	150 hp
• Speed	327 rpm	327 rpm
• Runner Diameter	42 in.	42 in.
• Number of Blades	Four	Four
– Generator		
• Type	Vertical Induction Oil Filled	Vertical Induction Oil Filled
• Rated Output	120 kVA	120 kVA
• Power Factor	0.80	0.80
• Rated Power	96 kW	96 kW
• Speed	1835 rpm	1835 rpm
– Speed Increaser		
• Type	Planetary	Planetary

- Controls
  - Manufacturer .... General Electric
  - Type .... Programmable Controller GE III
- Switchgear
  - Manufacturer .... General Electric
  - Size .... Five

PENSTOCK DATA

- Number of Siphon Penstocks .... Three
- Diameter
  - Nominal .... 4.33 ft
  - At siphon .... 4.33 ft
- Length
  - Intake to top of siphon .... 14.5 ft
  - Top of siphon to unit .... 30.0 ft
- Elevation of Penstock Centerline at Top of Siphon .... El 818
- Siphon Lift
  - Maximum (minimum headwater level to penstock centerline at top of siphon) .... 7.20 ft
  - Normal (normal headwater level to penstock centerline at top of siphon) .... 6.50 ft

- Design Flow
  - Maximum .... 82 cfs
  - Normal .... 82 cfs
  - Minimum .... 38 cfs
- Penstock Material .... A36 Steel
- Material Thickness at Top of Siphon .... 3/8 in.

PENSTOCK INTAKE

- Inlet Flow Direction .... 55 degrees from vertical
- Opening Area .... 28 ft^2
- Material .... 3/8 in. A36 Steel
- Trashracks
  - Gross area .... 492 ft^2
  - Bar clear spacing .... 1 in.

SIPHON PRIMING SYSTEM

- Number of Vacuum Pumps .... One
- Vacuum Pump Data
  - Type .... Positive Displacement Lobe type
  - Manufacturer .... Holmes
  - Model Number .... HR 80 OS
  - Power .... 5 hp
  - Capacity .... 140 cfm at 10 in. Hg (2000 rpm)
- Vacuum Priming Valve
  - Manufacturer .... ASCO
  - Size (port) .... 3 in.
  - Operation .... Pilot Operated
- Air Inlet (Vacuum Breaker) Valve
  - Manufacturer .... Clearwater Hydro
  - Size (port) .... 4 in.
  - Operation .... Pilot Operated

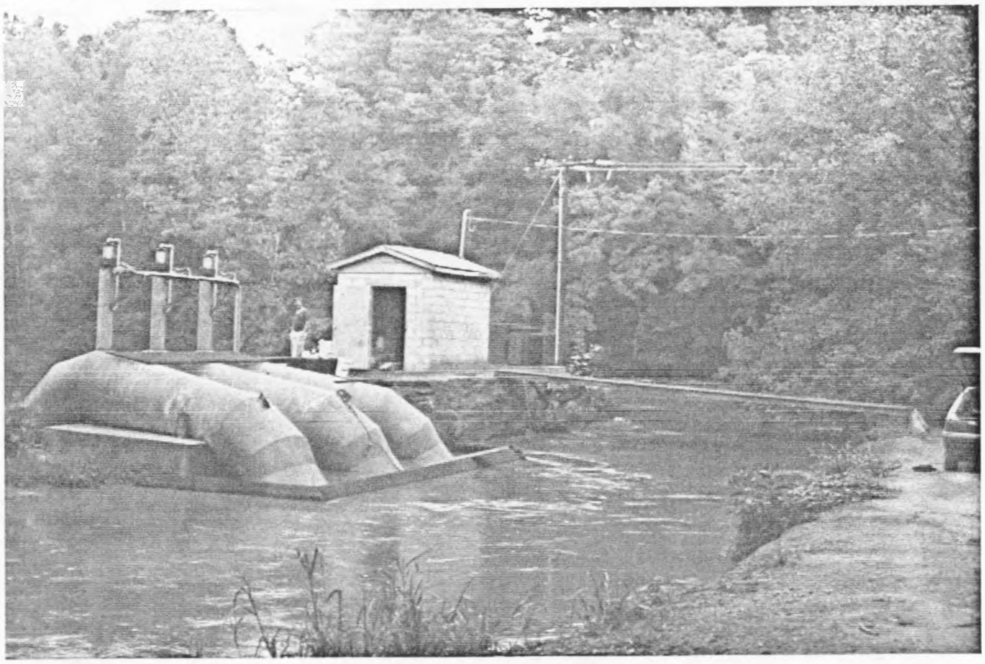


Figure H-1 Second Broad River - Upstream View

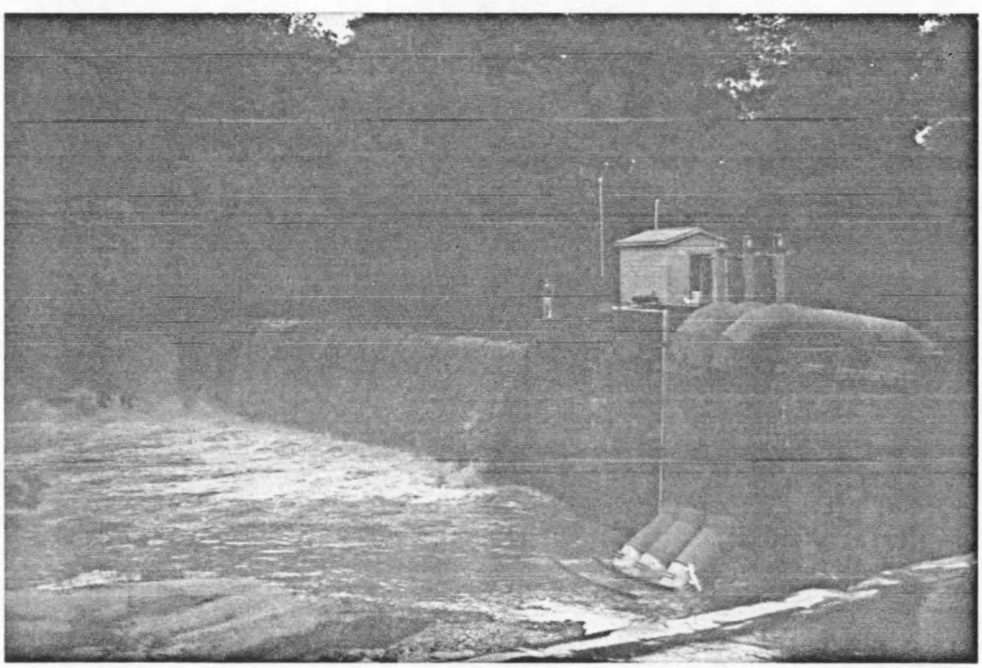
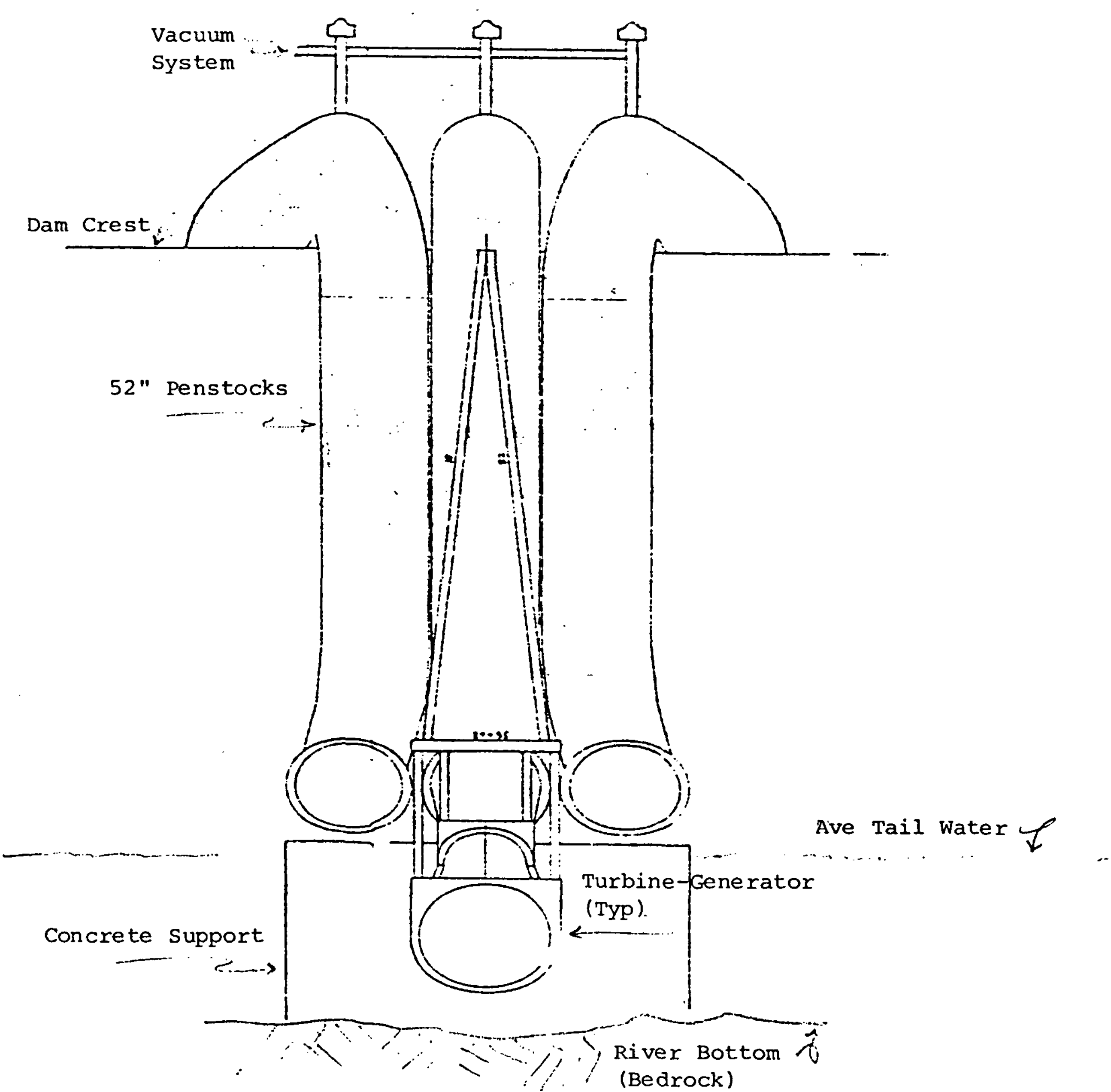
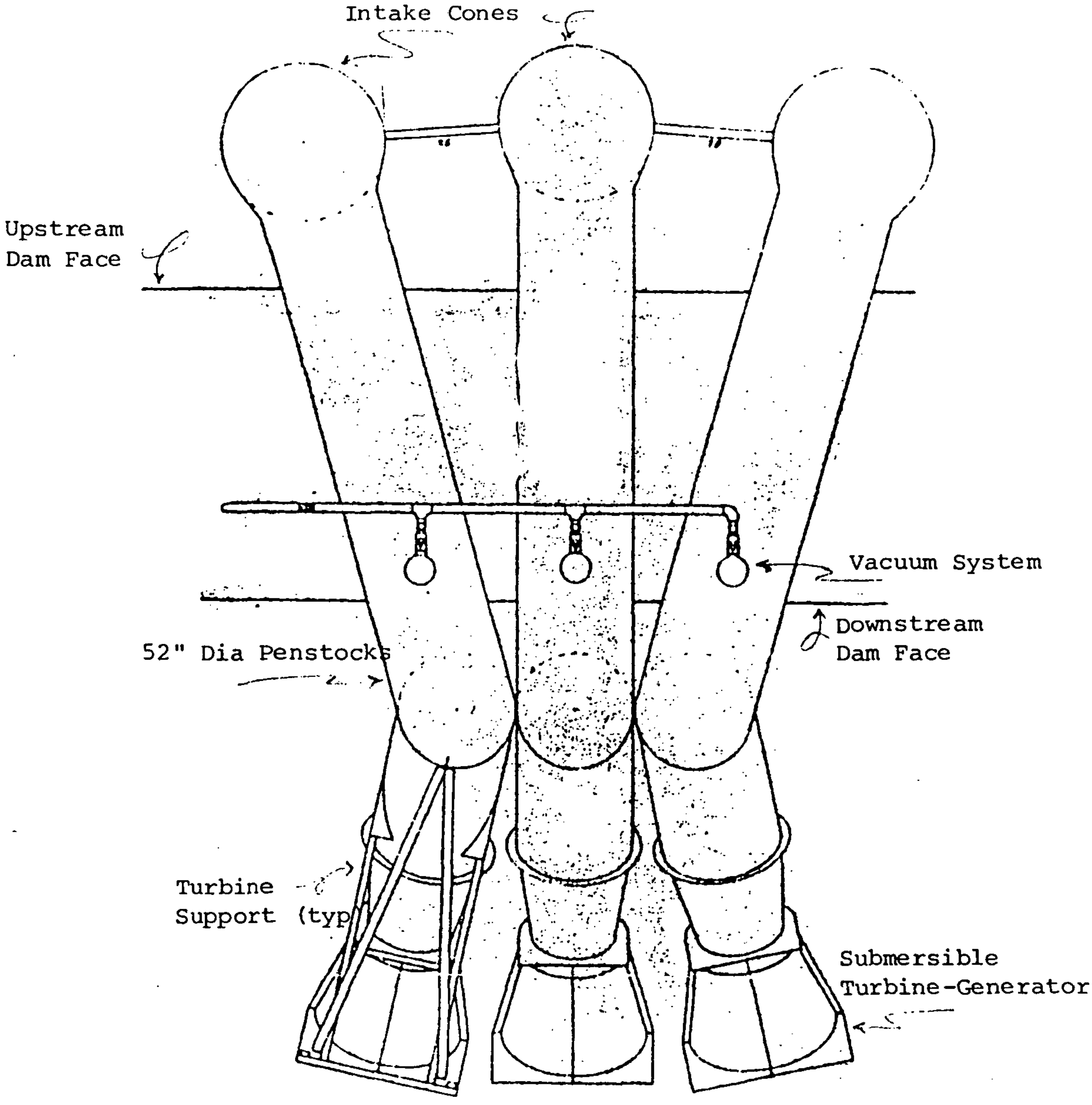


Figure H-2 Second Broad River - Downstream View

DOWN STREAM PROJECTION

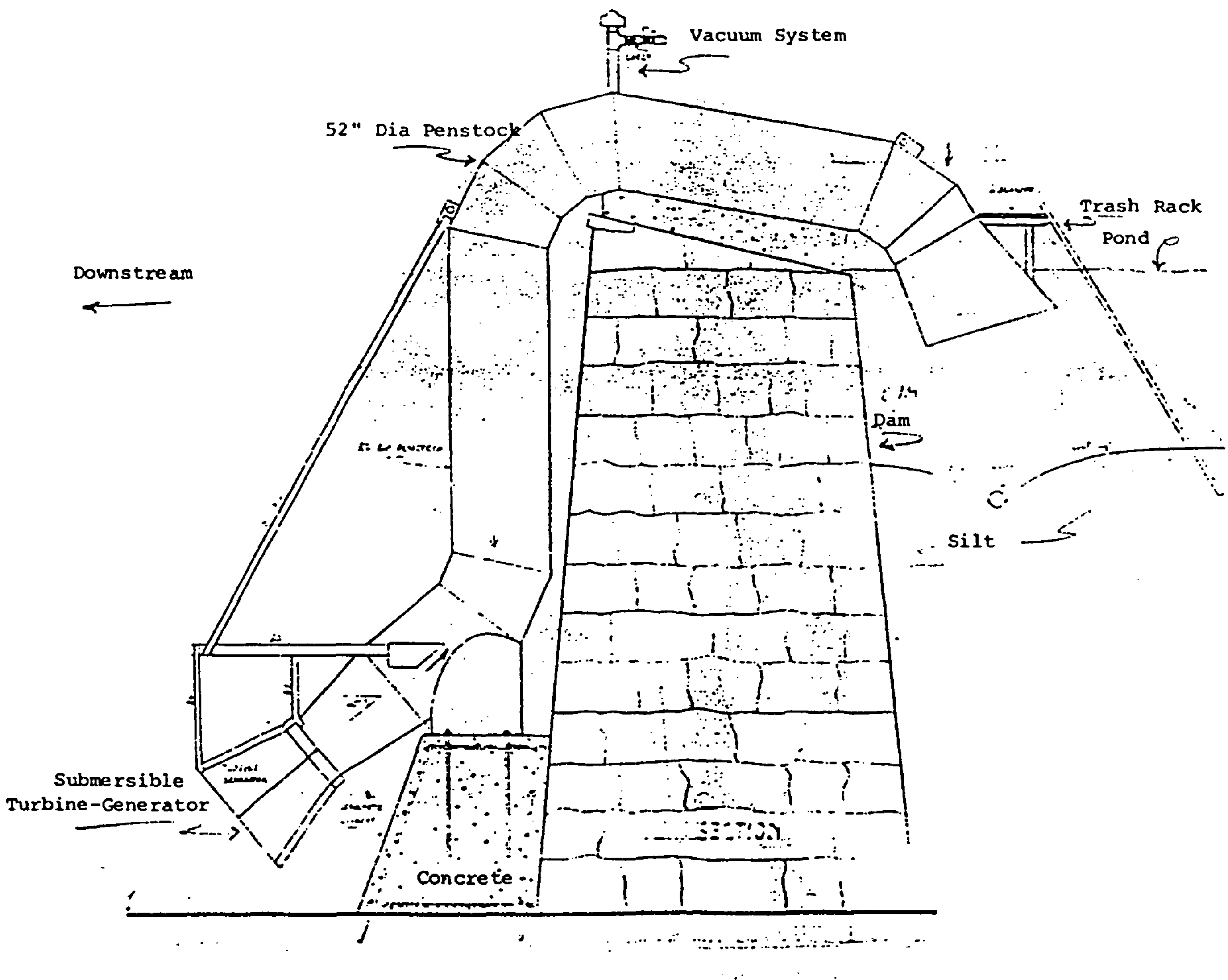


PLAN VIEW



Intake Cones
Upstream
Dam Face
Vacuum System
Downstream
Dam Face
52" Dia Penstocks
Turbine
Support (typ
Submersible
Turbine-Generator

SECTION VIEW



APPENDIX I

SUPERIOR DAM POWER STATION

SUPERIOR DAM POWER STATION

The Superior Dam Power Station is located in Ann Arbor, Michigan on the left bank of the Huron River. The power plant, which has a single 570 kW, 14 ft head unit, was constructed at the existing Superior Dam adjacent to the spillway radial gate chute and went into operation in 1986.

The intake consists of a horizontal Y-shaped transition to the single penstock. The intake has a vertical opening with vertical rack bars. There is no direct access for rack cleaning.

The penstock is of steel-lined reinforced concrete construction with a nominal inside diameter of 8 ft. The penstock is made from prefabricated sections with rubber gasketed bell and spigot-type joints. The upstream portion of the penstock is angled at about 20 degrees and follows the contour of the dam. This section of penstock is continually supported on a sand and gravel bed and is secured in place with concrete blocks and metal tie straps. At the crown of the siphon, the penstock has a 45-degree bend, which is encased in a reinforced concrete thrust block. The penstock is buried between the thrust block and the powerhouse. An access road for the dam passes over the penstock on the downstream side of the thrust block.

The overall penstock length is 150 ft, and the distance from the intake to the crown of the siphon is 56 ft.

The siphon priming system consists of two liquid ring seal vacuum pumps, a vacuum tank, and associated piping, valves, and controls. The vacuum pumps, tank and controls are located within the powerhouse, with a four-inch line connecting the vacuum system with the priming valve at the crown of the siphon. A vacuum breaker valve is also located at the crown of the siphon.

The powerhouse is founded on soil and has a reinforced concrete substructure and superstructure, and a metal roof. The generating unit is an inclined axis tubular unit with an adjustable blade propeller turbine with adjustable wicket gates. The generator is an induction type driven through a parallel shaft speed increaser. The turbine is controlled by an electronic positioner. The generator is connected through switchgear and a step-up transformer to the electrical grid.

Draft tube stoplogs are provided for dewatering the turbine waterpassages. The waterpassages are isolated from the headwater level by breaking the siphon in the penstock.

The excavated tailrace channel directs water flow back into the river.

The plant is operated on a run-of-river basis to maintain constant headwater level. Flows in excess of the turbine discharge are handled by the radial spillway gate. Flood flows in excess of the combined capacity of the unit and the gate pass over the ungated barrel arch spillway.

The unit is automatically controlled by a programmable controller in the powerhouse. An operator is required to initiate the siphon priming operation.

SUPERIOR DAM POWER STATION

PROJECT OWNER:	CITY OF ANN ARBOR
FERC NO.:	3152
LOCATION:	ANN ARBOR, MICHIGAN HURON RIVER
ENGINEER:	HARZA ENGINEERING COMPANY

Year of Initial Operation	1986
Plant Capacity	570 kW
Plant Flow	567 cfs
Rated Head	14.0 ft
Number of Units	One

HYDRAULIC CONDITIONS

– Headwater Level	
• Maximum (for plant operation)	El 731.5
• Normal	El 729.5
• Minimum (for plant operation)	El 728.0
– Tailwater Level	
• Maximum (for plant operation)	El 721.0
• Normal	El 714.0
• Minimum (for plant operation)	El 713.5
– Gross Head	
• Maximum (for plant operation)	17.5 ft
• Normal	15.5 ft
• Minimum (for plant operation)	13.5 ft

GENERATING UNIT DATA

– Turbine	
• Manufacturer	Voest-Alpine
• Type	Inclined Shaft Full Kaplan
• Rated Net Head	14.0 ft
• Rated Power	570 kW
• Speed	185 rpm
• Runner Diameter	74.8 in.
• Number of Blades	Four

SUPERIOR DAM POWER STATION

– Generator
- Manufacturer .... Ideal Electric Company
- Type .... "ATG" Incline Mounted Induction
- Rated Output .... 574 kVA
- Rated Factor 1.0
- Rated Power .... 574 kW
- Speed .... 900 rpm
- Voltage .... 2,300 V

– Speed Increaser
- Manufacturer .... Voest Alpine
- Type .... Parallel Shaft, Single Reduction Helical Gear, No. 145HT-1
- Rating .... 917 hp
- Service factor 1.5

– Gate/Blade Positioner
- Manufacturer .... Voest Alpine
- Type .... PID Electronic, Rack Mounted

– Controls
- Manufacturer .... Westinghouse Electric Corporation
- Type .... Programmable Controller

– Switchgear
- Manufacturer .... Westinghouse Electric Corporation
- Type .... VAC-CLAD Medium Voltage, Metal-clad Indoor
- Voltage .... 2,300 V
- Frequency .... 60 Hz

– Transformer
- Manufacturer .... National Industri Transformers, Inc.
- Type .... Indoor-dry-substation
- Class .... 5 kV
- Number of phases 3
- Frequency .... 60 Hz
- Primary/Secondary Voltage .... 2,300/4,800 V

PENSTOCK DATA

Number of Siphon Penstocks .... One

– Diameter
- Nominal .... 8 ft
- At siphon .... 8 ft

– Length
- Intake to top of siphon .... 56 ft
- Top of siphon to unit .... 94 ft

– Elevation of Penstock Centerline at Top of Siphon .... El 737.0

- Siphon Lift
  - Maximum (minimum headwater level to penstock centerline at top of siphon) .... 9 ft
  - Normal (normal headwater level to penstock centerline at top of siphon) .... 7.5 ft

- Design Flow
  - Maximum .... 600 cfs
  - Normal .... 567 cfs
  - Minimum .... 100 cfs

- Penstock Material .... Reinforced Concrete with Embedded Steel Cylinder

- Material Thickness at Top of Siphon
  - Steel Cylinder .... 16 ga.
  - Concrete .... 7.5 in.

PENSTOCK INTAKE

- Inlet Flow Direction .... Horizontal
- Opening Area .... 127 ft^2
- Material .... Reinforced Concrete with Embedded Steel Cylinder
- Trashracks
  - Gross Area .... 194 ft^2
  - Bar Clear Spacing .... 3.5 in.

SIPHON PRIMING SYSTEM

- Number of Vacuum Pumps .... Two

- Vacuum Pump Data
  - Type .... Liquid Ring Seal
  - Manufacturer .... SIHI
  - Model number .... 40517 SIHI
  - Power .... 10 hp
  - Capacity .... 153 acfm at 20 in. Hg

- Priming Valve
  - Manufacturer .... APCO
  - Size .... 4 in.

- Air Inlet (Vacuum Breaker) Valve
  - Manufacturer .... APCO
  - Size .... 4 in.

- Vacuum Control Tank Size .... 5.9 ft^3

- Volume of Air to be Removed for Siphon Priming .... 8,000 ft^3

- Siphon Priming Time .... 45 min.

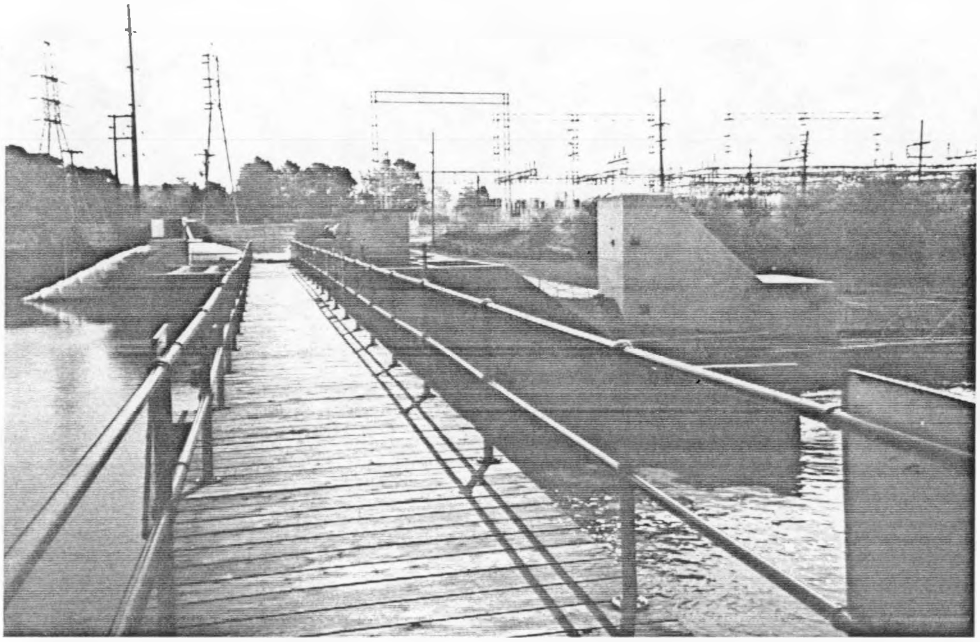


Figure I-1 Superior Dam Power Station

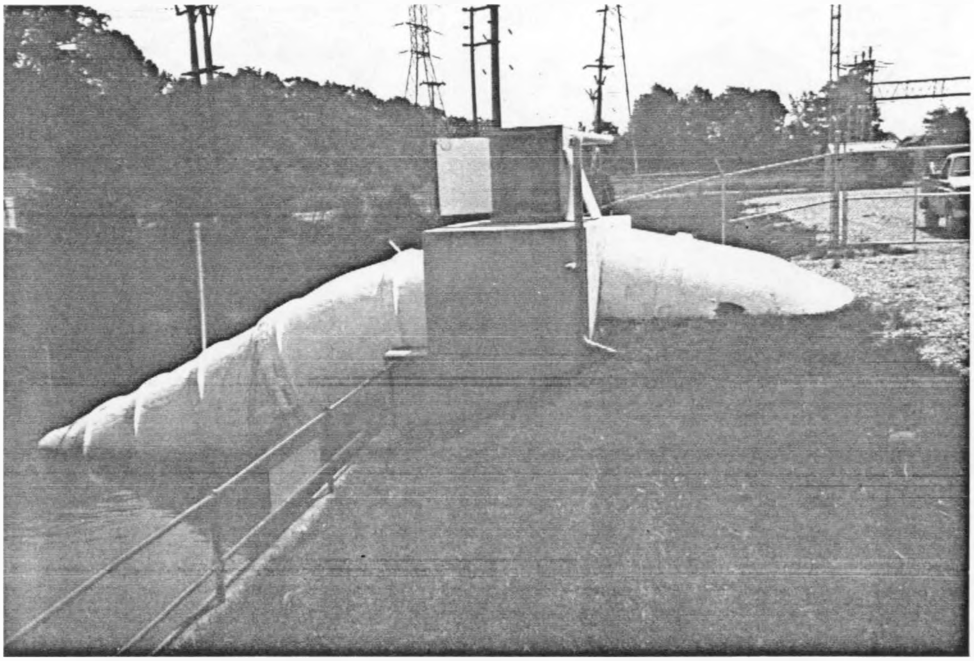


Figure I-2 Superior Dam - Siphon Crown Area

Figure I-3 Superior Dam - Powerhouse

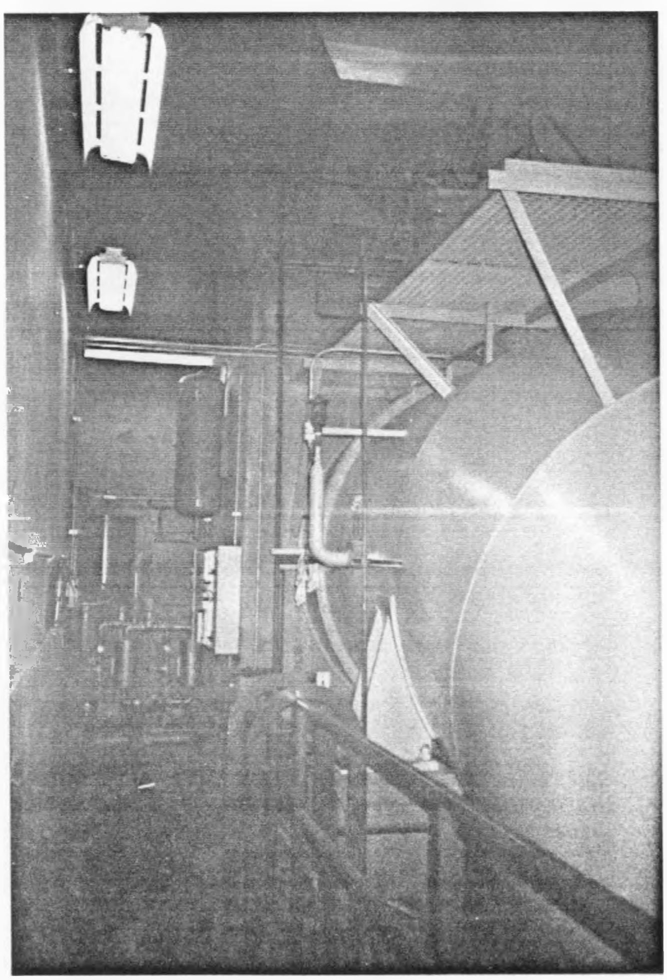
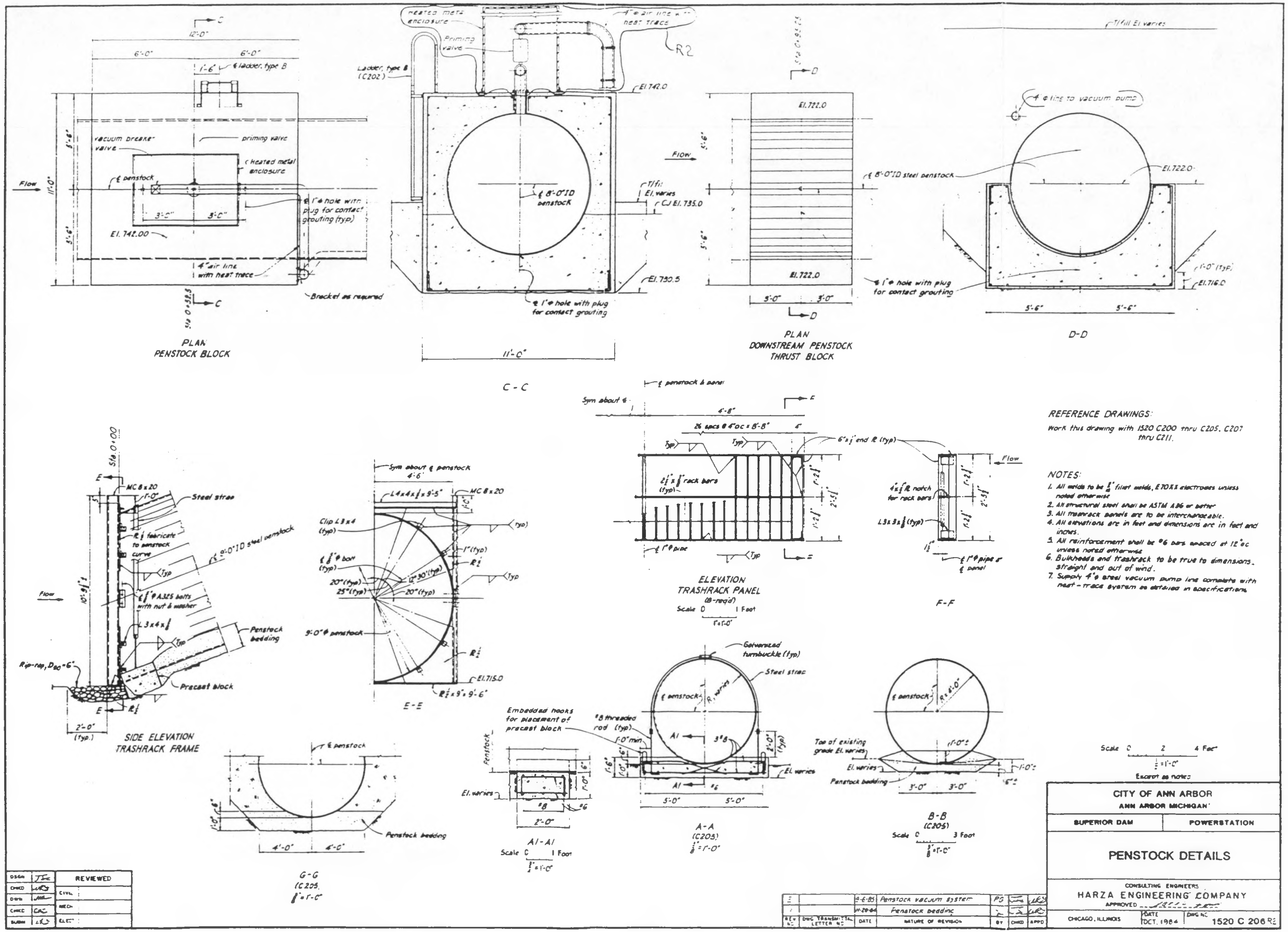
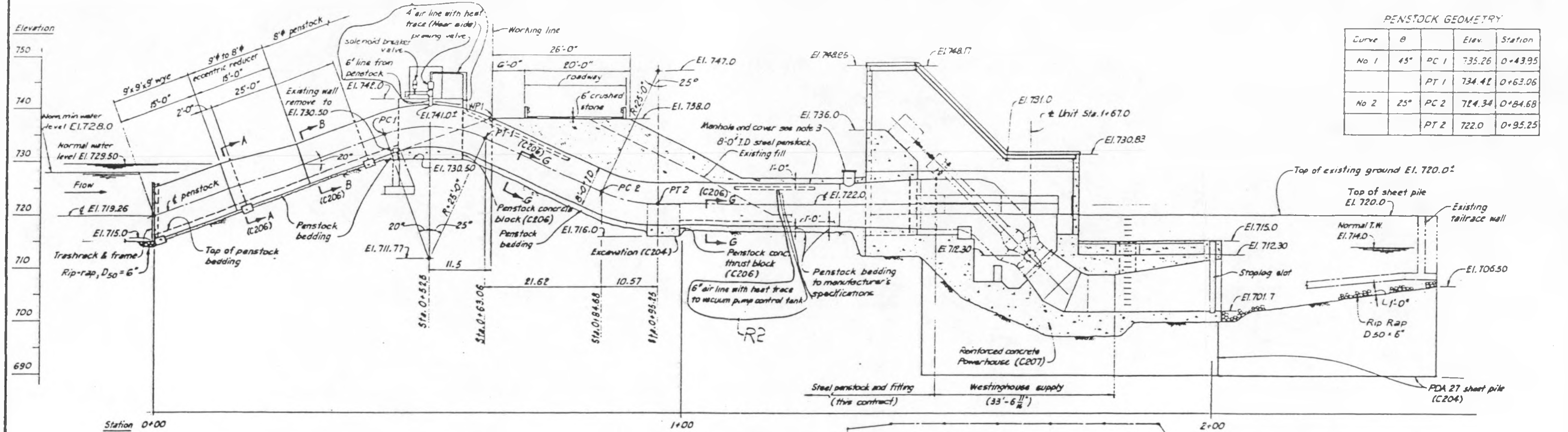


Figure I-4 Superior Dam - Powerhouse Interior Showing Turbine Casing (Right) and Siphon Priming System (Left)


PLAN
PENSTOCK BLOCK
Flow
vacuum breaker valve
priming valve
heated metal enclosure
℄ penstock
1" ϕ hole with plug for contact grouting (typ)
El. 742.00
4" air line with heat trace
Bracket as required
℄ ladder, type B
12'-0"
6'-0"
6'-0"
1'-6"
11'-0"
5'-6"
5'-6"
3'-0"
3'-0"
C - C
Heated metal enclosure
Priming valve
4" ϕ air line with heat trace
R2
Ladder, type B (C202)
El. 742.0
℄ 8'-0" ID penstock
T/fill El. varies
CJ El. 735.0
El. 730.5
℄ 1" ϕ hole with plug for contact grouting
11'-0"
PLAN
DOWNSTREAM PENSTOCK
THRUST BLOCK
Flow
El. 722.0
El. 722.0
5'-6"
5'-6"
5'-0"
5'-0"
℄ 1" ϕ hole with plug for contact grouting
D-D
T/fill El. varies
4" ϕ line to vacuum pump
℄ 8'-0" ID steel penstock
El. 722.0
1'-0" (typ)
El. 716.0
5'-6"
5'-6"
SIDE ELEVATION
TRASHRACK FRAME
MC 8 x 20
1'-0"
Steel strap
℄ 9'-0" ID steel penstock
Flow
℄ 1" ϕ A325 bolts with nut & washer
L 3 x 4 x 3/8
Penstock bedding
Rip-rap, D50 = 6"
Precast block
2'-0" (typ.)
E-E
Sym about ℄ penstock
4'-6"
L 4 x 4 x 1/2 x 9'-5"
MC 8 x 20
Clip L 3 x 4 (typ)
9'-0" ϕ penstock
El. 715.0
ELEVATION
TRASHRACK PANEL
(8-req'd)
Sym about ℄
℄ penstock & panel
4'-8"
26 spcs @ 4" oc = 8'-8"
6" x 1/2" end ℞ (typ)
2 1/2" x 3/8" rack bars (typ)
℄ 1" ϕ pipe
F-F
Flow
L 3 x 3 x 1/4 (typ)
℄ 1" ϕ pipe & ℄ panel
G-G
(C205)
1/8" = 1'-0"
℄ penstock
Penstock bedding
4'-0"
4'-0"
A1-A1
Embedded hooks for placement of precast block
Scale 0 1 Foot
1/2" = 1'-0"
A-A
(C205)
3/8" = 1'-0"
Galvanized turnbuckle (typ)
Steel strap
℄ penstock
#8 threaded rod (typ)
El. varies
5'-0"
5'-0"
B-B
(C205)
Scale 0 3 Foot
3/8" = 1'-0"
Top of existing grade El. varies
El. varies
Penstock bedding
3'-0"
3'-0"
REFERENCE DRAWINGS:
Work this drawing with 1520 C200 thru C205, C207 thru C211.
NOTES:
1. All welds to be 1/4" fillet welds, E70XX electrodes unless noted otherwise
2. All structural steel shall be ASTM A36 or better
3. All trashrack panels are to be interchangeable.
4. All elevations are in feet and dimensions are in feet and inches.
5. All reinforcement shall be #6 bars spaced at 12" oc unless noted otherwise
6. Bulkheads and trashrack to be true to dimensions, straight and out of wind.
7. Supply 4" ϕ steel vacuum pump line complete with heat-trace system as detailed in specifications
Scale 0 2 4 Feet
1/4" = 1'-0"
Except as noted
CITY OF ANN ARBOR
ANN ARBOR MICHIGAN
SUPERIOR DAM
POWERSTATION
PENSTOCK DETAILS
CONSULTING ENGINEERS
HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS
DATE OCT. 1984
DWG NO 1520 C 206 R2
4-6-85 Penstock vacuum system
11-20-84 Penstock bedding
REV NO
DWG TRANSMITTAL LETTER NO
DATE
NATURE OF REVISION
BY
CHKD
APPD
REVIEWED
CIVIL
MECH
ELECT

PENSTOCK GEOMETRY

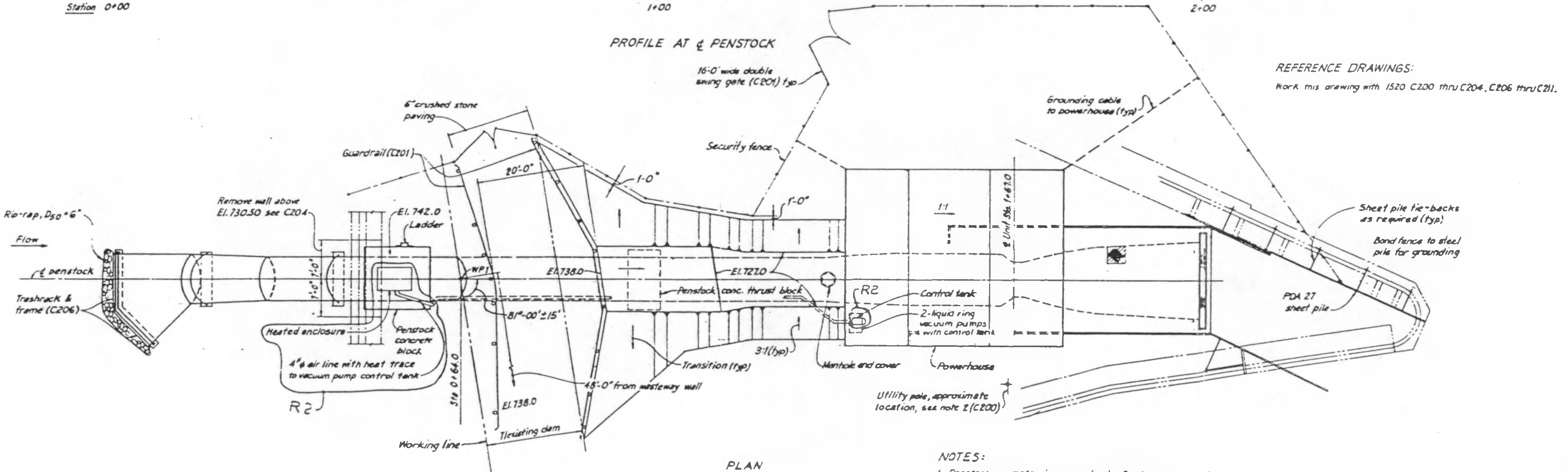
Curve	θ		Elev.	Station
No 1	45°	PC 1	735.26	0+43.95
		PT 1	734.42	0+63.06
No 2	25°	PC 2	724.34	0+84.68
		PT 2	722.0	0+95.25



PROFILE AT ℄ PENSTOCK

REFERENCE DRAWINGS:

Work this drawing with 1520 C200 thru C204, C206 thru C211.



PLAN

NOTES:

1. Penstock geometry is approximate, Contractor may bid any of 3 alternatives; Steel, Fiberglass, or concrete.
2. Concrete reinforcement shall be #6 bars @12" o.c. each face unless noted otherwise.
3. Contractors shall design, and install an access manhole with cover for an internal pressure or vacuum of 15 psi
4. Contractor shall design the penstock and fittings for an internal pressure or vacuum of 15 psi in combination with external overburden pressure where applicable. Allowances shall be made for temperature deflections in a steel penstock due to temperature differential of 50°F for exposed penstock and 20°F for buried penstock.

Scale 0 8 16 Feet
1/8" = 1'-0"

DSGN		REVIEWED		
CHKD		CIVIL		
DWN		MECH		
CHKD	CAC			
SUBM		ELECT.		

REV NO	DWG TRANSMITTAL LETTER NO	DATE	NATURE OF REVISION	BY	CHKD	APPD
2		9-6-85	Penstock vacuum system			
1		11-20-84	Minor revisions			

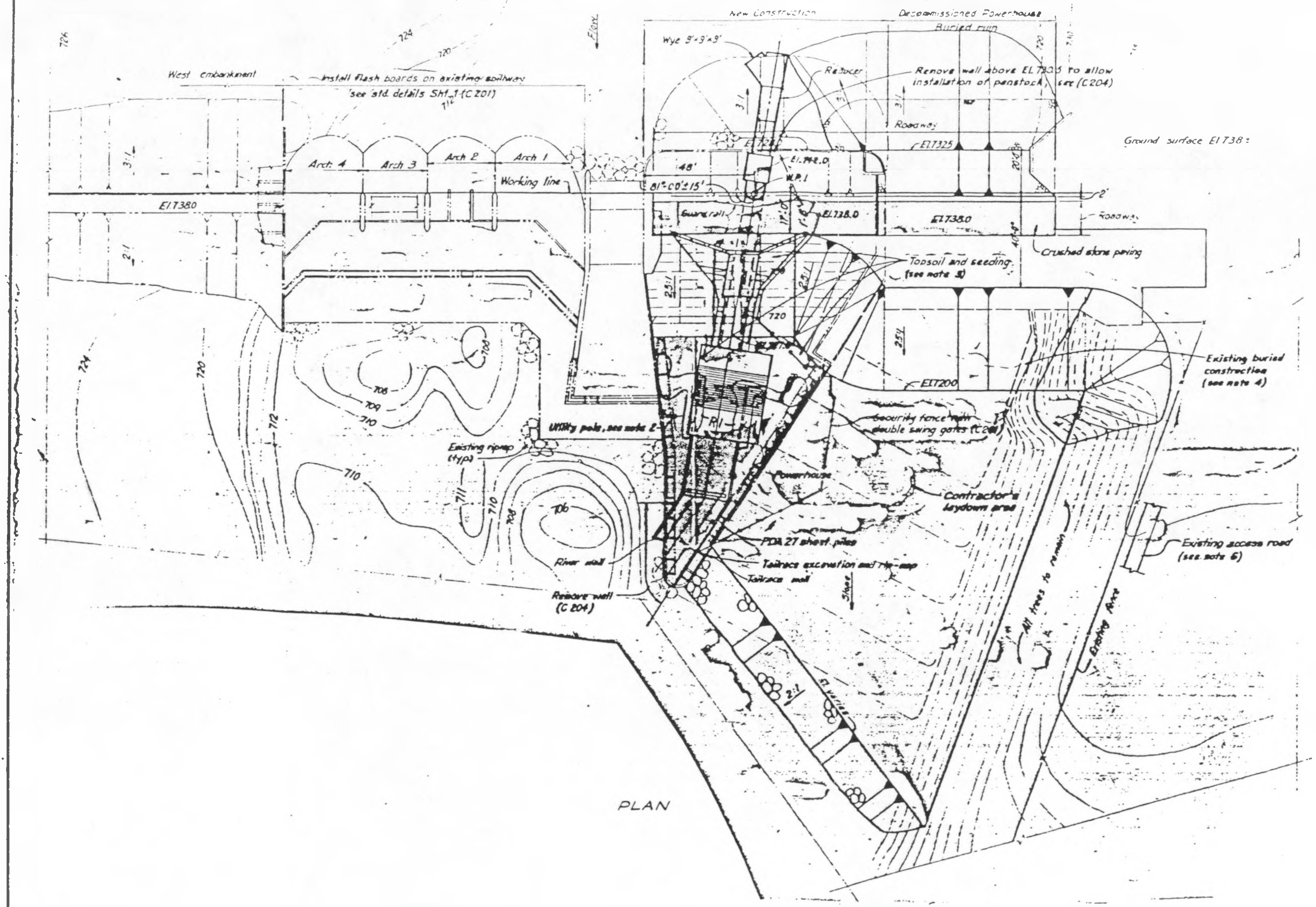
CITY OF ANN ARBOR
ANN ARBOR MICHIGAN

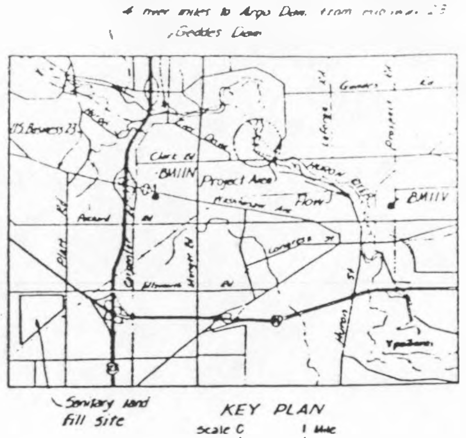
SUPERIOR DAM | POWERSTATION

PENSTOCK
PLAN AND PROFILE

CONSULTING ENGINEERS
HARZA ENGINEERING COMPANY
APPROVED

CHICAGO, ILLINOIS | DATE OCT. 1984 | DWG NO 1520 C 205 R2





KEY PLAN

Scale 0 — 1 Mile

BM11N, El 836.068 – About 25' south of Washtenaw Ave., ¼ mile east of Carpenter Rd between Dayton Dr. & Carlton Dr., about 12' east of a fire hydrant.
BM11V, El. 765.021 – At the northwest corner of the intersection of Forest, about 4' west of a fire hydrant.

REFERENCE DRAWINGS:

Work this drawing with 1520 C 201 thru C 211.

NOTES:

1. CONDITIONS AND DIMENSIONS OF EXISTING PROJECT FEATURES ARE AS KNOWN TO THE CITY. CONTRACTOR SHOULD VERIFY CONDITIONS AND DIMENSIONS IN THE FIELD PRIOR TO THE START OF ANY WORK.
2. IT WILL BE THE CONTRACTOR'S RESPONSIBILITY TO MAINTAIN THE INTEGRITY AND OPERABILITY OF THE EXISTING UTILITY POLE. RELOCATION WILL BE DONE ONLY WITH APPROVAL OF THE APPROPRIATE AUTHORITIES AND AT THE COST OF THE CONTRACTOR.
3. CONTRACTOR SHALL PLACE TOPSOIL AND SEED ALL AREAS AROUND PENSTOCK FILL AND POWERHOUSE CONSTRUCTION TO MATCH EXISTING GRASS COVERED AREAS.
4. EXISTING BURIED CONSTRUCTION IS DETAILED ON ORIGINAL CONSTRUCTION DRAWINGS AND ON DAM REHABILITATION DRAWINGS.
5. SHADING [ ] INDICATES AREAS OF WORK COVERED IN THIS CONTRACT.
6. EXISTING ACCESS ROAD TO BE MAINTAINED IN GOOD CONDITION AND KEPT CLEAR FOR DETROIT EDISON TRAFFIC DURING THE LENGTH OF THIS CONTRACT.

Scale 0 20 40 Feet
1" = 20'

CITY OF ANN ARBOR ANN ARBOR MICHIGAN	
SUPERIOR DAM	POWERSTATION
LOCATION MAP	
CONSULTING ENGINEERS HARZA ENGINEERING COMPANY APPROVED	
CHICAGO, ILLINOIS	DATE OCT. 1984 · DWG NO. 1520 C 200 P

REV NO.	DWG TRANSMITTAL LETTER NO.	DATE	NATURE OF REVISION	BY	CHKD	APPD
		11-20-84	Sheet pile location			

		REVIEWED
DSGN	JS	CIVIL
CHKD		MECH
DWN		ELECT
CHKD		
SUBM		

APPENDIX J

TIERCKENKILL FALLS HYDROELECTRIC PROJECT

TIERCKENKILL FALLS HYDROELECTRIC PROJECT

The Tierckenkill Falls Hydroelectric Project is located in Rensselaer, New York on the south bank of Mill Creek approximately 500 ft downstream from an existing dam. The subsurface powerhouse contains one 23 kW unit and one 55 kW unit, each rated at 105 ft head. The plant went into operation in 1986.

The intake, which is a horizontal extension of the penstock, consists of nine 12-inch wide vertical openings cut half way around the intake pipe. The intake openings are covered with 20 gauge, 1/2-inch galvanized wire screen which is fastened to the pipe with stainless-steel bands. There are no trash handling facilities at the intake.

The penstock is high density polyethylene pipe with a nominal inside diameter of 1.36 ft. The penstock sections have butt-fusion joints, and flanged joints at the anchor blocks. The vertical upstream portion of the penstock, which is connected by a 90-degree bend to the horizontal intake pipe, conforms to the shape of the dam. Heavy steel, horseshoe-shaped collars secure the intake and upstream penstock to the dam. The downstream portion of the penstock follows the contour of the streambed for approximately 200 ft and then bends 45 degrees to head overland toward the powerhouse. A portion of the overland penstock is covered by a shallow embankment. Concrete anchor blocks are provided immediately downstream of the dam, about 200 ft downstream of the dam, and at the powerhouse. Chain type restraints are also provided at strategic locations.

The overall penstock length is 532 ft, with a distance of 12 ft from the intake to the crown of the siphon.

The siphon priming system consists of a rotary vane vacuum pump, a vacuum tank, and associated piping, valves, and controls. The aboveground control building adjacent to the powerhouse contains the vacuum pump, tank, and controls. The priming valve, located at the dam, is connected to the crown of the siphon by three-inch piping. The vacuum system is connected to the priming valve by a nominal two-inch polyethylene pipe.

The subsurface powerhouse is a prefabricated concrete modular structure which extends from the ground surface to below the streambed. The generating units have vertical "reverse pump" turbines each with a pneumatically operated inlet butterfly valve and direct-connected vertical induction generator. The generators are connected to the utility grid through the switchgear and the station transformer.

The penstock system is drained by opening the vacuum breaker valve in the priming valve enclosure at the dam.

Discharge from the turbines is directed back into the creek through the two outfall pipes.

The plant is operated on a run-of-river basis and maintains constant headwater level allowing a flow of at least one cfs over the weir at the crest of the dam for aesthetic purposes. Flood flows in excess of the combined capacity of the units and the weir pass over the dam.

The units are automatically controlled by a programmable logic controller located in the control building. An operator is required to initiate the siphon priming operation. The vacuum priming system thereafter functions automatically to maintain operational readiness even during extended periods of inoperation.

TIERCKENKILL FALLS HYDROELECTRIC PROJECT

PROJECT OWNER:	MODULAR HYDRO RESEARCH CORPORATION
FERC NO.:	8929-000
LOCATION:	CITY OF RENSSELAER, RENSSELAER COUNTY, NEW YORK MILL CREEK
ENGINEER:	J. KENNETH FRASER AND ASSOCIATES, P.C.

Year of Initial Operation	1986
Plant Capacity	70 kW
Plant Flow	11.9 cfs
Rated Head	100 ft
Number of Units	Two

HYDRAULIC CONDITIONS

– Headwater Level	
• Maximum (for plant operation)	El 131.0
• Normal	El 128.5
• Minimum (for plant operation)	El 126.6
– Tailwater Level	
• Maximum (for plant operation)	El 22.0
• Normal	El 21.0
• Minimum (for plant operation)	El 20.6
– Gross Head	
• Maximum (for plant operation)	109.0 ft
• Normal	107.0 ft
• Minimum (for plant operation)	106.0 ft

GENERATING UNIT DATA

– Unit No.	1	2
– Turbine		
• Manufacturer	Byron Jackson	Byron Jackson
• Type	Standard Vertical Turbine Pump	Standard Vertical Turbine Pump
• Model	2518-OH-DO-VKW	2512-OH-DO-VKW
• Rated Net Head	105 ft	105 ft
• Rated Power	74 hp	33 hp
• Speed	1,200 rpm	1,800 rpm

Unit No.	1	2
• Pump Bowl Assembly Diameter	18 in.	12 in.
• Runner Diameter	12 in. (approx.)	8 in. (approx.)
– Generator		
• Manufacturer	U.S. Electrical Motors	U.S. Electrical Motors
• Type	Vertical Induction	Vertical Induction
• Rated Output	63 kVA	34 kVA
• Power Factor	0.877	0.877
• Rated Power	56 kW	30 kW
• Speed	1,200 rpm	1,820 rpm
• Voltage	480 V	480 V
– Intake Valves		
• Manufacturer	Keystone Valve	Keystone Valve
• Type	Butterfly	Butterfly
• Diameter	16 in.	10 in.
• Type of Operator	Pneumatic	Pneumatic

– Controls
- Manufacturer .... Assembled by Electropak Co.
- Type .... Relay type for Utility intertie. Programmable Controller for supervising and monitoring

PENSTOCK DATA

– Number of Siphon Penstocks .... One

– Diameter
- Nominal .... 18 in. outside diameter; 16.3 in. inside diameter
- At Siphon .... 18 in. outside diameter; 15.9 in. inside diameter

– Length
- Intake to top of siphon .... 12 ft
- Top of siphon to unit .... 520 ft

– Elevation of Penstock Centerline at Top of Siphon .... El 129.7 ft

– Siphon Lift
- Maximum (minimum headwater level to to penstock centerline at top of siphon) .... 3.1 ft
- Normal (normal headwater level to penstock centerline at top of siphon) .... 1.2 ft

– Design Flow	
• Maximum	12 cfs
• Normal	3.7, 8.7, or 11.9 cfs
• Minimum	3.5 cfs
– Penstock Material	High Density Polyethylene Pipe
– Material Thickness at Top of Siphon	1.06 in.

PENSTOCK INTAKE

– Inlet Flow Direction	Horizontal
– Opening Area	24 ft^2
– Material	Polyethylene Pipe
– Trashracks	
• Gross area	24 ft^2
• Bar clear spacing	1/2 in. Galvanized Wire Mesh Screen 20 AWG

SIPHON PRIMING SYSTEM

– Number of Vacuum Pumps	One
– Vacuum Pump Data	
• Type	Rotary Vane
• Manufacturer	ITT Pneumotive
• Model Number	195-2 Type E
• Power	1.5 hp
• Capacity	16 cfm at 5 in. Hg
– Priming Valve	
• Manufacturer	APCO
• Model Number	#200 AP Priming Valve
• Size	1 in.
– Air Inlet (Vacuum Breaker) Valve	
• Type	Ball Valve
• Manufacturer	Watts Regulator Company
• Model Number	EMV II Motorized Ball Valve
• Size	3 in.
– Vacuum Control Tank Size	8 ft^3
– Volume of Air to be Removed for Siphon Priming	750 ft^3
– Siphon Priming Time (Empty Penstock)	45 min.

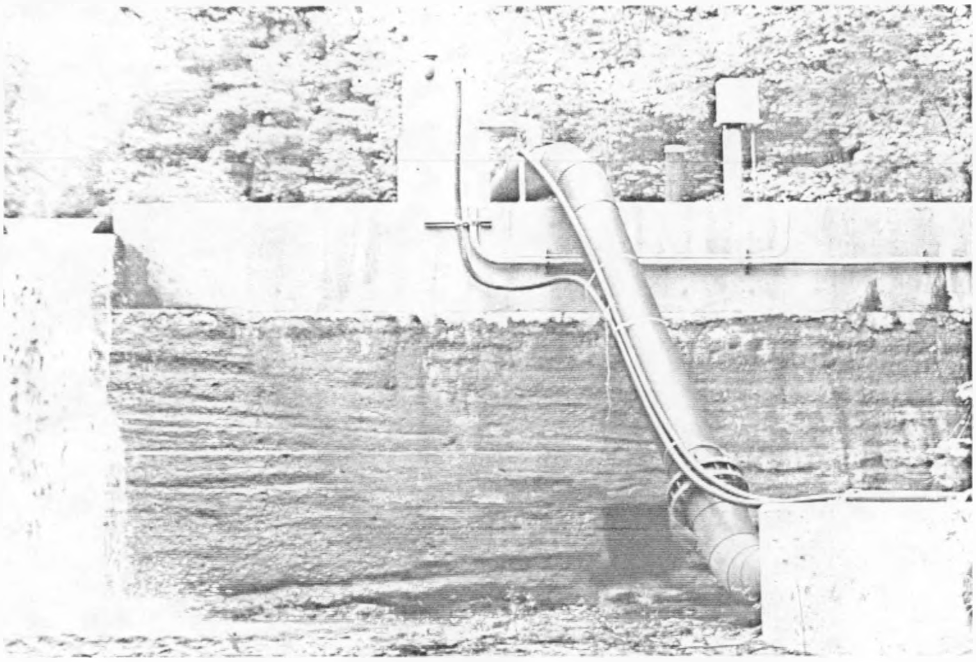


Figure J-1 Tierckenkill Falls - Penstock Section Downstream of Dam

Figure J-2 Tierckenkill Falls - Penstock Between Dam and Powerhouse

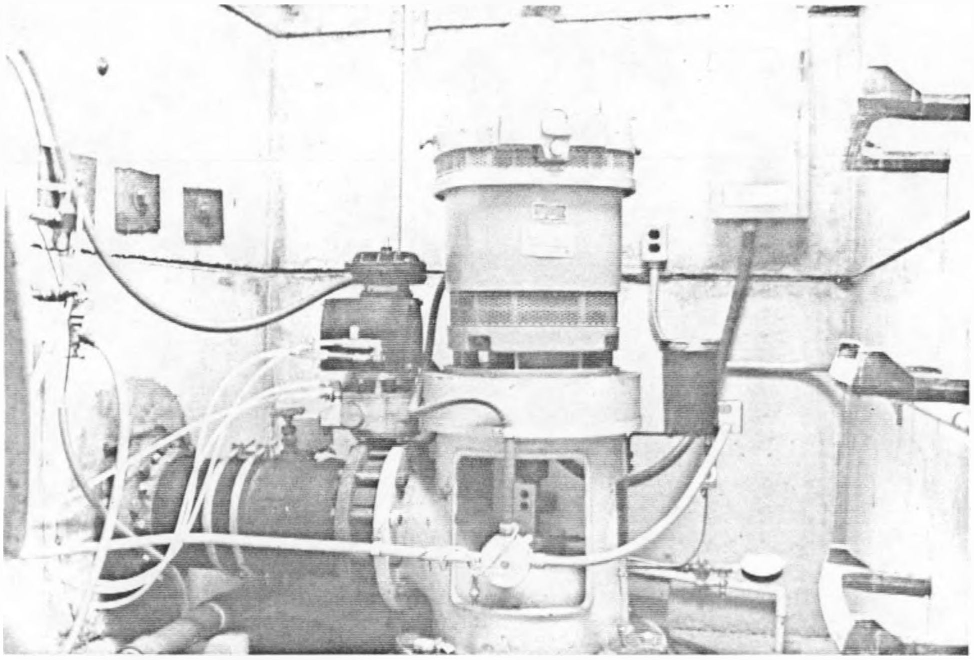


Figure J-3 Tierckenkill Falls - Unit 2

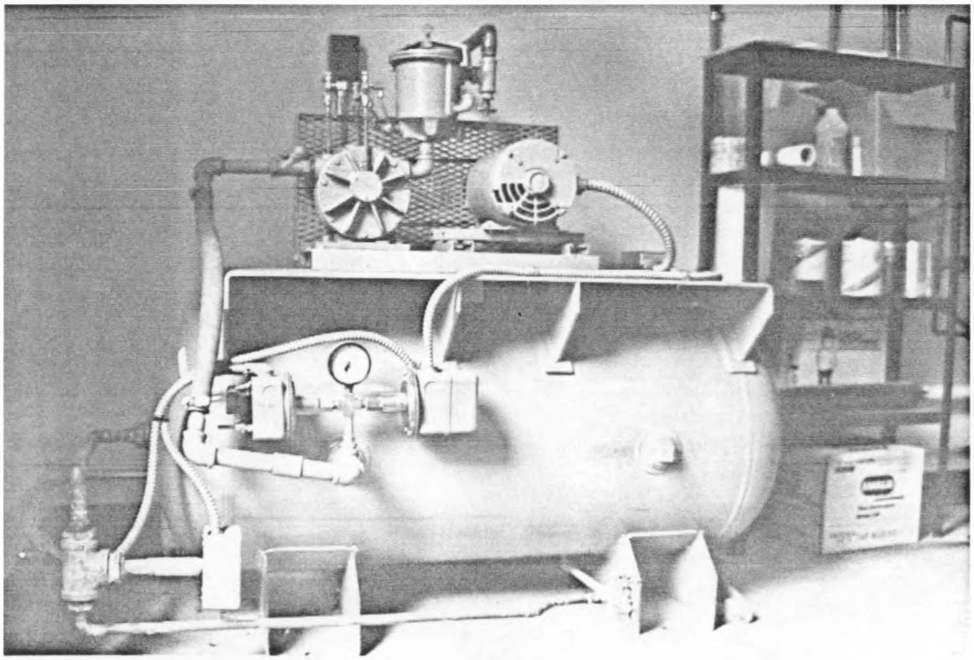
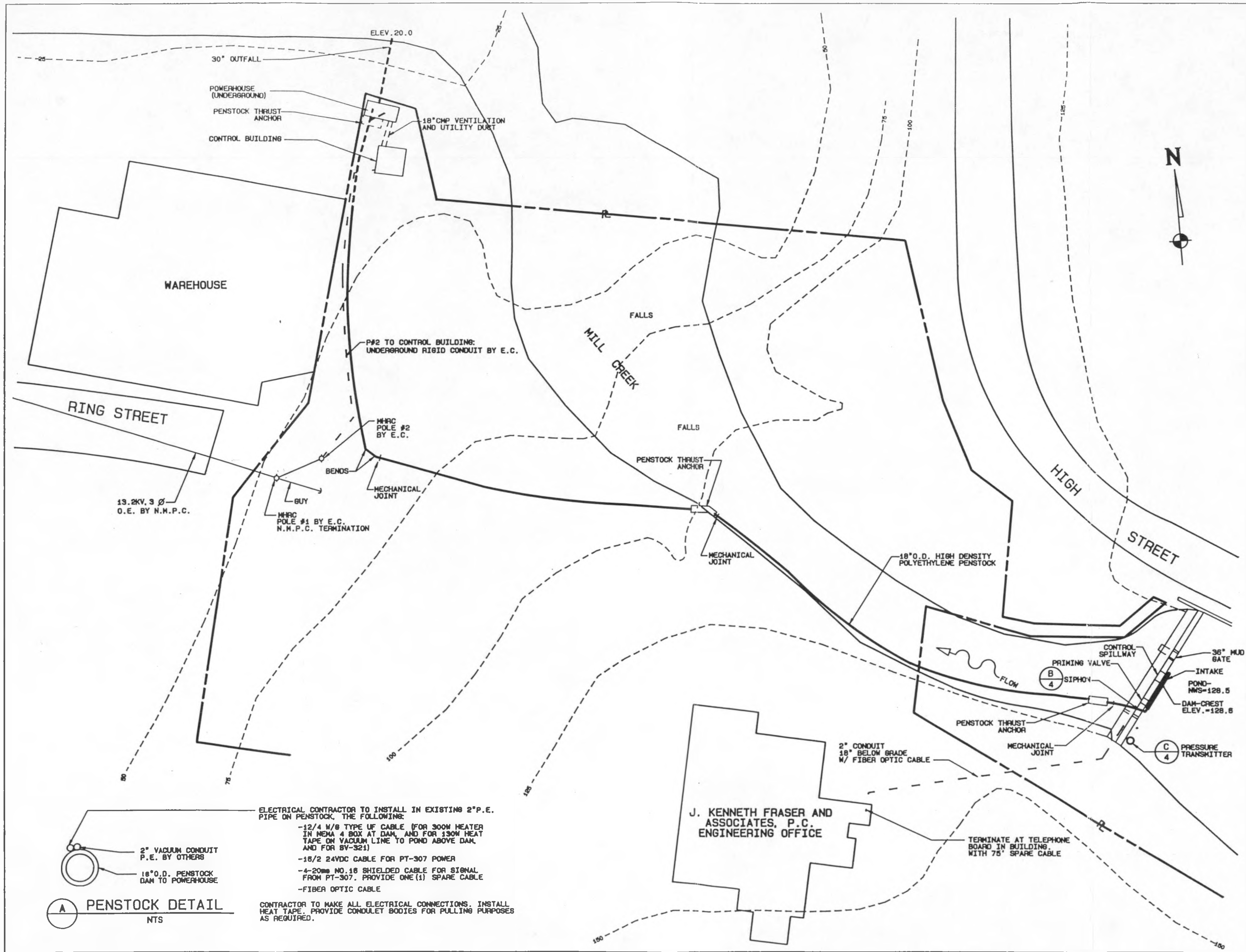


Figure J-4 Tierckenkill Falls - Siphon Priming System



SCALE

KEY PLAN

NOTES

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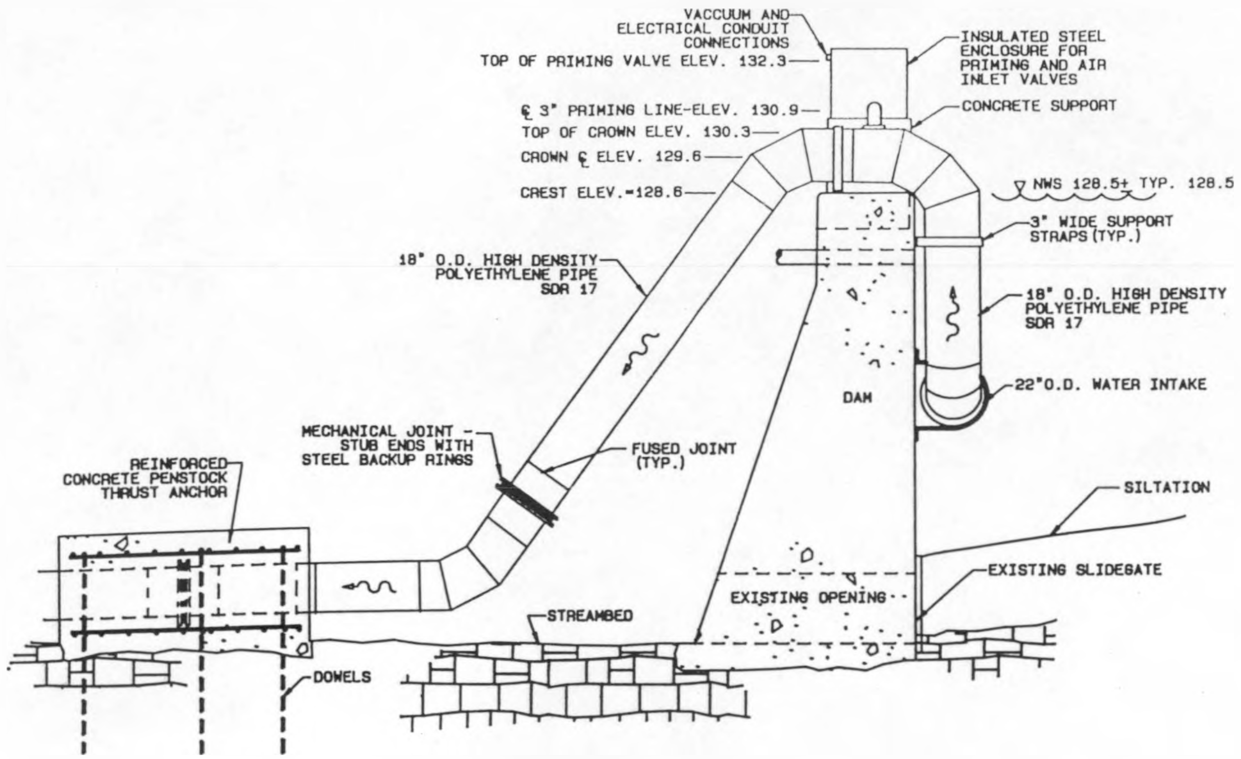
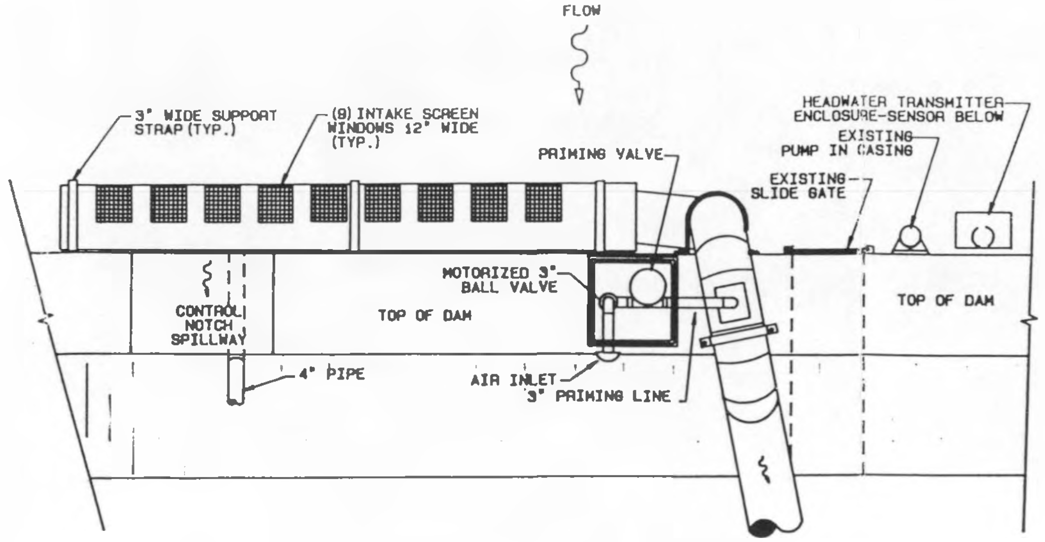
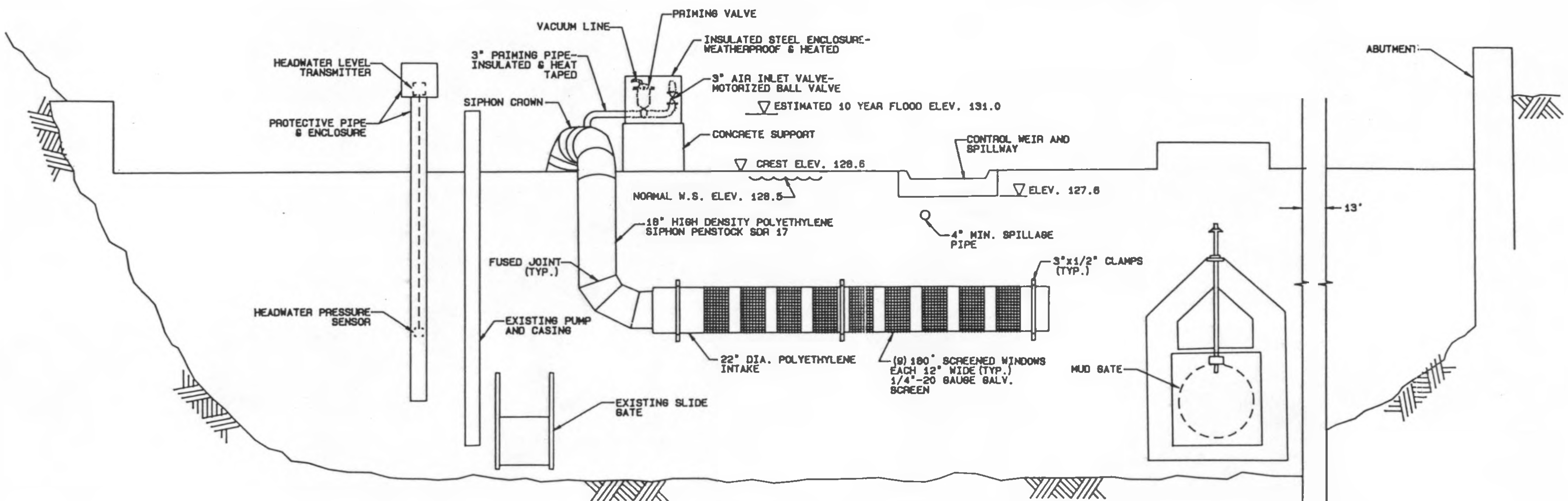


SIPHON INTAKE PROFILE
SCALE: 3/8"=1'-0"



SIPHON/INTAKE PLAN
SCALE: 3/8"=1'-0"



FRONT ELEVATION-DAM
SCALE: 3/8"=1'-0"

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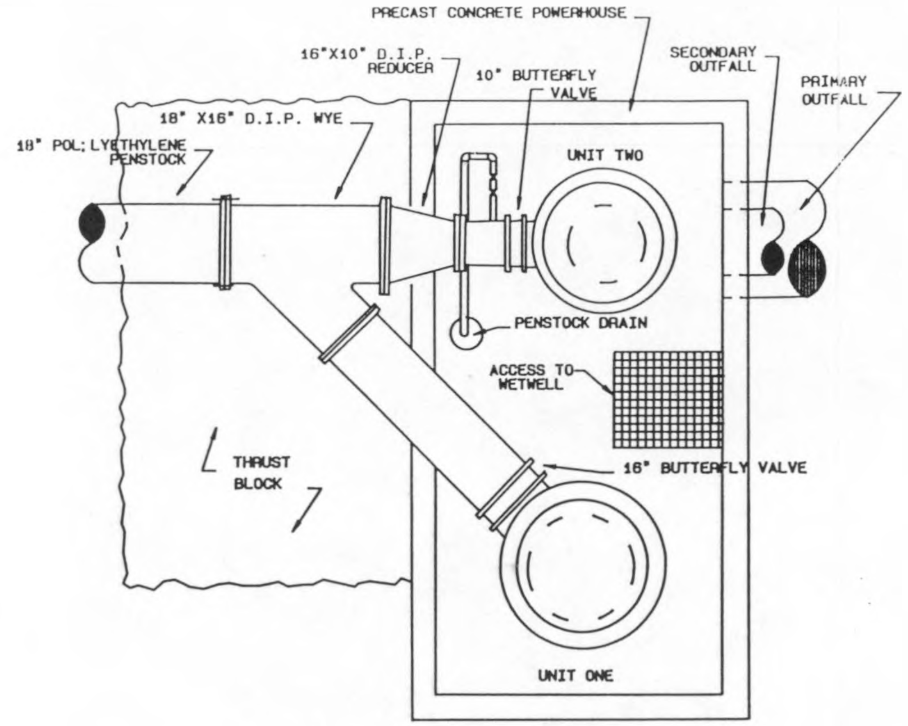
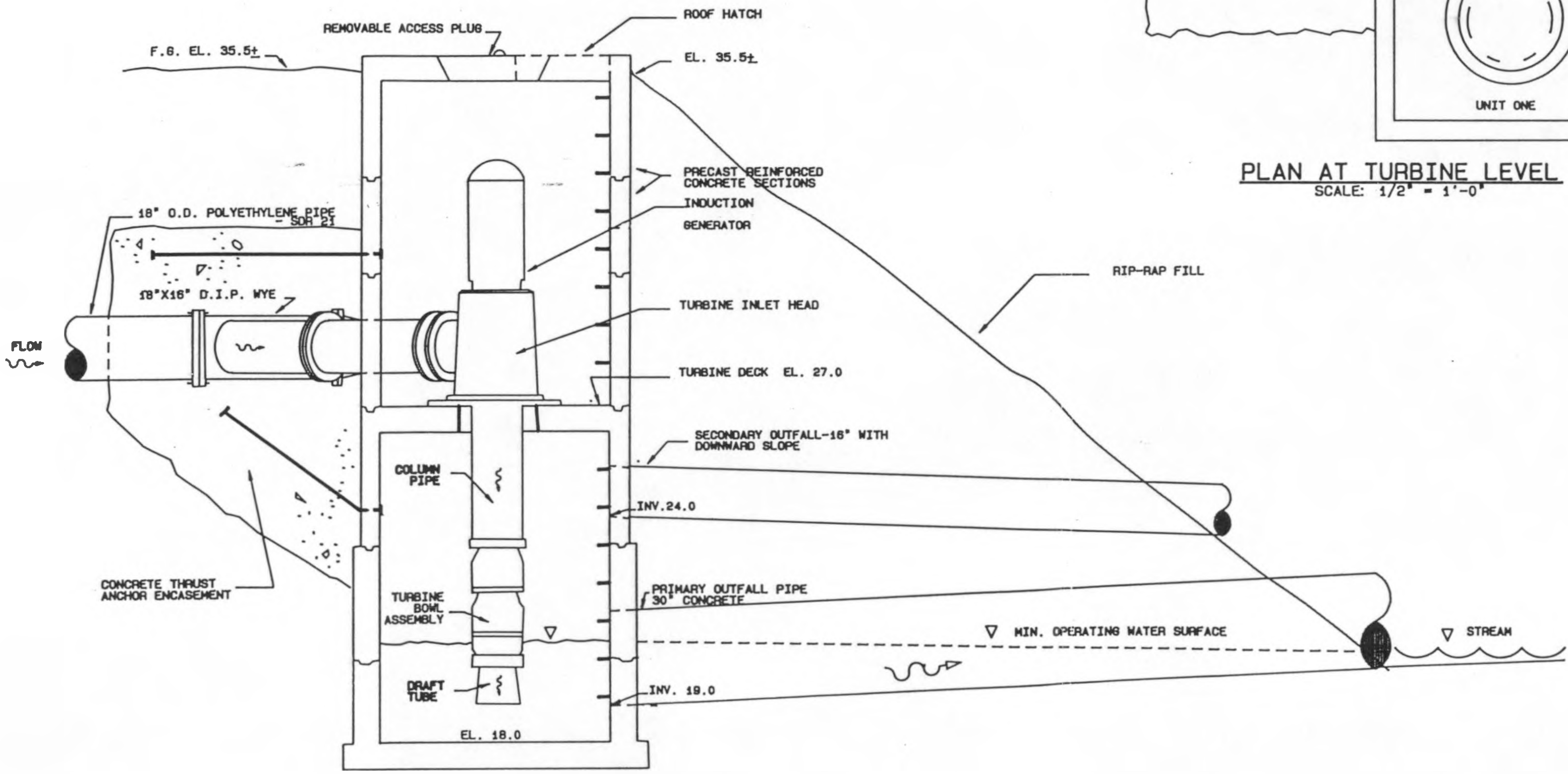


PLAN AT TURBINE LEVEL
SCALE: 1/2" = 1'-0"



POWERHOUSE SECTION
SCALE: 1/2" = 1'-0"

SCALE
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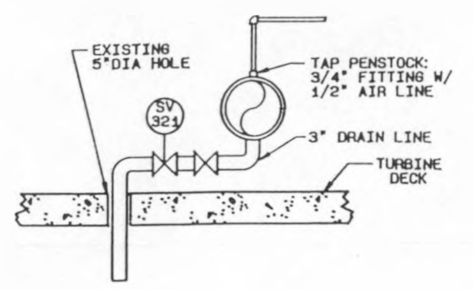
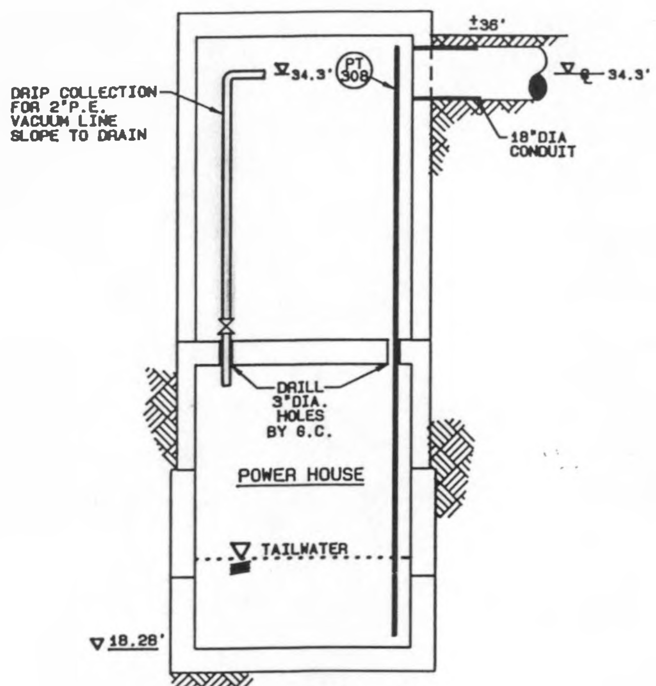
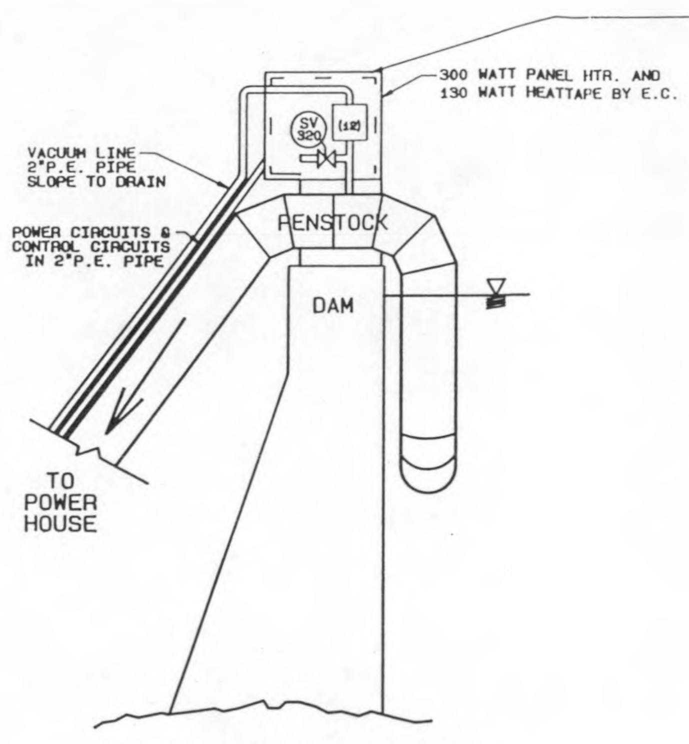


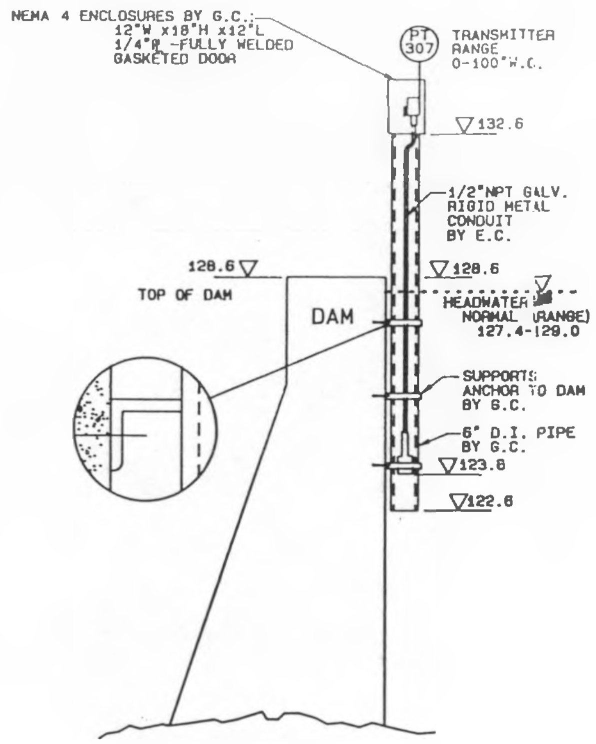
SECTION 'A'
SCALE: 1/2"=1'-0"



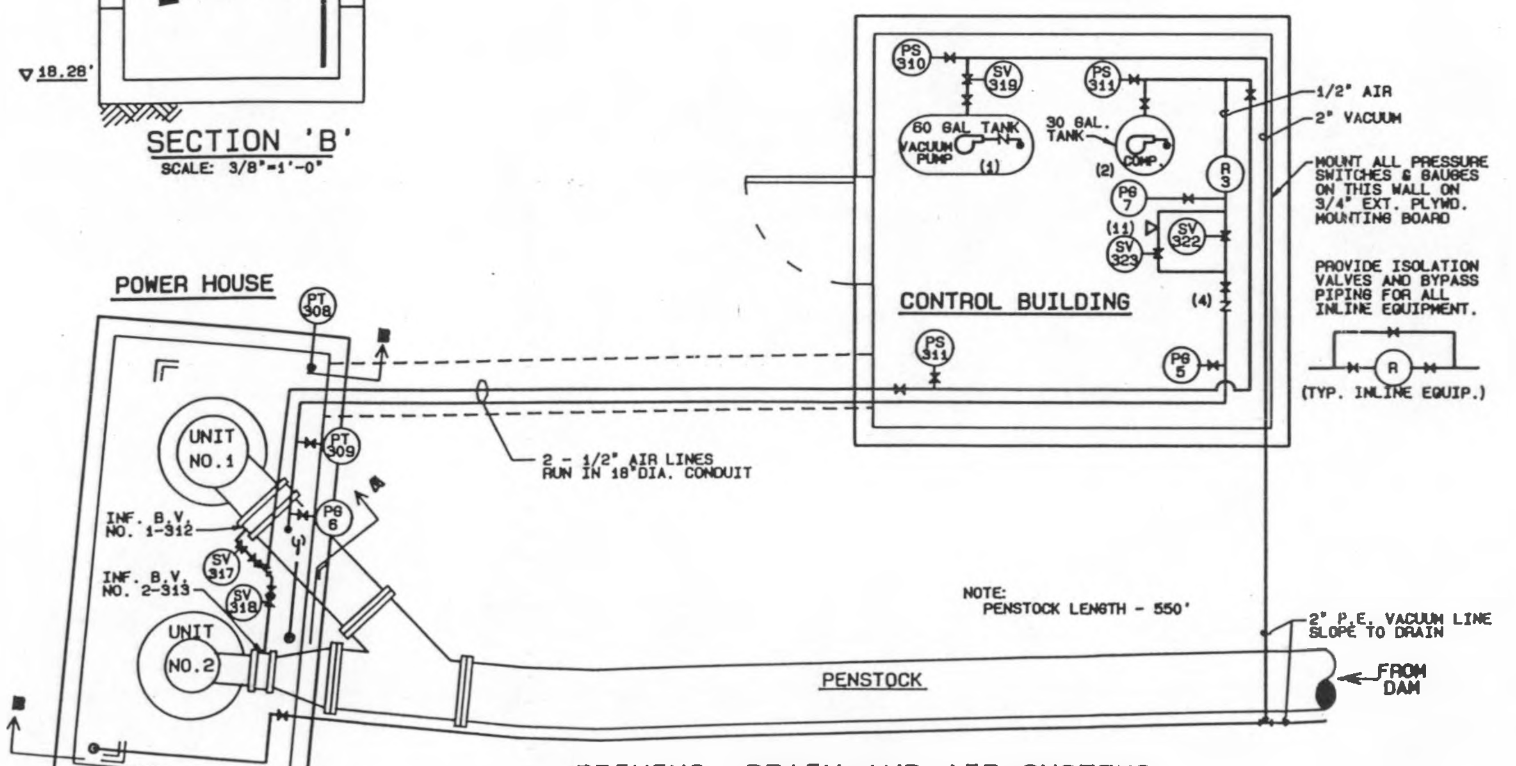
SECTION 'B'
SCALE: 3/8"=1'-0"



B/1 PENSTOCK AT DAM
SCALE: 3/8"=1'-0"



C/1 PRESSURE TRANSMITTER AT DAM
SCALE: 3/8"=1'-0"



PRIMING, DRAIN AND AIR SYSTEMS
SCALE: 3/8"=1'-0"

MATERIALS LIST

ITEM	DESCRIPTION	FURNISH	INSTALL	WIRE
1	VACUUM SYSTEM - VACUUM PUMP W/60 GAL. TANK, ITT PNEUMOTIVE 190-2	OWNER	G.C.	E.C.
2	AIR SYSTEM - COMPRESSOR W/ 30 GAL. VERT. TANK, SPEEDAIR #3Z 423			
3	AIR REGULATOR - 1PSI OUTPUT			
4	CHECK VALVE			
5	PRESSURE GAUGE - 0-100 PSI			
6	PRESSURE GAUGE - 0-100 PSI			
7	PRESSURE GAUGE - 0-100 PSI			
8	OMIT			
9	OMIT			
10	OMIT			
11	NEEDLE VALVE			
12	PRIMING VALVE - 1"-200AP - V-APCO			
13	OMIT			
14	OMIT			
15	OMIT			
16	OMIT			
307	PRESSURE TRANSMITTER - HEADWATER			
308	PRESSURE TRANSMITTER - TAILWATER			
309	PRESSURE TRANSMITTER - PENSTOCK			
310	PRESSURE SWITCH - VACUUM SYSTEM			
311	PRESSURE SWITCH - AIR SYSTEM			
317	SOLENOID VALVES - B.V. NO.1 (2 REQ'D - 1 OPEN, 1 CLOSE)			
318	SOLENOID VALVES - B.V. NO.2 (2 REQ'D - 1 OPEN, 1 CLOSE)			
319	SOLENOID VALVE - VACUUM SYSTEM ISOLATION			
320	SOLENOID VALVE - PENSTOCK DRAIN @ DAM			
321	SOLENOID VALVE - PENSTOCK DRAIN @ POWER HOUSE			
322	SOLENOID VALVE, PENSTOCK AIR - FILL ASCO#8210C93			
323	SOLENOID VALVE, PENSTOCK AIR - MAINTAIN ASCO#82619			

SCALE

KEY PLAN

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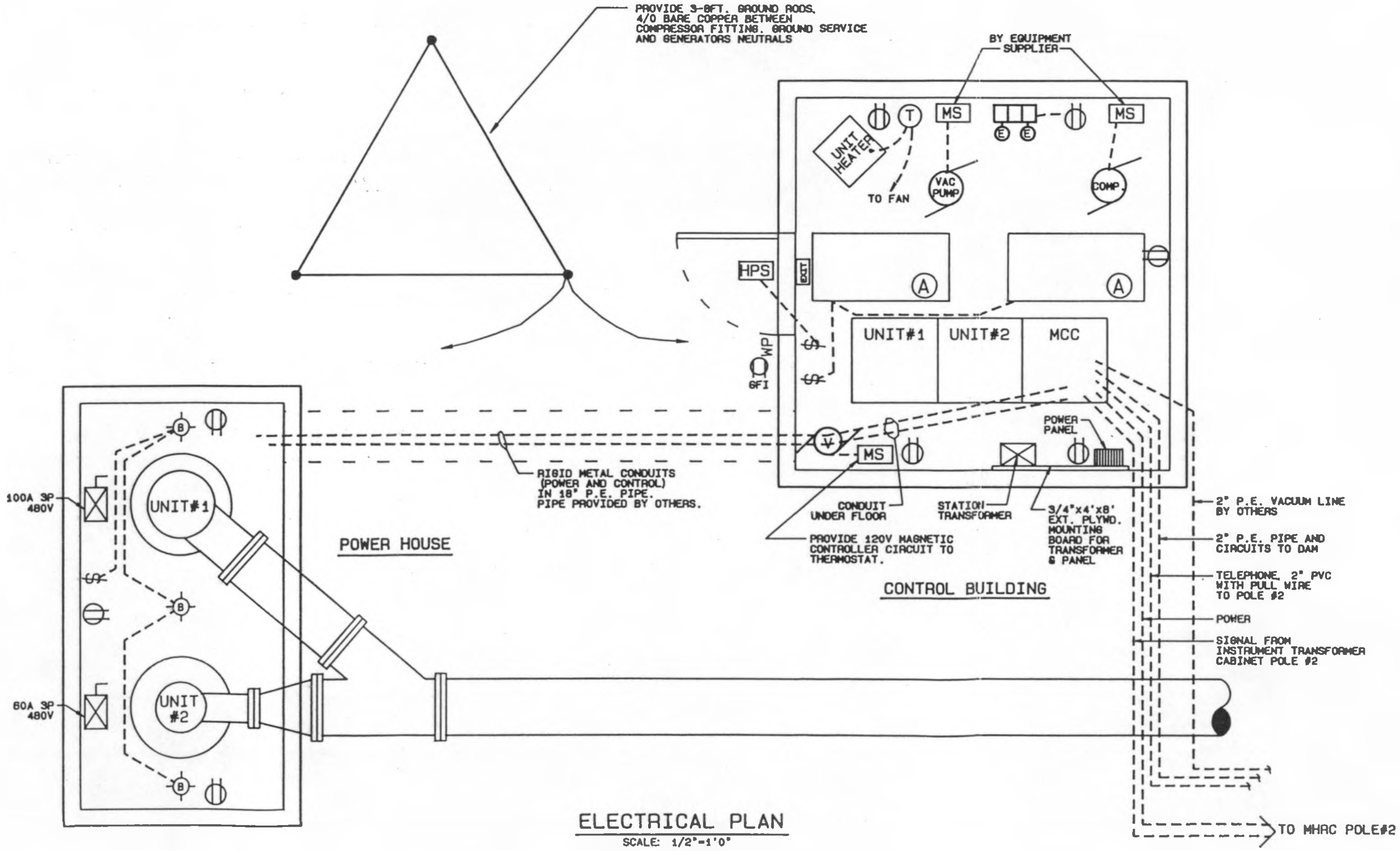
ELECTRICAL CONTRACTOR TO PROVIDE ALL WIRING.
E.C. TO PROVIDE ITEMS LISTED BELOW, EXCEPT WHERE NOTED.

POWER PANEL P1:

50A 3P M.C.B., 120/208V
3-PHASE 4W, SURFACE WITH
FOLLOWING CIRCUIT BREAKERS

QUANITY	CIRCUIT BREAKER	WIRE	ITEM
3	20A 3P	#12	UNIT HEATER, VACUUM PUMP, COMPRESSOR
5	20A 1P	#12	RECEPTACLES, VENT FAN, LIGHTS, ENVIRONMENTAL MONITORS (2)
1	20A 1P	#12	POWERHOUSE RECEPTACLES
7	20A 1P		ITEMS 317 TO 323
1	20A 1P		CIRCUIT TO DAM
4	20A 3P	#12	SPARES
2	20A 1P	#12	SPARES



ELECTRICAL PLAN

SCALE: 1/2"=1'0"

EQUIPMENT LEGEND

ITEM	DESCRIPTION
UNIT 1	GENERATOR 75HP, 480V, 3 ø BY OTHERS
UNIT 2	GENERATOR 40HP, 480V, 3 ø BY OTHERS
VAC PUMP	VACUUM PUMP 1 1/2HP, 208V, 3 ø BY OTHERS
COMP	COMPRESSOR 1HP, 208V, 3 ø BY OTHERS
UH	UNIT HEATER-3KW EMERSON CEILING MOUNTED 208V, 3 ø WITH CONTACTOR
A	FLUORESCENT FIXTURE 4-40W LAMPS COLD WEATHER BALLAST
V	VENTILATION FAN 1/2HP, 120V, 1 ø
HPS	EXTERIOR LIGHT FIXTURE 150W H.P.S. W/PHOTO CELL STONCO
T	THERMOSTAT-HEAT/COOL FOR U.H. & FAN 40° 80°F
E E	EMERGENCY LIGHT 6.V. NICKLE CADMIUM BATTERY EMERGI-LIGHT JSC-25
B	VAPOR TIGHT INCADESCENT LIGHT FIXTURES -100WATTS LUMAX - "VAPOTRON A"
EXIT	EXIT LIGHT EMERGI-LIGHT X12
	DISCONNECT
	RECEPTICAL -DUPLEX 48"AFF
WP	RECEPTICAL DUPLEX WEATHER PROOF GFI 48"AFF
MS	MOTOR STARTER
$	SWITCH

SCALE

KEY PLAN

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SIPHON PENSTOCK REPORT
D.O.E. CONTRACT
DE-AC07-82ID12356

SHEET TITLE: ELECTRICAL PLAN

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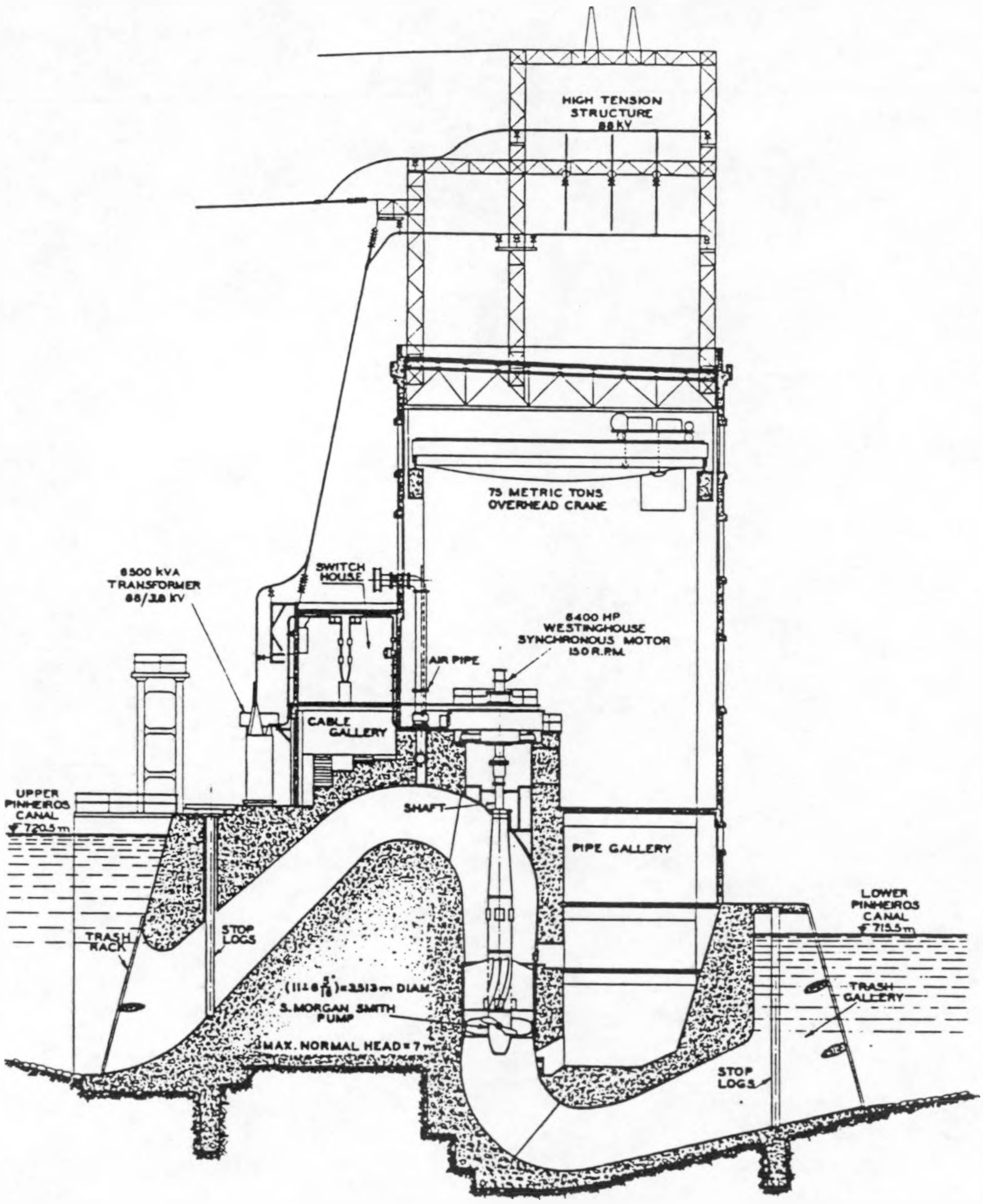
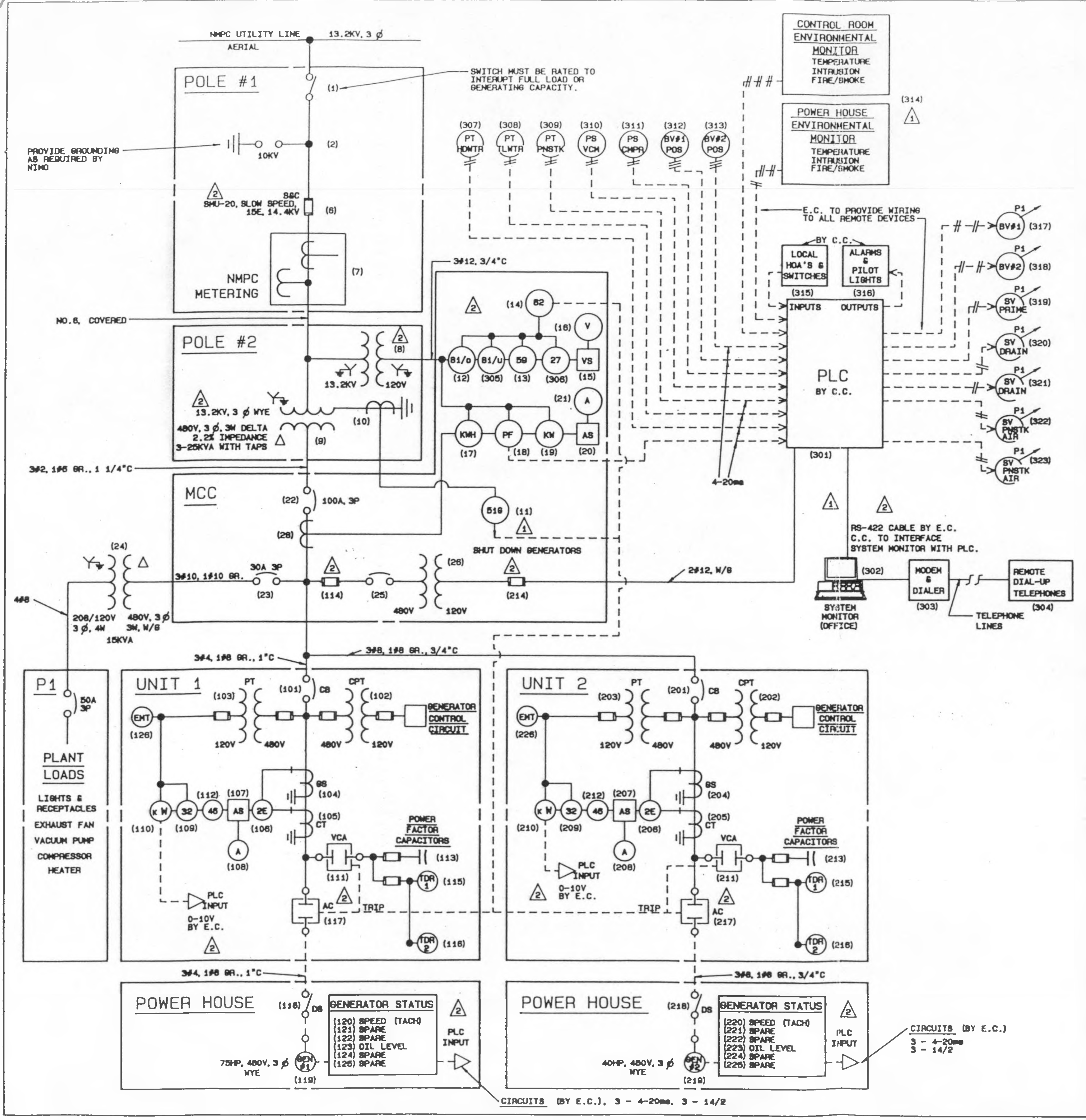


Cross-section through Traição pump station



ITEM	QTY	DESCRIPTION	LOCATION	SUPPLY	INSTALL
1	1	HORN GAP SWITCH 3P, 14.4KV	POLE #1	E.C.	E.C.
2	3	LIGHTNING ARRESTORS, 10KV	POLE #1	E.C.	E.C.
		3, 4, 5 OMIT			
6	3	FUSES	POLE #1	E.C.	E.C.
7	1	NMPC METERING	POLE #1	NMPC	E.C.
8	3	INSTRUMENT TRANSFORMER	POLE #2	E.C.	E.C.
9	1	STEP UP TRANSFORMER	POLE #2	E.C.	E.C.
10	1	CURRENT TRANSFORMER 5/5	POLE #2	E.C.	E.C.
11	1	OVERCURRENT RELAY - G.F.P.	POLE #2	C.C.	C.C.
12	1	OVER FREQUENCY RELAY	MCC	C.C.	C.C.
13	3	OVER VOLTAGE RELAY	MCC	C.C.	C.C.
14	1	TIME DELAY	MCC	C.C.	C.C.
15	1	VOLTMETER SWITCH	MCC	C.C.	C.C.
16	1	VOLTMETER	MCC	C.C.	C.C.
17	1	KILOWATT HOUR METER	MCC	C.C.	C.C.
18	1	POWER FACTOR METER & TRANSDUCER	MCC	C.C.	C.C.
19	1	KILOWATT METER	MCC	C.C.	C.C.
20	1	AMMETER SWITCH	MCC	C.C.	C.C.
21	1	AMMETER	MCC	C.C.	C.C.
22	1	CIRCUIT BREAKER	MCC	C.C.	C.C.
23	1	CIRCUIT BREAKER	MCC	C.C.	C.C.
24	1	TRANSFORMER - PLANT LOADS	MCC	E.C.	E.C.
25	1	CIRCUIT BREAKER	MCC	C.C.	C.C.
26	1	TRANSFORMER - PLC 2KVA	MCC	C.C.	C.C.
27					
28	3	CURRENT TRANSFORMER 150/5	MCC	C.C.	C.C.
101	1	CIRCUIT BREAKER	UNIT #1	C.C.	C.C.
102	1	TRANSFORMER - GEN#1 CNTRL	UNIT #1	C.C.	C.C.
103	3	TRANSFORMER - GEN#1 INSTRMNT	UNIT #1	C.C.	C.C.
104	1	GROUND FAULT SENSOR	UNIT #1	C.C.	C.C.
105	3	CURRENT TRANSFORMER 150/5	UNIT #1	C.C.	C.C.
106	1	MOTOR PROTECTION RELAYS	UNIT #1	C.C.	C.C.
107	1	AMMETER SWITCH	UNIT #1	C.C.	C.C.
108	1	AMMETER	UNIT #1	C.C.	C.C.
109	1	REVERSE POWER RELAY	UNIT #1	C.C.	C.C.
110	1	KILOWATT METER	UNIT #1	C.C.	C.C.
111	1	VACUUM CONTACTOR	UNIT #1	C.C.	C.C.
112	1	PHASE BALANCE	UNIT #1	C.C.	C.C.
113	1	POWER CAPACITORS 25KVAR	UNIT #1	C.C.	C.C.
114	1	FUSE	UNIT #1	C.C.	C.C.
115	1	TIME RELAY	UNIT #1	C.C.	C.C.
116	1	BYPASS REVERSE POWER RELAY	UNIT #1	C.C.	C.C.
117	1	AIR CONTACTOR	UNIT #1	C.C.	C.C.
118	1	DISCONNECT	POWER HSE	E.C.	E.C.
119	1	GENERATOR	POWER HSE	OWNER	OWNER
120	1	SPEED (TACH) 4-20ma	POWER HSE	C.C.	E.C.
121	1	SPARE 4-20ma	POWER HSE	C.C.	E.C.
122	1	SPARE 4-20ma	POWER HSE	C.C.	E.C.
123	1	OIL LEVEL	POWER HSE	C.C.	E.C.
124	1	SPARE	POWER HSE	C.C.	E.C.
125	1	SPARE	POWER HSE	C.C.	E.C.
126	1	ELAPSED TIME METER	UNIT #1	C.C.	C.C.
201	1	CIRCUIT BREAKER	UNIT #2	C.C.	C.C.
202	1	TRANSFORMER - GEN#1 CNTRL	UNIT #2	C.C.	C.C.
203	3	TRANSFORMER - GEN#1 INSTRMNT	UNIT #2	C.C.	C.C.
204	1	GROUND FAULT SENSOR	UNIT #2	C.C.	C.C.
205	3	CURRENT TRANSFORMER 100/5	UNIT #2	C.C.	C.C.
206	1	MOTOR PROTECTION	UNIT #2	C.C.	C.C.
207	1	AMMETER SWITCH	UNIT #2	C.C.	C.C.
208	1	AMMETER	UNIT #2	C.C.	C.C.
209	1	REVERSE POWER RELAY	UNIT #2	C.C.	C.C.
210	1	KILOWATT METER & TRANSDUCER	UNIT #2	C.C.	C.C.
211	1	VACUUM CONTACTOR	UNIT #2	C.C.	C.C.
212	1	PHASE BALANCE	UNIT #2	C.C.	C.C.
213	1	POWER CAPACITORS 15KVAR	UNIT #2	C.C.	C.C.
214	1	FUSE	UNIT #2	C.C.	C.C.
215	1	TIME RELAY	UNIT #2	C.C.	C.C.
216	1	BYPASS REVERSE POWER RELAY	UNIT #2	C.C.	C.C.
217	1	AIR CONTACTOR	UNIT #2	C.C.	C.C.
218	1	DISCONNECT	POWER HSE	E.C.	C.C.
219	1	GENERATOR	POWER HSE	OWNER	OWNER
220	1	SPEED (TACH) 4-20ma	POWER HSE	C.C.	E.C.
221	1	SPARE 4-20ma	POWER HSE	C.C.	E.C.
222	1	SPARE 4-20ma	POWER HSE	C.C.	E.C.
223	1	OIL LEVEL	POWER HSE	C.C.	E.C.
224	1	SPARE	POWER HSE	C.C.	E.C.
225	1	SPARE	POWER HSE	C.C.	E.C.
226	1	ELAPSED TIME METER	POWER HSE	C.C.	C.C.
301	1	PROGRAMABLE LOGIC CONTROLLER	MCC	C.C.	C.C.
302	1	SYSTEM MONITOR	OFFICE	OWNER	OWNER
303	1	MODEM AND DIALER	OFFICE	OWNER	OWNER
304	1	REMOTE DIALUP TELEPHONES	REMOTE	OWNER	OWNER
305	1	UNDER FREQUENCY RELAY	MCC	C.C.	C.C.
306	3	UNDER VOLTAGE RELAY	MCC	C.C.	C.C.
307	1	PRESS. TRANSD. HEADWATER	DAM	OWNER	OWNER
308	1	PRESS. TRANSD. TAILWATER	POWER HSE	OWNER	OWNER
309	1	PRESS. TRANSD. PENSTOCK	CTRL BLDG	OWNER	OWNER
310	1	PRESS. SWITCH VACUUM PUMP	CTRL BLDG	OWNER	OWNER
311	1	PRESS. SWITCH COMPRESSOR	CTRL BLDG	OWNER	OWNER
312	1	B. VALVE #1 POSITION 4-20ma	POWER HSE	OWNER	OWNER
313	1	B. VALVE #2 POSITION 4-20ma	POWER HSE	OWNER	OWNER
314	1	ENVIRONMENTAL MONITORS	PH, CBLDG	OWNER	OWNER
315	1	LOCAL HOA & SWITCHES	UNIT#1&#2	C.C.	C.C.
316	1	LOCAL ALARMS & PILOT LIGHTS	UNIT#1&#2	C.C.	C.C.
317	1	B. VALVE #1 ACTUATOR 2.5V, O/C	POWER HSE	OWNER	OWNER
318	1	B. VALVE #2 ACTUATOR 2.5V, O/C	POWER HSE	OWNER	OWNER
319	1	SOLENOID VALVE PRIMING SYSTEM	POWER HSE	OWNER	OWNER
320	1	SOLENOID VALVES AIR DRAIN	DAM	OWNER	OWNER
321	1	SOLENOID VALVE AIR DRAIN	P.H.	OWNER	OWNER
322	1	SOLENOID VALVE PENSTOCK AIR (FILL)	CTRL BLDG	OWNER	OWNER
323	1	SOLENOID VALVE PENSTOCK AIR (MAINTAIN)	CTRL BLDG	OWNER	OWNER

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TIERCKENKILL FALLS HYDROELECTRIC PROJECT

SIPHON PENSTOCK REPORT
D.O.E. CONTRACT
DE-AC07-82ID12356

SHEET TITLE: ONE LINE DIAGRAM

DATE: OCTOBER 1987 SHEET 6 OF 6

APPENDIX K

TRAICAO HYDROELECTRIC PROJECT

TRAICAO HYDROELECTRIC PROJECT

The Traicao Hydroelectric Project is a pumping/generating plant located near Sao Paulo, Brazil, on the Pinheiros Canal between the Tiete River and the Rio Grande Reservoir. The power plant has four 2000 kW, 21 ft head units which were installed in 1944, 1946, 1957, and 1977.

Each of the four units have siphon intakes (in the turbine direction) which are integral with the concrete powerhouse substructure. The intakes are similar in configuration to an inverted elbow draft tube. Each intake has a rectangular cross section with the intake opening inclined at an angle 15 degrees from vertical. Trashracks are provided at each intake opening.

The overall length of each penstock is 107.5 ft, and the distance from each intake to the crown of the siphon is 63.5 ft.

The powerhouse has a reinforced concrete substructure with a steel superstructure. Each pump/generating unit has a vertical, axial flow, adjustable-blade propeller type pump-turbine. The pump-turbines have no wicket gates, and flow is stopped by breaking the siphon. The motor-generators are a direct connected, vertical synchronous type. The turbines are controlled by a hydraulic governor. The motor-generators are connected to the utility grid through the switchgear and the station transformers. The siphon is primed using vacuum pumps, and two vacuum breaker valves are provided at each unit for breaking the siphon.

The turbine waterpassages are dewatered by installing stoplogs in the intake and draft tube waterpassages.

The plant is mainly operated as a pumping station and operates as a generating facility when the Rio Grande Reservoir has excess water.

TRAICAO HYDROELECTRIC PROJECT

PROJECT OWNER: ELETRICIDADE DE SAO PAULO, S.A.

LOCATION: SAO PAULO, BRAZIL
On canal between Rio Grande Reservoir and Tiete River

Year of Initial Operation 1944

Plant Capacity
- Generating .... 8570 kW
- Pumping .... 21335 kW

Plant Flow
- Generating .... 8333 cfs
- Pumping .... 9887 cfs

Rated Head .... 21.3 ft

Number of Units .... Four

HYDRAULIC CONDITIONS (Turbine)

– Headwater Level
  - Maximum (for plant operation) .... El 2365.6
  - Minimum (for plant operation) .... El 2355.8

– Tailwater Level
  - Maximum (for plant operation) .... El 2350.7
  - Minimum (for plant operation) .... El 2342.6

– Gross Head
  - Maximum (for plant operation) .... 23.0 ft
  - Normal .... 21.3 ft
  - Minimum (for plant operation) .... 9.8 ft

GENERATING UNIT DATA

– Turbine
  - Manufacturer .... S. Morgan Smith (Units 1-3)
    Voith Brazil (Unit 4)
  - Type .... Axial Flow, Adjustable
    Blade Propeller
  - Rated Net Head .... 21.3 ft
  - Rated Power .... 3000 hp
  - Speed .... 150 rpm
  - Runner Diameter .... 138 in.
  - Number of Blades .... Four

- Generator
  - Manufacturer .... Westinghouse Electric
  - Type .... Vertical, Synchronous
  - Rated Output .... 5500 kVA
  - Power Factor 0.90
  - Rated Power .... 4950 kW
  - Speed .... 150 rpm

INTAKE DATA (Each Unit)

- Intake Cross Sectional Areas
  - Nominal .... 415.4 ft^2
  - At siphon .... 270.5 ft^2

- Length
  - Intake to top of siphon .... 63.5 ft
  - Top of siphon to centerline of runner .... 44.0 ft

- Elevation of Intake Centerline at Top of Siphon .... 2375.7 ft

- Siphon Lift
  - Maximum (minimum headwater level to centerline of waterpassage at top of siphon) .... 19.9 ft

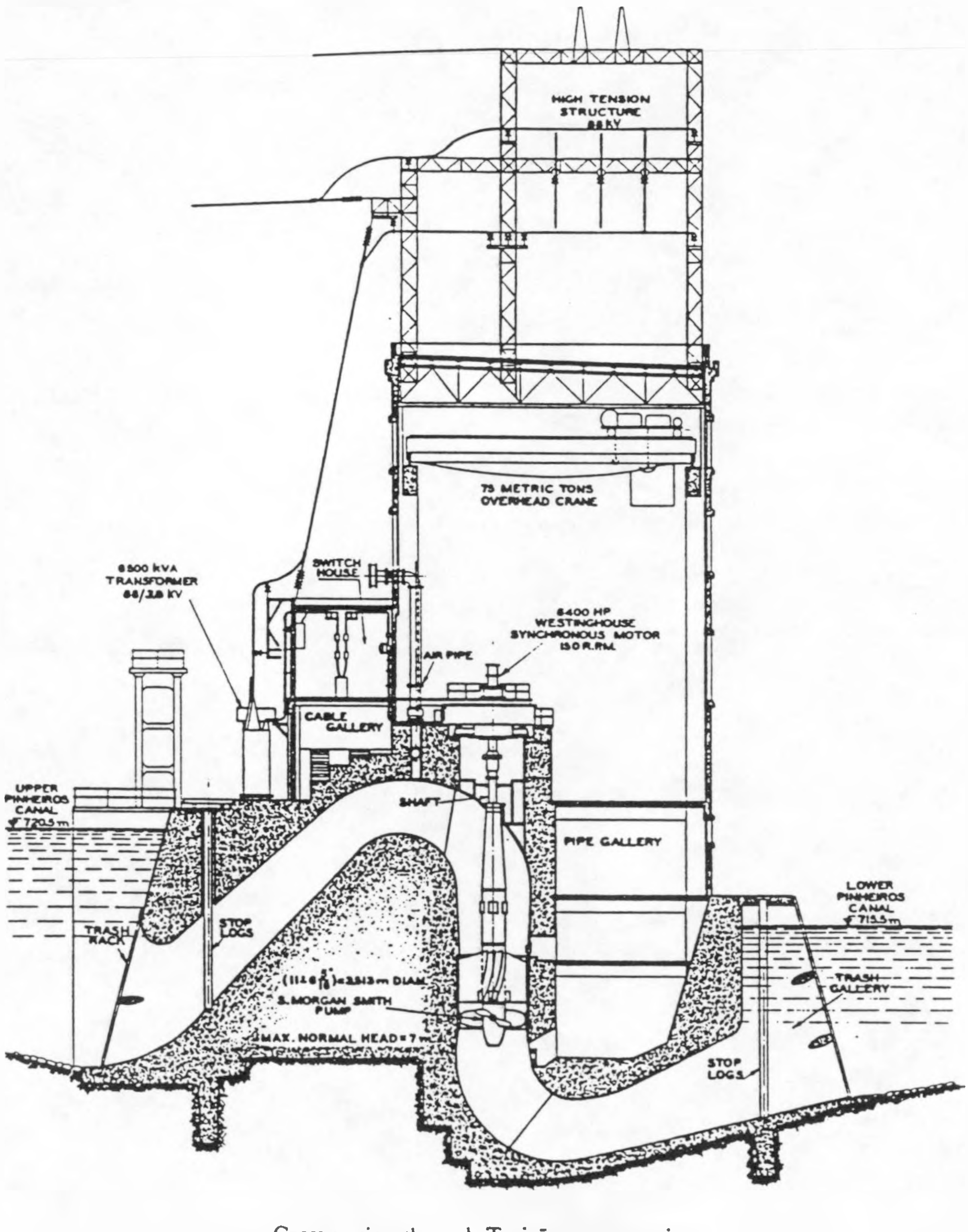
- Design Flow
  - Maximum .... 1780 cfs
  - Normal .... 1700 cfs
  - Minimum .... 500 cfs (approx.)

INTAKE ENTRANCE

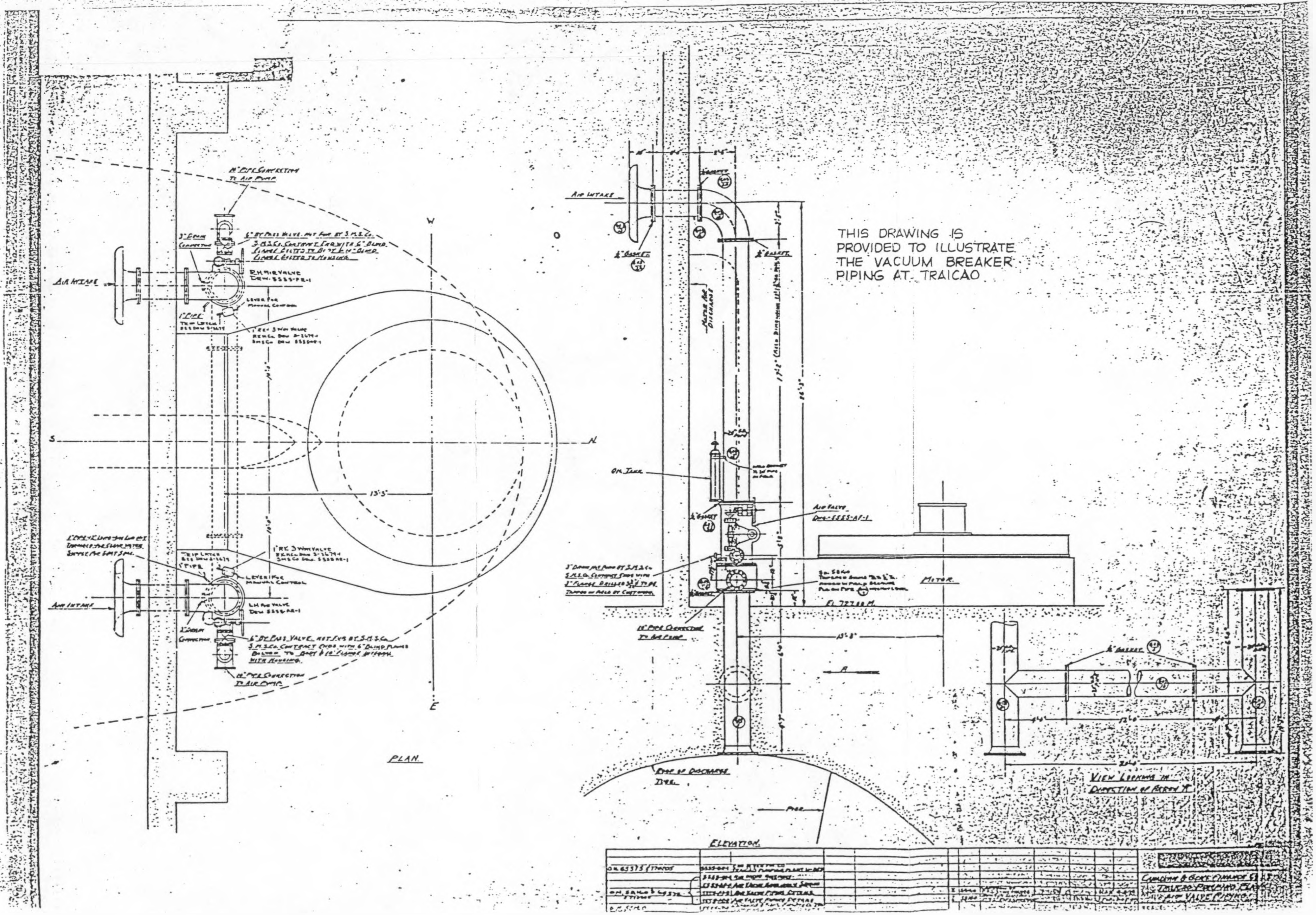
- Inlet Flow Direction .... 15 degree inclined
- Opening Area (36.75 ft wide by 24.5 ft high) .... 900 ft^2
- Material .... Concrete
- Trashracks
  - Gross area .... 977 ft^2
  - Bar clear spacing .... 5.9 in.

SIPHON PRIMING SYSTEM

– Number of Vacuum Pumps	2 for Units 1-3	1 for Unit 4
– Vacuum Pump Data		
• Type	Liquid Ring	Liquid Ring
• Manufacturer	Nash	Voith
• Model Number	L-7	8-E
• Power	50 hp	75 hp
• Capacity	800 cfm	1100 cfm
– Siphon Priming Time (approx.)	20 min.	15 min.



Cross-section through Traição pump station


THIS DRAWING IS PROVIDED TO ILLUSTRATE THE VACUUM BREAKER PIPING AT TRAICAO
AIR INTAKE
AIR INTAKE
W
S
N
E
13'-5"
PLAN.
AIR INTAKE
MOTOR
13'-8"
ELEVATION.