EFSTIDALUR PROJECT
ON THE
UPPER BRUARA

A REVIEW REPORT

FOR

THE STATE ELECTRICITY AUTHORITY

GOVERNMENT OF ICELAND

HARZA ENGINEERING COMPANY INTERNATIONAL
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ARZA ENGINEERING COMPANY INTERNATIONAL
CONSULTING ENGINEERS • RIVER PROJECTS

December 7, 1962

Air Mail

The State Electricity Authority
P. O. Box 40
Reykjavik, Iceland

Subject: Efstidalur Project
Upper Bruara
Summary

Gentlemen:

We take pleasure in submitting our review of the Efstidalur Project on the Upper Bruara as presented by Mr. Sigurdur Thoroddsen, Consulting Engineer, in his Appraisal Report dated May 1962.

Our review is essentially an independent cost estimate based on the project plan presented by Mr. Thoroddsen but with a few modifications included as a result of our studies. Further design modifications are likely to be introduced during advanced project planning. We do not now expect, however, that future investigations and studies will adversely affect the project economics as presented herein.

We concur in the general project plan outlined by Mr. Thoroddsen and believe that it represents an optimum or near optimum development of the resources available. The plan is considered as technically feasible and not involving any unusual construction or operation problems. The Efstidalur Project as proposed will develop about 79 meters of a total drop of 109 meters available in the reach of the river studied. The remainder of the head could be developed by two small projects, Kalfa and Reykir. It appears, however, on the basis of preliminary estimates made by Mr. Thoroddsen, that the economics of these two projects are rather unfavorable at this time. We have, therefore, not reviewed the Kalfa and Reykir Projects in detail.

The State Electricity
Authority

December 7, 1962

The Efstidalur Project will be a run-of-river plant designed primarily for base load operation. We believe however, that it is necessary to provide some pondage for peaking and have, therefore, included in our design a reservoir of about 100,000 cubic meters for that purpose. This pondage would permit peaking for about three hours during low flow periods on the basis of the station flow capacity selected.

The station flow capacity, when operating at best efficiency and at the normal net head of 73 meters, was chosen equal to the average river flow, about 35 cubic meters per second. The station output is estimated at 22,500 kilowatts under these operating conditions. The dependable peaking capability is estimated to be approximately 22,000 kilowatts delivered at Reykjavik. Our selection of plant capacity is based primarily on judgement which would need to be verified by economic studies during further planning.

We concur in the selection of one unit only inasmuch as the unit size is reasonable in comparison with the existing system capacity. The added cost of providing two units, each of smaller size, is considered not justified.

The Transmission Plant includes the entire line from Efstidalur to Reykjavik and a tie-in at Irafoss with the existing Sog System. The section from Irafoss to Reykjavik will serve also the Sog power plants, but no credit was taken for this in the cost estimate.

The power plant will be provided with semi-automatic control equipment for remote control of load and voltage from Irafoss Substation. This arrangement is considered preferable both from economic and operational viewpoints.

Our estimate of Total Construction Cost including the Transmission Plant is $8,300,000. This amount includes import duties and taxes, allowances for omissions and contingencies, cost escalation, and such indirect costs as preliminary investigations, engineering, supervision of construction and owner's overhead. Our estimate of Total Project Investment is U.S. $8,900,000. This amount was determined by adding estimated interest during construction to the Total Construction Cost. The cost of establishing working capital and interest reserves was not considered.

The foreign currency requirements are estimated at the equivalent of $5,3000,000. The requirements in local currency are estimated at $3,800,000 or 165,000,000 Iceland Kronur; of which import duties and taxes amount to about 75,000,000 Kronur and local labor and materials to about 90,000,000 Kronur.

The annual primary energy delivered from the Efstidalur Project is estimated to be 150 million kilowatt hours. This estimate was based on estimated streamflows in a dry year and 98 percent utilization of all flows up to 35 cubic meters per second. It includes allowances for all losses. Secondary energy will be available, and will amount to about 15 million kilowatts hours in an average water supply year. Some of this secondary energy might be firmed by integrated system operations.

Our estimates of annual costs include operation and maintenance expenses, reserves, water rights, and debt service. The debt service charges will depend on ultimate financing terms, currently unknown. Our estimate for the unit costs are based on: (1) the sale of the annual delivered primary energy of 150 million kilowatt hours, (2) annual costs other than debt service in the amount of $205,000, and (3) a range of level debt service charges expressed as a percentage of Total Project Investment. On this basis our estimate of unit energy costs varies on a nearly straight line relationship from 4.3 mills U.S. for five percent to 6.7 mills U.S. for nine percent of the debt service as expressed above. An amortization period of 25 years and six percent interest rate would result in a unit cost of about six mills U.S.

Our estimated project costs is considerably higher than that obtained by Mr. Thoroddsen. It should be noted, however, that our estimate is based on a larger plant capacity, higher dam, and a larger and longer transmission line. Furthermore, we used the price level as of October 1962 as the basis for our estimates of unit rates and cost of equipment whereas Mr. Thoroddsen's estimates were based on the somewhat lower price level of 1961.

Additional field investigations will be required for further planning of the Efstidalur Project. Alternative locations of the dam and powerhouse should be investigated and studied. The problem of reservoir leakage will need careful study. Hydraulic and hydrographic measurements and surveys will be required at the locations of the dam and the tailrace outlet. Further reconnaissance, sampling and testing of natural construction materials will be required. This work for the most part can probably be accomplished in a single summer season.

The Efstidalur Project could be an economical source of power to meet the load growth of the present market in South-West Iceland. It is understood that the estimate presented herein will be used for economic comparisons with alternative sources of power.

We appreciate very much the opportunity of providing you the service represented by this Review Report.

Very truly yours,

HARZA ENGINEERING COMPANY INTERNATIONAL

C. K. Willey

C. K. Willey

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TABULATION OF SIGNIFICANT DATA

Drainage Area	215 sq. km.
Average Discharge	35 cms
Design Flood	200 cms ±
Maximum Normal Reservoir Elevation	159.0 m.
Minimum Reservoir Elevation	157.5
Live Storage	100,000 cm.
Normal Tailwater Elevation	80.5
Woodstave Pipeline Diameter	3.8 m.
Surgetank Diameter	15.0 m.
Maximum Surge Elevation	164.6 m.
Penstock Diameter	3.6 to 3.2 m.
Powerstation, type	Indoor
Headlosses at normal flow	5.25 m.
Headlosses at peaking	7.5 m.
Turbine	
Type	Francis
Capacity at rated head (73 m.)	37,000 metric hp.
Discharge at best gate, rated head	35.0 cms.
Speed	300 rpm.
Generator	
Type	Vertical-shaft
Rating	25,000 kva
Power factor	0.9
Voltage	11 kv
Cycles per second	50
Main transformers	
Number (total)	Two
Type	Outdoor-Three phase OA/FA/FOA
Rating	15/18.2/25 mva.
Voltage	11-138 kv.
Main Transmission Line	
Length	75 km.
Voltage	138 kv.
Number of circuits	One
Size of conduit	477 MCM
Construction	Woodpole

EFSTIDALUR

UPPER BRUARA

AN APPRAISAL REVIEW

INTRODUCTION

General. This report presents a review of the general design and cost estimate of the Efstidalur Project on the Upper Bruara as developed by Sigurdur Thoroddsen in his Appraisal Report dated September 1962 (English translation). No previous engineering studies have been made of the development of the Bruara; Thoroddsen's report represents the first technical and economical evaluation of this resource.

Project Location. The project is located about 70 kilometers east of Reykjavik in the upper reaches of the Bruara, a right bank tributary to the Hvita. The Bruara rises in the lavafields northeast of Efstadalsfjall and Middalsfell and flows southward in a generally steep gradient east of those mountains until it reaches the plains at Efstidalur about 7 kilometers northeast of Apavatn. It joins the Hvita at Vordufell about 25 river kilometers farther downstream. The section of the river studied by Thoroddsen reaches from the confluence with the left bank tributary, Kalfa-Fremri, in the north, to the junction with the tributary, Fullsaell, in the south, a river distance of about 10 kilometers. The total natural fall through this reach is about 109 meters from elevation 182 at Kalfa-Fremri to elevation 73 at Fullsaell. The major portion of the drop is, however, concentrated in a four kilometer section downstream from the outfall of Hruta, an intermediate left bank tributary, where about 70 meters is developed through a series of falls and rapids east of Efstadalsfell.

Development Alternatives. Thoroddsen has proposed development of the 10 kilometer reach by three projects: (1) Kalfa, (2) Efstidalur and (3) Reykir listed in order, proceeding downstream. The gross head developed would be 22 meters, 75.5 meters and 7.5 meters, respectively, a total of 105 meters. About 4 meters of the total drop available would remain undeveloped with this plan. As an alternative to the Efstidalur Project, Thoroddsen has also studied a two-step development of this river segment by the Hruta Project utilizing 33 meters of gross head and the Valla Project utilizing 36 meters of gross head. The Reykir Project would in that case develop 10 meters of head, so that the total gross head developed would be 101 meters or four meters less than with the Efstidalur alternative.

Thoroddsen's estimates show that the Efstidalur Project or its alternative Hruta and Valla Projects is much more economical than either Kalfa or Reykir. The cost of energy would be approximately one half of that of the two smaller projects. His findings appears to be reasonable, in part, because the much flatter river slopes developed by the Kalfa and Reykir Projects would tend to increase the relative cost of the water conductors.

Mr. Thoroddsen has eliminated the Kalfa and Reykir Projects from further consideration at this time. We agree that it is not necessary to include these less economical projects for appraisal purposes. It is possible that development of the 30 meters of gross head of the Bruara represented by the two projects, Kalfa and Reykir, can never be justified economically. Sacrifice of some head for economic reasons is not unusual.

The power potential thus left undeveloped would amount to about 5000 kilowatts and 44 million kilowatt hours of annual energy.

We concur with Thoroddsen in his selection of the one-step Efstidalur Project in preference to the two-step Hruta and Valla Projects. His estimates indicate that the Efstidalur Project is slightly more economical and has a greater power potential. These advantages in addition to more economical operation because of one powerplant instead of two are in our opinion sufficient reasons for selecting the one-step Efstidalur Project as the most suitable one for the purpose of appraising the economics of a power development on the upper Bruara.

Field Information. Our review of the Efstidalur Project is based on information given in Thoroddsen's Report, on additional data supplied by him and the State Electricity Authority (SEA) and on site inspection by Harza engineers and geologists.

The entire project area has been surveyed and mapped in scale 1:5000 with two meter contours. Fifty-seven soundings have been made to determine the depth of overburden at the site of the proposed structures. In addition four holes have been core drilled at the damsite and one at the powerhouse site. Undisturbed samples for classification of the overburden have been taken at eight locations. The borelogs from the above explorations and a description of the overburden were made available to us.

The streamflows were estimated from water level records obtained at the damsite since August 1961 and from 14 years of record from the Dynjandi station located about 20 kilometers farther downstream on the Bruara.

The hydrographs for the damsite station for the period of August 1961 through March 1962 and for the period of record at Dynjandi was made available to us in addition to gage height observations and rating curves for both stations.

The field information received is considered adequate for making reasonably accurate appraisal estimates.

STREAMFLOW

The average monthly streamflows have been estimated by us for the period September 1949 through March 1962 based on correlation studies of the period of simultaneous records, September 1961 through March 1962. The correlation thus obtained is considered satisfactory for appraisal purposes especially since the flow of the Bruara is very uniform because of the characteristics of the drainage basin. We have not reviewed the actual rating curves developed for the two gaging stations. The two hydrographs appear, however, to correlate very well.

The results of our studies are given in the tabulation below for the median month year and the driest year of record, 1950-51.

COMPARATIVE MEAN MONTHLY DISCHARGE

IN CUBIC METERS PER SECOND

BRUARA AT DYNJANDI AND EFSTADALUR DAMSITE

	Dynjandi (observed)		Efstidalur (estimated)	
Month	Median 1949-60	Critical 1950-51	Median 1949-60	Critical 1950-51
September	52	47	32	29
October	65	47	39	28
November	65	50	32	25
December	66	56	39	33
January	68	56	37	30
February	65	48	34	25
March	60	53	36	32
April	66	50	37	28
May	58	51	34	36
June	52	47	33	30
July	52	46	33	29
August	50	44	32	28
Average Annual	60.0	50.3	34.8	29.4

Bruara is a spring fed river and shows remarkably uniform flows. The average flow in the median month year is estimated at about 35 cubic meters per second (cms) as compared to about 29.5 cms in the dry year, 1950-51. The lowest mean monthly discharge is estimated at 25 cms occurring in two months of 1950-51. The minimum daily flow is expected to be not more than ten percent below the minimum monthly average.

According to Thoroddsen, the State Electricity Authority's Hydrologic Survey has estimated the flood of record at 200 cms. Our preliminary studies indicate that the maximum probable flood may be between 500 and 1000 cms. On this basis we believe that the design should provide for a flood of not less than 400 cms.

PROJECT LAYOUT

General. The project as presented by Thoroddsen consists of the following elements: (1) a Reservoir provided by a low diversion dam with spillway weir on the Bruara near the confluence with Hruta; (2) a short headrace canal leading from the reservoir to (3) the power intake and (4) a 2.5 kilometer long woodstave pipeline; (5) a surgetank located at the downstream end of the pipeline and connected to (6) a steel penstock leading to (7) a surface powerhouse and appurtenances located about 700 meters north-east of the farm, Efstidalur; (8) a 1000 meter long tailrace canal discharging into the Bruara at a bend located due east of the farm; (9) an outdoor switchyard near the powerhouse; (10) a transmission line to Reykjavik with a tie at Irefoss; and (11) access roads and bridges.

The general layout as described above appears on the basis of present knowledge to offer the most economical development of the natural resources available. Tunnel development is not recommended because of the serious water problems that are expected to arise in any underground excavations. The topography is not suitable for economic development by canal. Development of the head by dams would obviously be uneconomical because of the steep gradient of the river and the relatively low flow available.

We agree with Thoroddsen that the Efstidalur Project should be designed as a base load plant, essentially. It appears desirable, however, to provide some pondage for daily peaking in order to permit some operational flexibility. We believe also that the station flow capacity should be somewhat larger than was assumed by Thoroddsen in his estimates. This was suggested by Thoroddsen in the text of his report on the basis of additional streamflow records that became available after he had completed the design and cost estimates. We have assumed for the purposes of this appraisal that the station flow capacity with the turbine operating at best gate will be 35 cms as compared to 30 cms assumed by Thoroddsen.

We have estimated the area and volume of the reservoir for a dam at the location chosen by Thoroddsen. The results are tabulated below:

EFSTIDALUR PONDAGE

Elevation - m	Area - m^2	Volume - m^3
152.5	0	0
155.0	15,000	14,000
157.5	50,000	90,000
160.0	100,000	275,000
162.5	200,000	650,000

We have tentatively selected elevation 159.0 as the maximum operating level with 1.5 meters permissible drawdown. This will provide about 100,000 cubic meters of storage for daily peaking, and will allow an increase in station flow to 35 cms over a three hour period assuming a base flow of 25 cms, and over a six hour period with a base flow of 30 cms.

Our comments to the general design of the structures are presented below:

Reservoir, Dam and Spillway. The location of the dam and spillway chosen by Thoroddsen appears reasonable and was adopted as the basis for our cost estimate. We suggest, however, that an economic comparison be made in the planning phase of the project with an alternative location below the confluence with Hruta. A possible alignement is indicated on Exhibit 1. Preliminary estimates indicate that it will be economical to provide a gated spillway section in addition to a free overflow weir. We have therefore included a tainter gate 7 meters wide by 5.5 meters high, and with crest at elevation 155.0 in our spillway design, as shown on Exhibit 2. This gated section and the overflow weir, which will total 24 meters long, will occupy the entire width of the river. The capacity of the gate section is estimated at 120 cubic meters with the reservoir at elevation 159.0 and at 220 cubic meters per second with the reservoir at elevation 160.0 (one meter surcharge). The ungated section with crest at elevation 159.0 will discharge about 50 cubic meters per second with the reservoir at elevation 160.0. The discharge at elevation 161.0 will be about 140 cubic meters per second. The crest of the dikes on the left and right bank was chosen at elevation 161.5 with a low parapet provided at the upstream face for wave protection. Floods in the order of 100 to 150 cubic meters per second can therefore be discharged over the spillway without overtopping the dikes, even if the tainter gate is inoperable. As an additional precaution we suggest that the crest of the dike at a section where it crosses the Hruta be constructed one-half of one meter lower than the remainder of the dike in order to limit the damage if overtopping of the dike should ever take place.

The design of the spillway as shown on Exhibit 2 must be considered as preliminary only because the data required to determine the tailwater levels with sufficient accuracy were not available. It is possible that the gated section should be located near the right bank, instead of the left bank as shown on Exhibit 2, because it may give better approach conditions during floods from the Hruta.

The spillway structure will be founded on the Younger Bruara Basalt, which is considered to have sufficient strength to support the relatively low structures required. The rock is quite pervious, however, so that grouting may be required underneath the dam to reduce leakage. We have included a lump sum item in the estimate for this purpose.

We have no comments to Thoroddsen's desing of the left bank dike, which is essentially as shown on Exhibit 3. The problem of leakage underneath the dam will require additional field explorations and study. The fact that most of the rock is under artesian pressure would tend to reduce leakage. On the other hand, the rock is generally pervious and with open channels that may require some treatment. We have, therefore, included a lump sum in the estimate for foundation treatment. The nature of such treatment will be determined on the basis of more detailed field explorations.

Intake Canal. Comparative estimates between the cost of woodpipe and canal indicate that the intake canal should be made shorter than shown on Thoroddsen's drawings. One reason for this is that the canal will be deeper with the higher reservoir levels chosen by us. The proposed new location of the intake is shown on Exhibit 1, it is about 200 meters upstream of the location chosen by Thoroddsen.

We have made only minor changes to the section of the canal as designed by Thoroddsen. The principal difference is that we have strenghtened the left embankment by replacing more of the peat with moraine gravel. Our proposed design, on which our estimates are based, is shown on Exhibit 3. A vertical core section as for the left bank dike would also be suitable. Treatment may be required under the embankment to reduce leakage. A lump sum item has been included in the estimate for this purpose.

Intake. The intake will be a conventional concrete structure founded on the Younger Bruara Basalt. The design shown by Thoroddsen is considered adequate, except that the trashrack area is somewhat smaller than normal practice would indicate. This can, however, easily be taken care of by minor changes which would not affect appreciably the cost estimate.

Woodstave Pipeline. The design presented by Thoroddsen of the woodstave pipeline is based on Scandinavian practice and we have no important comments to make. The length of the pipe will be about 2650 meters. We have checked the economics of the pipe and found that the diameter of 3.8 meters as chosen by Thoroddsen will also be suitable for the slightly increased flows assumed by us. The thickness of the woodstaves will be 3 1/2 inches. The steel bands will be made of flat irons of about four square centimeters cross-section, and will be spaced at approximately 10 centimeters.

Surgetank. We agree with the location and general design of the surgetank as shown by Thoroddsen. Our only suggestion is that the orifice connection between the pipeline and the tank proper can be made smaller, thus reducing the required surgetank volume. This would tend to increase the portion of the waterhammer that would be transmitted from the penstock to the woodstave pipeline but our studies show that the waterhammer in the woodstave pipeline will be only five percent of the static head which is considered acceptable. With the smaller orifice the height of the surge tank may be slightly reduced even with the increased station flow capacity and longer pipeline assumed by us. The dimensions of the surge tank used in our cost estimates are shown on Exhibit 4. The thickness of the steel in the tank was estimated at 16 millimeters at the bottom and 8 millimeters at the top.

We believe that a surge tank and powerhouse location about 350 further south is worthy of study during further planning of the project. This location would require a longer woodstave pipeline, but would on the other hand reduce the powerhouse and tailrace excavations. An economic comparison based on general design layouts would be necessary for final selection.

Penstock. A comparison of costs, including head losses, between penstock and tailrace canal indicates that the powerhouse should be located farther downstream than chosen by Thoroddsen. We assumed a location about 100 meters farther downstream. The penstock will be 250 meters long or about 100 meters longer than assumed by Thoroddsen. The tailrace canal will be shorter by approximately the same amount.

The diameter of the penstock will be 3.6 meters except in the steeply inclined section near the powerhouse where it will be reduced to 3.2 meters.

The thickness of the steel plate will be 8 millimeters at the surgetank increasing to 13 millimeters at the upstream wall of the powerhouse. The penstock is provided immediately below the surgetank with a Butterfly Valve for emergency closure.

Powerhouse. The powerhouse is located in a 25 meter deep rock excavation at the upstream end of the tailrace canal. Access will be by a road benched out in the right bank of the tailrace canal.

A suggested layout of the powerhouse is shown in plan on Exhibit 5 and in sections on Exhibit 6. It differs from the layout shown by Thoroddsen principally in the following aspects:

(a) The Erection Bay floor is at the same level as the generator floor. This permits a much lower powerhouse.

(b) The transformer is positioned downstream of the powerhouse near the Erection Bay. This will reduce and simplify the powerhouse excavation and will be more convenient for the high tension connection to the switchyard.

(c) The penstock enters the powerhouse at right angle.

(d) Operation of the draft tube gate is from a separate deck downstream of the powerhouse.

In our estimates of the powerhouse the above changes were included, although they do not affect the overall quantities to any appreciable degree.

Tailrace. We have no comments at this time to the tailrace design as presented by Thoroddsen. We have assumed the same tailwater levels and the same cross-sections and elevations of the canal as bases for our estimates. It will be necessary to establish a rating curve at the outlet of the canal for the detail design.

Turbine and Generator. We concur in the selection of only one unit for this power plant. Two smaller units do not appear to be economical as the total cost will be greatly increased. The saving that may be achieved by the installation of only one unit initially would not be of great significance because the second unit would probably be needed within two years.

The unit size selected by us will be about 25 percent larger than the one proposed by Thoroddsen. The turbine will be of the vertical Francis type and will be rated 31,500 metric horsepower at best gate and 73 meters head. The full gate output will be 35,000 horsepower under normal operating head and with a discharge of about 42 cms. The speed was chosen at 300 rpm.

The generator capacity was chosen 25,000 kilovolt ampere at 0.9 power factor. The present system power factor of 0.8 is likely to be improved in the future, possibly by the installation of capacitors or syncronous condensers.

The plant will be provided with semi-automatic control equipment for remote control of load and voltage. Starting operations will, however, take place at the plant. Equipment will also be provided at the plant to permit complete control in emergencies.

Switchyard and Transmission Line. We have tentatively selected 138 kilovolts as the most economical transmission voltage between Efstidalur and Reykjavik. This will eliminate the need for an auto transformer at the tie-in with Irafoss substation and thereby also eliminate one circuit breaker. The difference in overall cost between the 138 kilovolt system and the 69 kilovolt system selected by Thoroddsen is not significant, but we consider the higher voltage to be preferable from an operational viewpoint.

Thoroddsen assumed in his estimates that the transmission line from Efstidalur be constructed to the Irafoss substation only and that the Sog System would transmit the power from there to Reykjavik. It appears reasonable, however, to assume that the Efstidalur Project should be charged with some portion of the cost of providing additional transmission capacity required between Irafoss and Reykjavik. We have, therefore, in our estimates taken the most conservative approach and assumed that the project carry the cost of the entire line from Efstidalur to Reykjavik, a distance of 75 kilometers. This approach was also used in the appraisal estimates of the Hestvatn and Burfell 60 megawatt projects. A more detailed analysis of this question would ultimately be required when comparing the cost of alternative developments.

The main power transformer is rated 27,500 kilovolt amperes, three-phase 11/138 kilovolt, 50 cycles. It will be located outdoors near the main entrance to the powerhouse. Overhead lines will provide connection with the switchyard, located to the right of the tailrace canal and downstream of the powerhouse at about elevation 100.

POWER AND ENERGY

Energy. The energy output from the Efstidalur Project was estimated on a monthly basis for the median monthly year as well as for the critical year 1950-51. We assumed in our estimates that the highest average monthly plant factor would be 85 percent which would result in some spill of water during one month of the critical year and during five months of the median monthly year. The amount thus spilled would be less than one percent of the total inflow in the critical year and about three percent in the median monthly year.

The energy output in kilowatt hours has been estimated from the formula $E = 9.8 \times H_n \times e_1 \times e_2 \times Q \times T$ where

H_n = Net head in meters

e_1 = Overall efficiency

e_2 = Water utilization factor

Q = Average station flow

T = Time in hours

The water utilization factor was assumed at 98 percent in a critical year and 95 percent in the median-monthly year. This factor is a measure of loss of water that may occur from leakage, waste over the spillway other than that mentioned above, and starting of the unit.

Our estimate of the overall efficiency is given in the tabulation below. The tabulation also give the estimated efficiency under peaking conditions.

	For Energy Estimates	For Peaking Estimates
Turbine	0.91	0.88
Generator	0.97	0.97
Transformers	0.99	0.99
Transmission Line and Station Service	0.96	0.95
Overall	0.84	0.81
Headloss	5.25 meters	7.5 meters

The average gross head between the reservoir and the Bruara at the tailrace outlet was assumed at 78.0 meters.

The results of our energy estimates are shown in the tabulation below:

	Median Month Year		Critical Year	
Month	Average Station Flow in cms	Energy in Million kwh	Average Station Flow in cms	Energy in Million kwh
September	32	13.1	29	12.2
October	35*	14.8	28	12.2
November	32	13.1	25	11.6
December	35*	14.8	33	14.4
January	35*	14.8	30	13.1
February	34	13.0	25	9.9
March	35*	14.8	32	14.0
April	35*	14.3	28	11.8
May	34	14.4	35*	15.3
June	33	13.5	30	12.7
July	33	14.0	29	12.7
August	32	13.6	28	12.2
Annual Total		168.2		152.1

*Some water spilled

We have assumed on the basis of the above estimates that the primary energy production from the Efstidalur Project will be about 150 million kilowatt hours annually. This compares with Thoroddsen's estimate of 146 million kilowatt hours for a 15 percent smaller plant capacity. Secondary energy will average about 15 million kilowatt hours annually. Some of this secondary energy might be salable by integration with the existing system or to secondary energy customers, but was not considered in the economic evaluation.

Peaking Capability. The dependable peaking capability that the plant can deliver at Reykjavik is estimated at 22,000 kilowatts. This may be reduced slightly during periods of high tailwater which is, however, expected to occur very seldom, and would probably occur outside the critical period.

CAPITAL COSTS

Our review of the construction cost was carried out as an independent estimate based on the modified design shown on Exhibits 1 through 7 and as described above. The cost estimates are presented in Exhibit 8, which includes a summary estimate as well as detailed estimates of the various project features. The estimates represent our best judgment of unit prices and lump sums for the various items of work. All costs are expressed in U.S. Dollars. The rate of exchange used for converting Icelandic Kronur to U.S. Dollars was 43 Kronur to one Dollar.

The estimates were prepared as the result of a detailed quantity survey based on the drawings referred to above and supplemented by Thoroddsen's drawings and detailed sketches. The quantities estimated by us compared well with those given by Thoroddsen for the same structures. The unit prices used were estimated on the basis of labor rates and costs of material and equipment as of October 1962. Import duties and taxes have been included where applicable on imported materials and equipment including construction equipment. The estimate is in this respect comparable with the cost estimate for the Hestvatn Project and the Burfell 60 megawatt plant. An allowance was made in the unit prices for a reasonable profit to the general contractor or contractors.

The estimated cost for permanent equipment was based on recent quotations from well-known European manufacturers. All costs are for the equipment fully installed and include import duties and taxes.

The cost of land was not included. The cost of the water rights has been included as an annual charge as discussed below.

A contingency item of 15 percent was added to the subtotal of direct cost as an allowance for omissions and possible increases in quantities and prices. This allowance is considered reasonable in view of the information available on equipment cost and the generally conservative approach adopted in establishing the cost of the structures.

An allowance for price escalation of five percent was added to the estimated subtotal including contingencies. This allowance is considered appropriate and reasonable in view of recent price trends in Iceland and Western Europe.

The addition of the escalation allowance established the total direct cost. An allowance of eight percent of this total direct cost but without import duties and taxes was then applied to allow for such indirect costs as design engineering, supervision of construction and owner's overhead.

A further allowance of $100,000 was made to cover the estimated cost for preliminary planning basic to design and for necessary field investigations. These additions resulted in an estimated Total Construction Cost of $8,300,000.

Financing terms are, at present, not established. The cost of interest during construction can therefore not be accurately determined. However, the cost normally amounts to about three to four percent of the construction cost for each year of construction. An allowance of seven percent of total construction cost was, therefore, made to cover interest during the estimated two-year construction period. This addition resulted in an estimated Total Investment of $8,900,000.

The cost of establishing working capital and interest reserves was not included and may not be required.

Our estimates show that the foreign currency requirement will be the equivalent of about $5,250,000. The expenditure of local currency is estimated at $3,650,000 or 157,000,000 Icelandic Kronur, of which import duties and taxes amount to about 75,000,000 Kronur and local labor and materials to about 82,000,000 Kronur.

Our estimate is about 50 percent higher than Thoroddsen's estimate of 251,000,000 Kronur, or about $5,850,000. A comparison of the two estimates are tabulated below:

Item	Thoroddsen	Harza
Powerhouse Structures	$ 295,000	$ 303,700
Reservoirs, Dams and Waterways	2,480,000	3,530,650
Turbine & Generator	685,000	728,000
Accessory Electrical Equipment	86,000	135,000
Miscellaneous Power Plant Equipment	74,000	284,000
Roads	26,000	26,000
Operators Village	Included Above	35,000
Transmission Plant	476,000	1,341,000
Subtotal Direct Cost	4,122,000	6,383,020
Contingencies	828,000	956,980
Cost Escalation	None	360,000
Total Direct Cost	4,950,000	7,700,000
Engineering, etc.	400,000	500,000
Preliminary Investigations	None	100,000
Total Construction Cost	5,350,000	8,300,000
Interest During Construction	500,000	600,000
Total Investment	$5,850,000	$8,900,000

In comparing the above costs it should be recognized that our estimate is for a project with about 18 percent larger plant capacity and with 1.5 meters higher reservoir level. Our estimate for the transmission plant includes not only the line to Irafoss with a tie-in there as assumed by Thoroddsen but also the 45 kilometer extension to Reykjavik and the necessary additions to the Ellidar Substation. We have reduced the contingency allowance from 20 to 15 percent, but this is offset by our inclusion of a 5 percent allowance for cost escalation which was not included by Thoroddsen. Another item included by us but not by Thoroddsen is the cost of preliminary investigations.

ANNUAL COSTS

The annual charges against a power system include interest on invested capital, depreciation of the installation or amortization of investment, operation and maintenance expenses, insurance, and taxes.

We have estimated the annual operation and maintenance expenses of the Efstidalur Project including the transmission plant to be $95,000. This is based on the assumption that normal operation of the plant will be semi-automatic. This means that voltage and load regulation will be by remote control, whereas the starting of the units will be at the plant. We assumed that two attendants will be stationed at the plant at all times. Maintenance other than daily routine work will be by a separate crew.

Insurance and taxes were not included in our estimates of annual charges.

Interest and amortization charges (debt service) will represent the major portion of annual costs. This cost will, however, not be known until such time as the financing terms are established.

Compensation for the use of the water rights was included as an annual cost. This annual cost is considered to be the fair return on the value of such rights, which are not known definitely. We have also included reserve funds as an annual charge taken at about one percent of the estimated total construction cost. These funds are required as a sinking fund to cover expenses of an extraordinary nature not otherwise covered by insurance or normal maintenance.

The estimated annual costs other than debt service will then be as follows:

Operation and Maintenance		$ 95,000
Water Rights and Reserves		110,000
	Total	$205,000

PRIMARY ENERGY COSTS

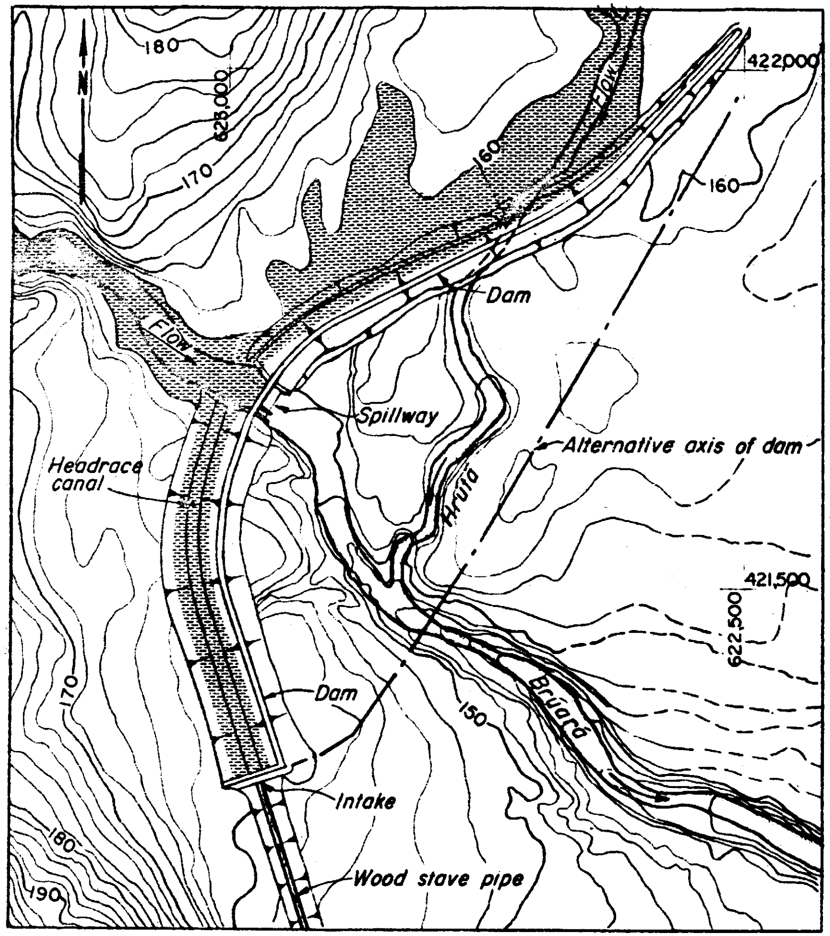
No consideration was given to the income from the sale of secondary energy in the evaluation of unit energy cost. The annual primary energy was taken at 150 million kilowatt hours delivered at Reykjavik as estimated above.

Inasmuch as the financing terms have not yet been established we chose to present the estimate of unit cost of energy as a graph for a range of annual debt service expressed as a percentage of the total project investment of $8,900,000 over a range of five to nine percent. This graph is shown on Exhibit 9. It includes, of course, the other estimated annual costs amounting to $205,000 as a fixed amount not varying with the debt service. The estimated unit cost is as delivered at the low tension side in Reykjavik, but does not include any allowance for profit. Import duties and taxes are included as appropriate on imported materials and equipment in the estimate of capital costs. It should be noted that the estimate also includes the entire cost of the transmission line to Reykjavik.

The graph shows that the cost of primary energy would be in the order of five to six U.S. mills per kilowatt hour for the more common financing conditions. An interest rate of five percent and a 40-year amortization period will give a unit energy cost of about five mills. A 25-year amortization period and six percent interest rate will result in a unit cost of about six mills. The total estimated annual cost in the latter case is approximately ten percent of the total project investment, a value which was used by Thoroddsen in his estimate of the energy cost.

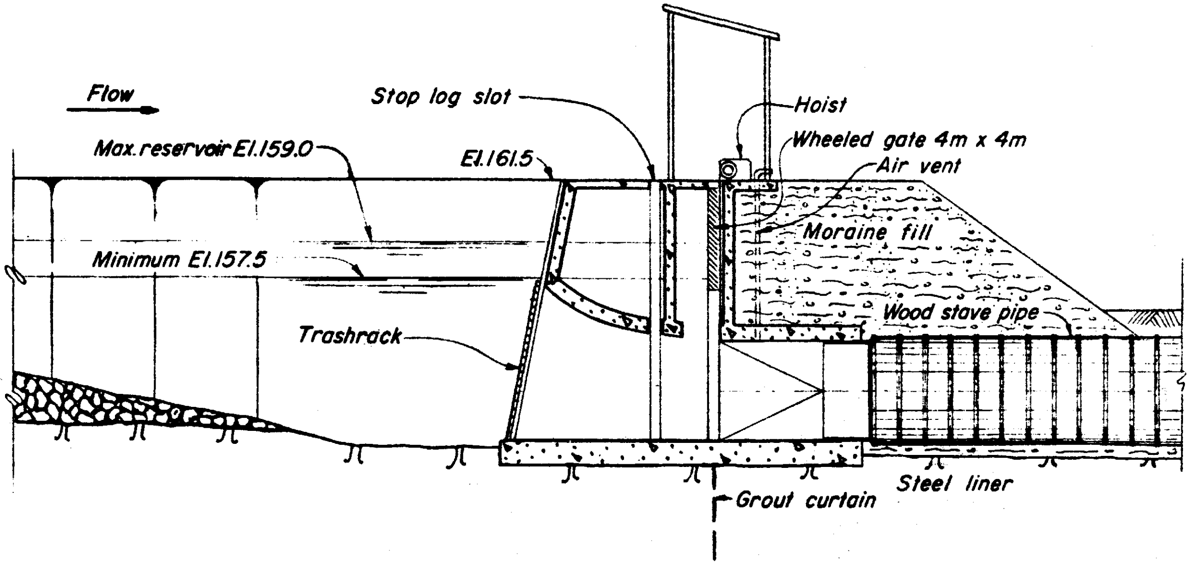
LIST OF EXHIBITS

EXHIBIT I



PLAN OF DAM AND HEADRACE CANAL

Scale 0 100 Meters



SECTION OF INTAKE

Scale 0 5 Meters

Except as shown

THE STATE ELECTRICITY AUTHORITY
ICELAND

EFSTIDALUR PROJECT

PLAN OF DAM AND SECTION OF INTAKE

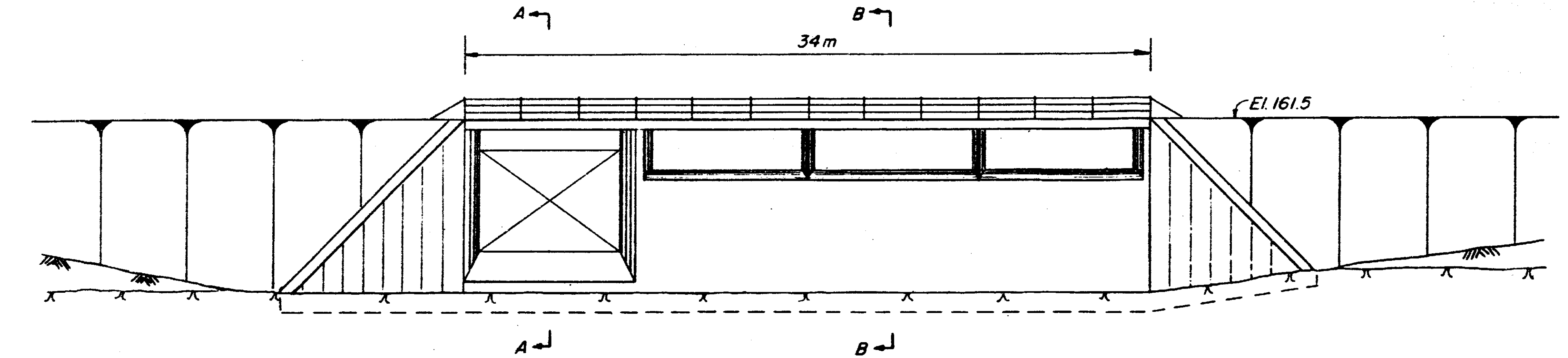
HARZA ENGINEERING COMPANY

APPROVED A.P. Gauss

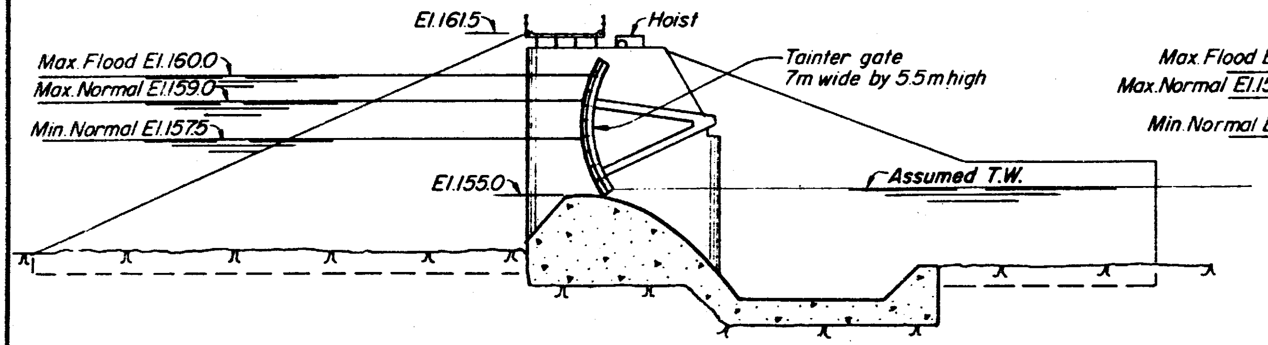
CHICAGO, ILLINOIS | DATE Nov. 1962 | DWG. NO. 299 P I

PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

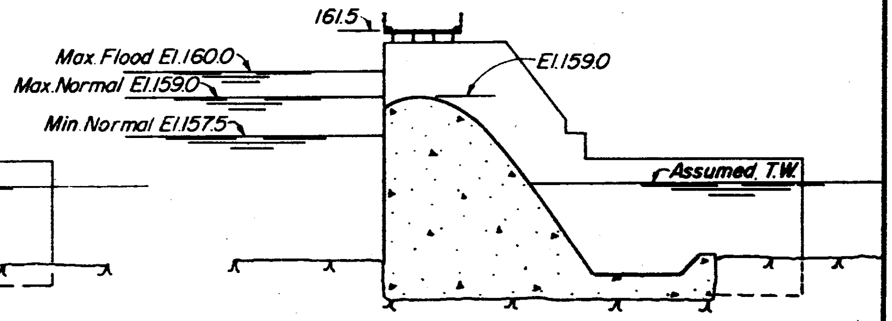
EXHIBIT 2



UPSTREAM ELEVATION



SECTION A-A



SECTION B-B

Scale 0 5 Meters

THE STATE ELECTRICITY AUTHORITY
ICELAND

EFSTIDALUR PROJECT

SPILLWAY

HARZA ENGINEERING COMPANY
APPROVED
CHICAGO ILLINOIS | DATE Nov. 1962 | DWG. NO. 299 P 2

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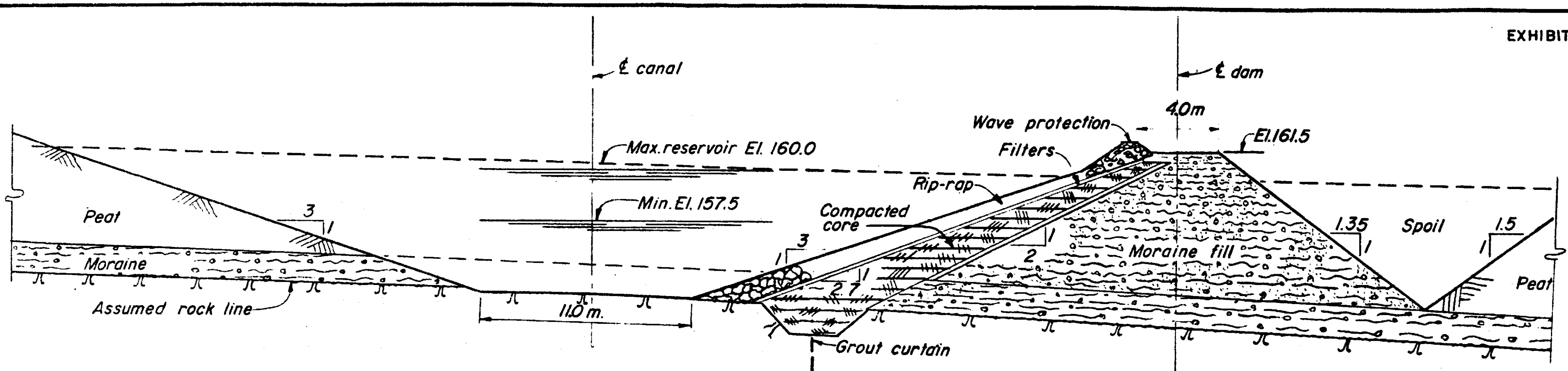
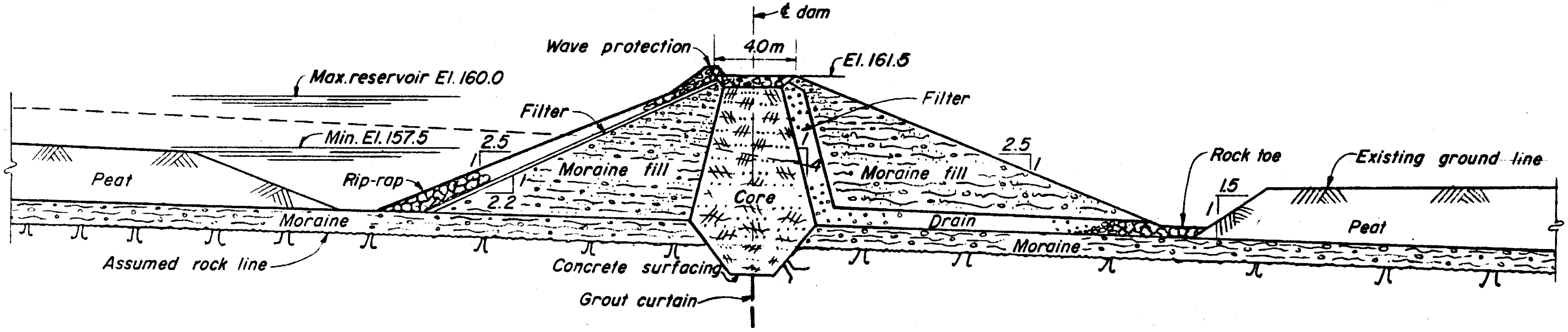
H-E

EXHIBIT 3



SECTION OF HEADRACE CANAL



SECTION-DAM EAST OF BRÚARÁ

Scale 0 5 Meters

THE STATE ELECTRICITY AUTHORITY
ICELAND

EFSTIDALUR PROJECT

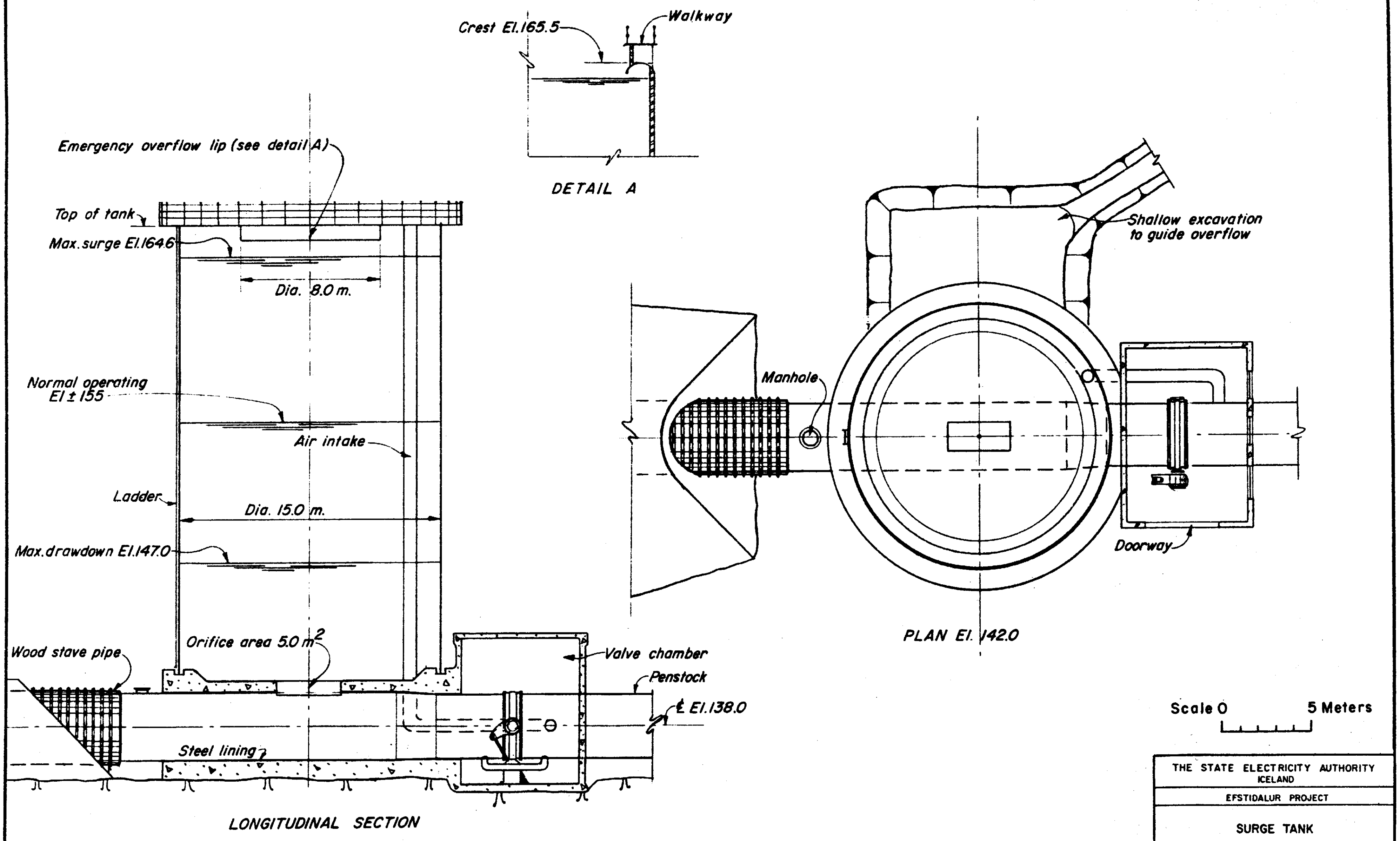
DAM AND HEADRACE CANAL
SECTIONS

HARZA ENGINEERING COMPANY
APPROVED
CHICAGO, ILLINOIS | DATE Nov. 1962 | DWG. NO. 299 P 3

PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

H-E ALBANENE 195L TRACING PAPER

EXHIBIT 4



THE STATE ELECTRICITY AUTHORITY
ICELAND

EFSTIDALUR PROJECT

SURGE TANK

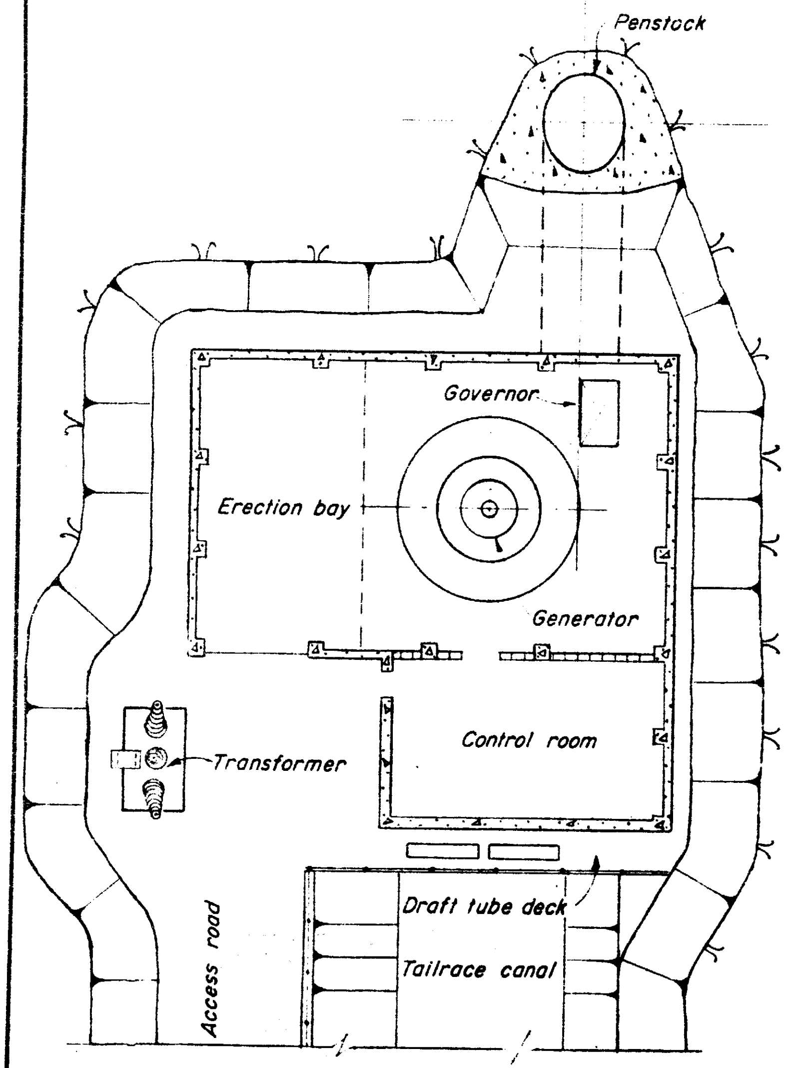
HARZA ENGINEERING COMPANY
APPROVED

CHICAGO, ILLINOIS	DATE Nov. 1962	DWG. NO. 299 P 4

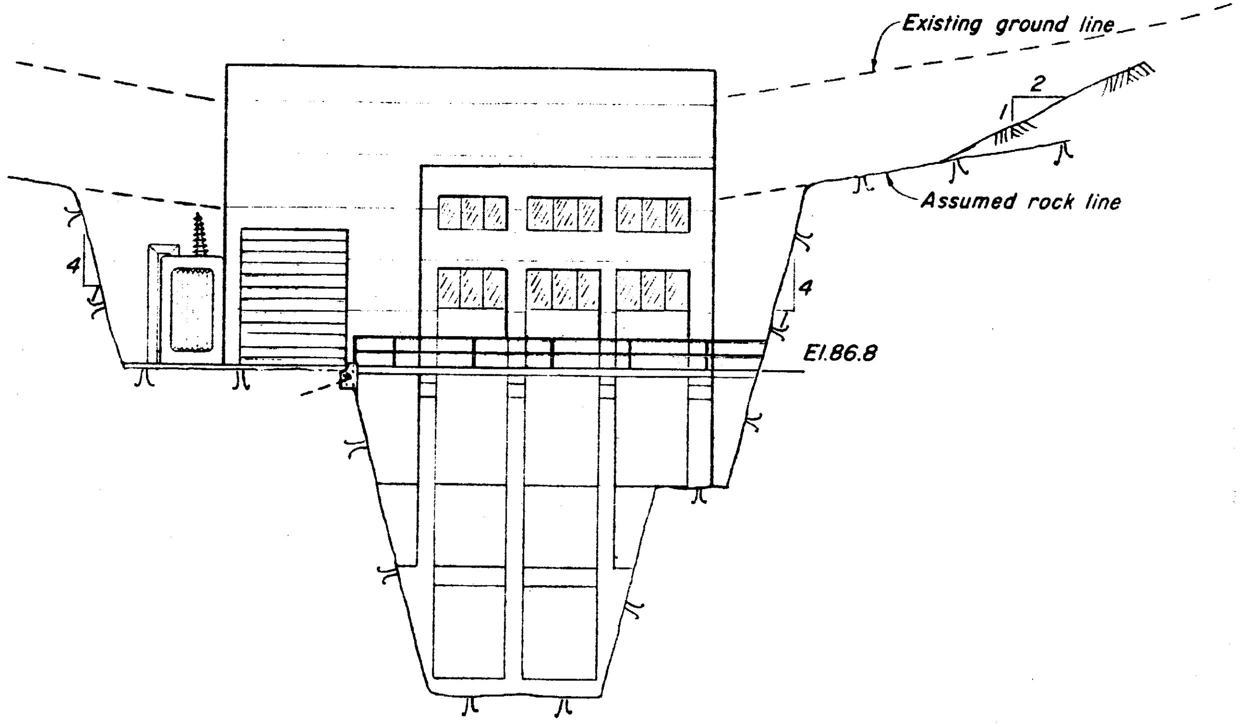
PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

K+E ALBANENE 100L

EXHIBIT 5



PLAN



ELEVATION

Scale 0 5 Meters

THE STATE ELECTRICITY AUTHORITY
ICELAND

EFSTIDALUR PROJECT

POWERHOUSE
PLAN AND ELEVATION

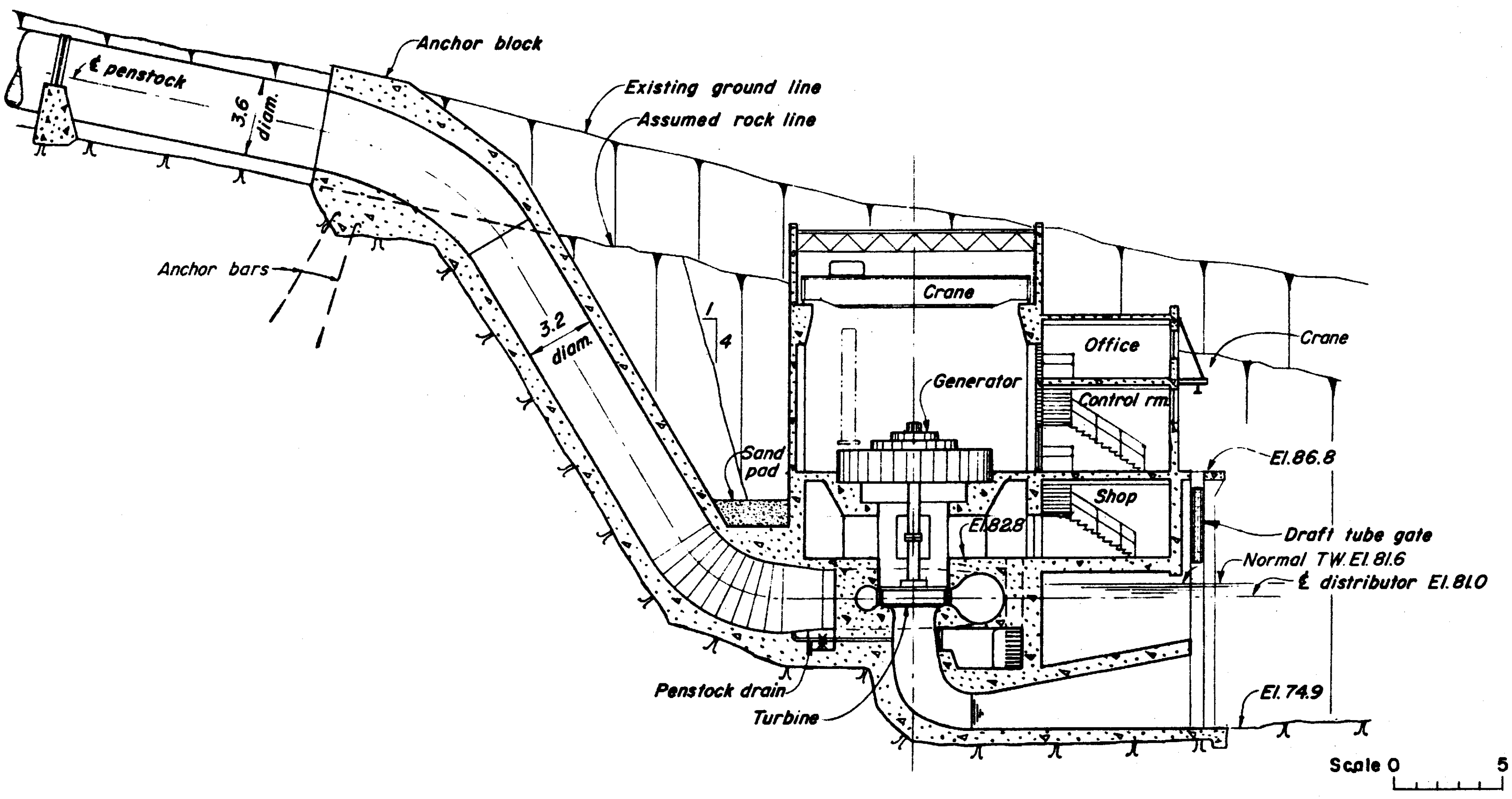
HARZA ENGINEERING COMPANY
APPROVED A.P. Geuss
CHICAGO, ILLINOIS | DATE Nov. 1962 | DWG. NO. 299 P 5

PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

K+E ALBANENE 196L ® TRACING PAPER

EXHIBIT 6

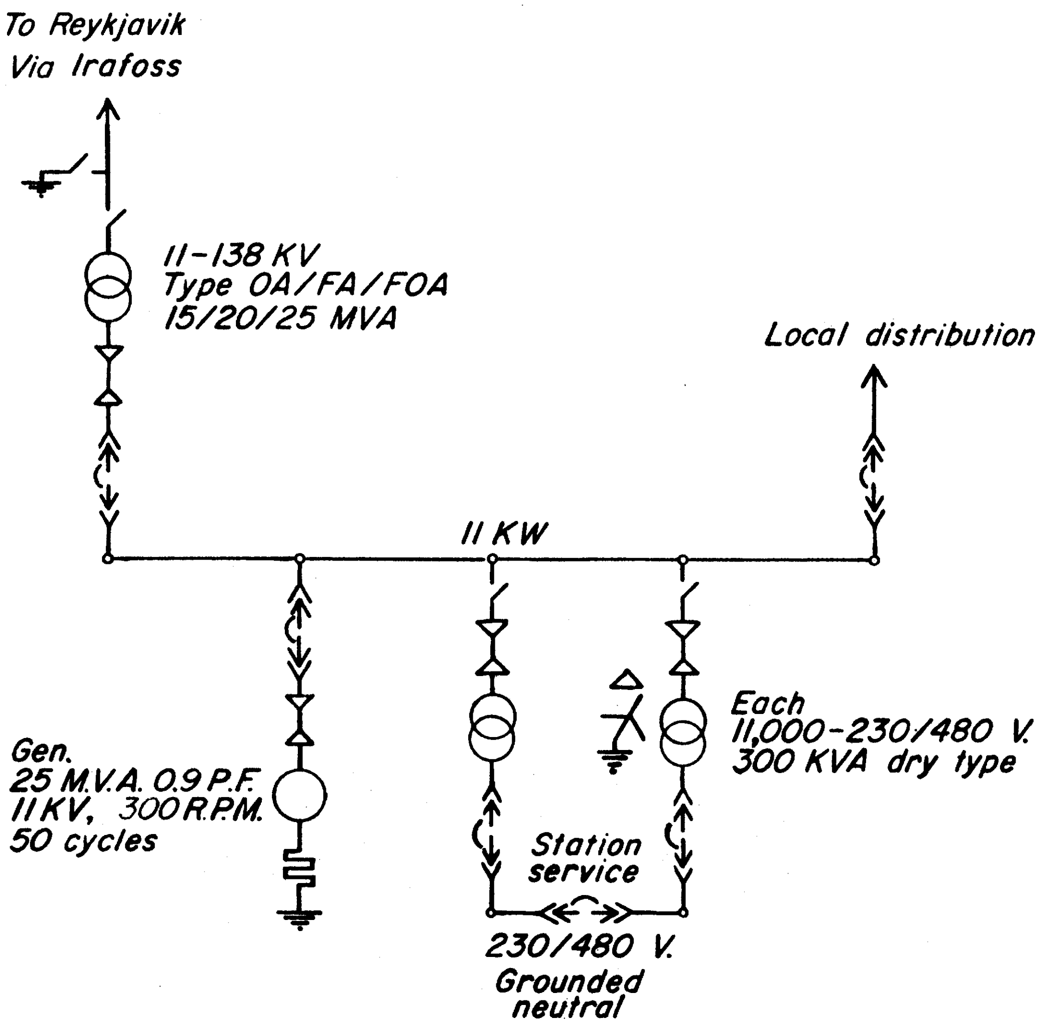
Turbine : Francis, 300 rpm, 35,000 metric hp at 73 meters net head.
Generator: Rated 25,000 kva at 0.9 power factor.



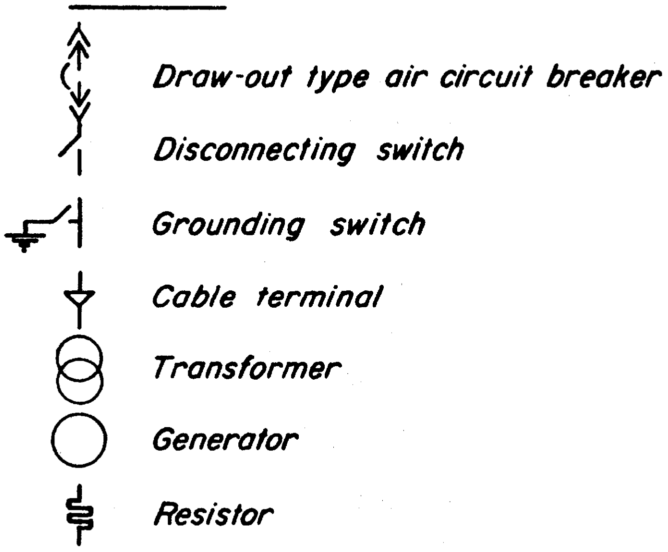
THE STATE ELECTRICITY AUTHORITY ICELAND
EFSTIDALUR PROJECT
POWERHOUSE TRANSVERSE SECTION
HARZA ENGINEERING COMPANY APPROVED
CHICAGO, ILLINOIS · DATE Nov 1962 · DWG. NO. 299 P 6

PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

EXHIBIT 7



LEGEND



PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

THE STATE ELECTRICITY AUTHORITY ICELAND		
EFSTIDALUR PROJECT		
ONE LINE DIAGRAM		
HARZA ENGINEERING COMPANY APPROVED A.P. Gouse		
CHICAGO, ILLINOIS	DATE Nov. 1962	DWG. NO. 299 P 7

COST ESTIMATE-SUMMARY
EFSTIDALUR PROJECT

Item	Total w/o Duties and Taxes U.S. $	Import Duties and Taxes U.S. $	Total with Duties and Taxes U.S. $
PRODUCTION PLANT			
Powerhouse	245,865	57,505	303,370
Reservoir, Dams, & Waterways	2,869,065	661,585	3,530,650
Turbine and Generator	542,000	186,000	728,000
Accessory Electrical Equipment	100,000	35,000	135,000
Miscellaneous Power Plant Equip.	212,000	72,000	284,000
Access Road	22,000	4,000	26,000
Operators Village	32,000	3,000	35,000
Subtotal Production Plant	4,022,930	1,019,090	5,042,020
TRANSMISSION PLANT			
Efstidalur Substation	77,000	28,500	105,500
Transmission Line	712,500	225,000	937,500
Irafoss Substation & Control Room	84,000	28,000	112,000
Ellidaar Substation	137,000	49,000	186,000
Subtotal Transmission Plant	1,010,500	330,500	1,341,000
SUBTOTAL DIRECT COST	5,033,430	1,349,590	6,383,020
Contingencies 15% ±	756,570	200,410	956,980
Subtotal	5,790,000	1,550,000	7,340,000
Cost Escalation 5% ±	280,000	80,000	360,000
TOTAL DIRECT COST	6,070,000	1,630,000	7,700,000
Engineering and Supervision, 8% of Direct Cost w/o Duties and Taxes	500,000		500,000
Preliminary Investigations	95,000	5,000	100,000
TOTAL CONSTRUCTION COST	6,665,000	1,635,000	8,300,000
Interest During Construction 7% ±	485,000	115,000*	600,000
TOTAL PROJECT INVESTMENT	7,150,000	1,750,000	8,900,000

* Interest on the cost component from duties and taxes.

COST ESTIMATE
EFSTIDALUR PROJECT

Item	Quantity	Unit Price* U.S. $	Amount* U.S. $	Import Duties and Taxes U.S. $
PRODUCTION PLANT				
POWERHOUSE				
Excavation, common	9,130 m^3	0.95	8,675	1,505
Excavation, rock	8,750 m^3	6.00	52,500	8,660
Foundation preparation and treatment		L.S.	10,000	1,800
Concrete, mass	630 m^3	35.00	22,050	3,780
Concrete, structural	1,000 m^3	80.00	80,000	20,700
Reinforcing steel	95,000 kg	0.25	23,750	7,600
Miscellaneous metal	7,300 kg	1.20	8,760	2,628
Backfill	130 m^3	1.00	130	22
Draft tube gates and guides	13,500 kg	1.00	13,500	4,050
Draft tube gate hoist	1 ea.	L.S.	5,000	1,600
Architectural treatment and miscellaneous		L.S.	21,500	5,160
SUBTOTAL POWERHOUSE			245,865	57,505
RESERVOIRS, DAMS, AND WATERWAYS				
EARTH DAM EAST OF BRUARA				
Excavation, common	56,500 m^3	1.25	70,625	11,865
Excavation, rock	1,000 m^3	6.00	6,000	990
Foundation preparation and treatment		L.S.	60,000	10,800
Impervious core	13,400 m^3	2.25	30,150	5,025

*Without Import Duties and Taxes

COST ESTIMATE
EFSTIDALUR PROJECT

Item	Quantity	Unit Price* U.S. $	Amount* U.S. $	Import Duties and Taxes U.S. $
PRODUCTION PLANT (continued)				
EARTH DAM EAST OF BRUARA (continued)				
Gravel filters and fill	34,000 m^3	1.90	64,600	10,710
Riprap lining and rock toe	4,400	2.50	11,000	1,850
Miscellaneous		L.S.	1,000	180
SUBTOTAL EARTH DAM EAST OF BRUARA			243,375	41,420
SPILLWAY AND RETAINING WALLS				
Excavation, common	100 m^3	1.50	150	30
Excavation, rock	1,350 m^3	7.00	9,450	1,620
Foundation preparation and treatment		L.S.	11,500	2,070
Concrete	2,650 m^3	38.00	100,700	16,700
Reinforcing steel	100,000 kg	0.25	25,000	8,000
Gates and frames and guides	10,000 kg	1.10	11,000	3,960
Hoists	1	L.S.	5,000	1,600
Miscellaneous		L.S.	1,000	240
Cofferdams and pumping		L.S.	14,000	2,520
SUBTOTAL SPILLWAY AND RETAINING WALLS			177,800	36,740
HEADRACE CANAL AND DIKE				
Excavation, common	140,000 m^3	0.95	133,000	21,000
Excavation, rock	5,000 m^3	6.00	30,000	4,950
Foundation preparation and treatment		L.S.	50,000	9,000

*Without Import Duties and Taxes

COST ESTIMATE
ESTIDAHER PROJECT

Item	Quantity	Unit Price* U.S. $	Amount* U.S. $	Import Duties and Taxes U.S. $
PRODUCTION PLANT (continued)				
HEADRACE CANAL AND DIKE (continued)				
Impervious core	9,600 m^3	2.25	21,600	3,600
Gravel filters and fill	43,000 m^3	1.90	81,700	13,550
Riprap lining and rock toe	9,000 m^3	2.50	22,500	3,780
Miscellaneous		L.S.	10,000	1,800
SUBTOTAL HEADRACE CANAL AND DIKE			348,800	57,680
INTAKE				
Excavation, common (included in headrace canal)	m^3	0.95		
Excavation, rock	100 m^3	7.00	700	120
Foundation preparation and treatment		L.S.	10,000	1,800
Concrete	1,600 m^3	45.00	72,000	12,000
Reinforcing steel	45,000 kg	0.25	11,250	3,600
Trashracks	12,000 kg	0.75	9,000	2,640
Service gate and guides	6,800 kg	1.25	8,500	2,590
Hoist		L.S.	5,000	1,500
Bulkhead gate and guides	5,000 kg	0.90	4,500	1,000
Miscellaneous		L.S.	10,000	1,800
SUBTOTAL INTAKE			130,950	27,050

*Without Import Duties and Taxes

COST ESTIMATE
EFSTIDALUR PROJECT

Item	Quantity	Unit Price* U.S. $	Amount* U.S. $	Import Duties and Taxes U.S. $
PRODUCTION PLANT (continued)				
HEADRACE PIPE				
Excavation, common	50,000 m^3	1.50	75,000	12,750
Excavation, rock	2,000 m^3	7.00	14,000	2,400
Gravel fill	27,000 m^3	1.90	51,300	8,505
Cover fill	19,500 m^3	1.00	19,500	3,215
Wood - stave pipe, 3.8 m dia.	2,650 m	350.00	927,500	278,250
Miscellaneous		L.S.	20,000	4,800
SUBTOTAL HEADRACE PIPE			1,107,300	309,920
SURGE TANK				
Excavation, common	600 m^3	1.50	900	155
Excavation, rock	100 m^3	7.00	700	120
Concrete	1,230 m^3	45.00	55,350	9,225
Reinforcing steel	11,000 kg	0.25	2,750	880
Steel, tank	133,000 kg	0.70	93,100	29,260
Steel, conduit liner	24,000 kg	0.65	15,600	4,800
Miscellaneous metal	7,700 kg	1.20	9,240	2,775
Valve, 3.6 m dia.		L.S.	64,000	20,480
Miscellaneous		L.S.	10,000	2,400
SUBTOTAL SURGE TANK			251,640	70,095

*Without Import Duties and Taxes

COST ESTIMATE
EFSTIDALUR PROJECT

Item	Quantity	Unit Price* U.S. $	Amount* U.S. $	Import Duties and Taxes U.S. $
PRODUCTION PLANT (continued)				
PENSTOCK				
Excavation, common	3,800 m^3	1.50	5,700	990
Excavation, rock	400 m^3	7.00	2,800	480
Concrete	1,130 m^3	55.00	71,500	10,170
Reinforcing steel	22,600 kg	0.25	5,650	1,810
Steel plate	223,000 kg	0.65	144,950	44,600
Miscellaneous		L.S.	2,500	450
SUBTOTAL PENSTOCK			233,100	58,500
TAILRACE CANAL				
Excavation, common	198,000 m^3	0.95	188,100	29,700
Excavation, rock	56,000 m^3	3.00	168,000	26,880
Cofferdams and pumping		L.S.	20,000	3,600
SUBTOTAL TAILRACE CANAL			376,100	60,180
SUBTOTAL RESERVOIRS, DAMS & WATERWAYS			2,869,065	661,585
TURBINE & GENERATOR				
Turbine and governor	1	L.S.	192,000	66,000
Generator and exciter	1	L.S.	350,000	120,000
SUBTOTAL TURBINE AND GENERATOR			542,000	186,000
ACCESSORY ELECTRICAL EQUIPMENT		L.S.	100,000	35,000

*Without Import Duties and Taxes

COST ESTIMATES
EFSTIDALUR PROJECT

Item	Quantity	Unit Price* U.S. $	Amount* U.S. $	Import Duties and Taxes U.S. $
PRODUCTION PLANT (continued)				
POWERHOUSE MECHANICAL EQUIPMENT		L.S.	212,000	72,000
ACCESS ROADS		L.S.	22,000	4,000
OPERATORS VILLAGE		L.S.	32,000	3,000
SUBTOTAL PRODUCTION PLANT			4,022,930	1,019,000
TRANSMISSION PLANT				
EFSTIDALUR SUBSTATION				
Transformer - 25 MVA	1	64,000	64,000	25,000
Foundations, grading, structures		L.S.	8,000	2,000
Switches, conduits, etc.		L.S.	5,000	1,500
SUBTOTAL EFSTIDALUR SUBSTATION			77,000	28,500
TRANSMISSION LINE - EFSTIDALUR-ELLIDAR VIA IRAFOSS				
738 kv single circuit on wood poles	75 km	9,500	712,500	225,000
IRAFOSS SWITCHYARD ADDITIONS				
Circuit breakers	2	27,000	54,000	18,000
Carrier current equipment		L.S.	6,000	2,000
Grounding, conduits, etc.		L.S.	3,000	1,000
SUBTOTAL IRAFOSS SWITCHYARD ADDITIONS			63,000	21,000
IRAFOSS CONTROL ROOM ADDITIONS		L.S.	21,000	7,000

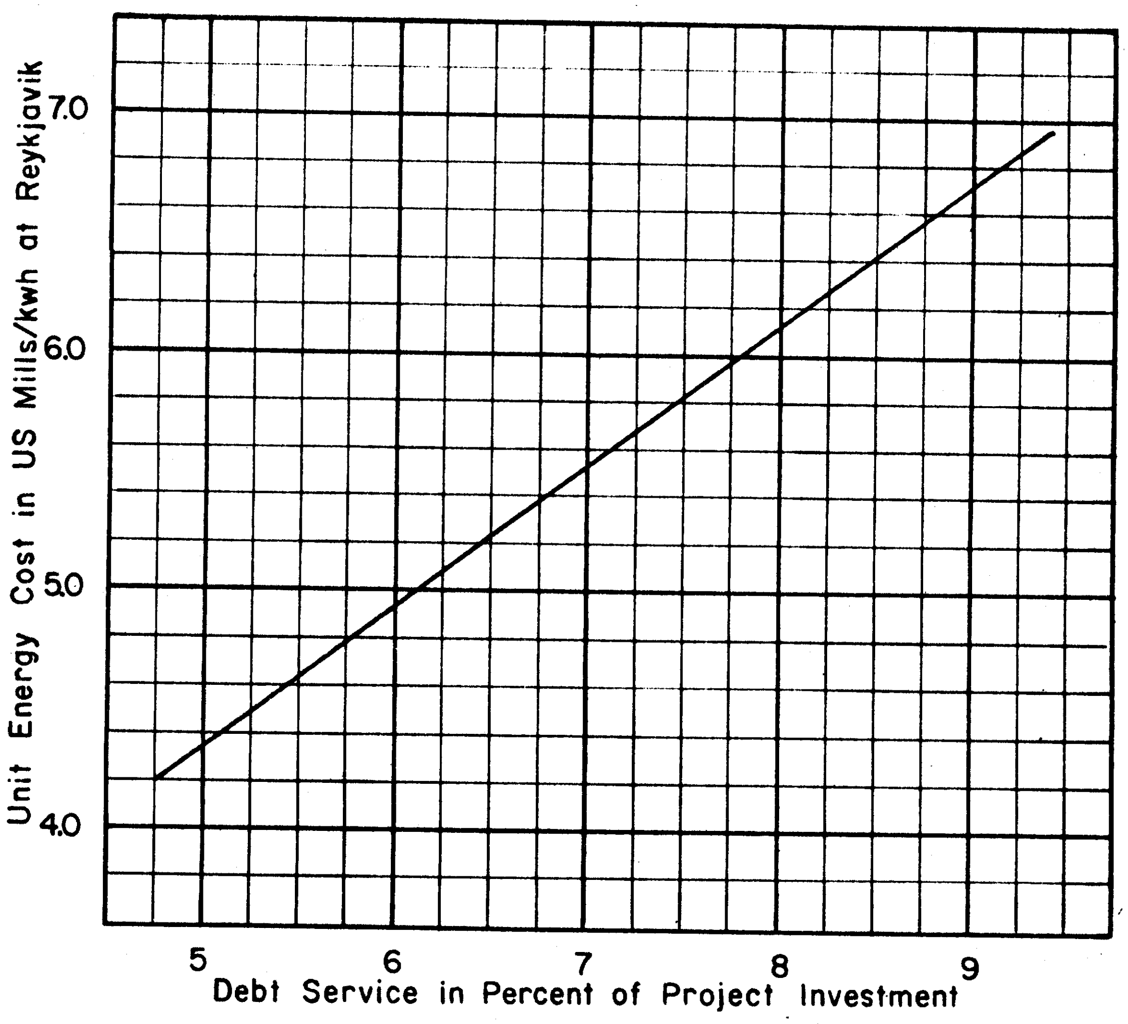
*Without Import Duties and Taxes

COST ESTIMATES
EFSTIDAULUR PROJECT

Item	Quantity	Unit Price* U.S. $	Amount* U.S. $	Import Duties and Taxes U.S. $
TRANSMISSION PLANT (continued)				
ELLIDAR SUBSTATION ADDITIONS				
Transformers - 25 MVA	1	64,000	64,000	25,000
Circuit breakers	2	27,000	54,000	18,000
Structures, switches, grounding, etc.		L.S.	19,000	6,000
SUBTOTAL ELLIDAR SUBSTATION ADDITIONS			137,000	49,000
SUBTOTAL TRANSMISSION PLANT			1,010,500	330,500

*Without Import Duties and Taxes

EXHIBIT 9



1. *Total project investment $ 8,900,000*
2. *Annual cost other than debt service $ 205,000*
3. *No allowance made for income from sales of secondary energy*
4. *Import duties and taxes included*

PREPARED FOR HARZA ENGINEERING COMPANY INTERNATIONAL

THE STATE ELECTRICITY AUTHORITY ICELAND		
EFSTIDALUR PROJECT		
ESTIMATED COST OF PRIMARY ENERGY		
HARZA ENGINEERING COMPANY APPROVED A P Gauss		
CHICAGO, ILLINOIS	DATE Nov 1962	DWG. NO. 299 P 9