PROJECT PLANNING REPORT

BURFELL PROJECT

BY THE

HARZA ENGINEERING COMPANY INTERNATIONAL

PREPARED FOR

THE STATE ELECTRICITY AUTHORITY

GOVERNMENT OF ICELAND

JANUARY 1963

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HARZA ENGINEERING COMPANY INTERNATIONAL
CONSULTING ENGINEERS
RIVER PROJECTS

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REPRESENTED IN THE UNITED STATES BY
HARZA ENGINEERING COMPANY
CHICAGO, ILLINOIS

January 24, 1963

CABLE ADDRESS "HARZINT"

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CHICAGO 6, ILLINOIS

TELEX NUMBER CG 1-4385

BURFELL HYDROELECTRIC PROJECT

SUMMARY OF REPORT

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

Gentlemen:

Introduction

We are pleased to present our Project Planning Report on the Burfell Hydroelectric Project. The Report is presented in two Volumes, Volume I represents the main body of the Report and summarizes our engineering investigations and studies on the Project to date. Volume II contains supplementary information of a detailed nature, primarily of interest to technical specialists. That Volume contains Appendices on hydraulics and hydrology, geology, natural construction materials, and Thorisvatn initial storage.

Volume I consists of seven Chapters. Chapter I is an "Engineering Summary" which briefs, for the general interest reader, the more detailed engineering data presented in the subsequent six Chapters. Economic data is presented in Chapter II.

Our engineering interest in the Burfell Project began in 1959 with general studies of the hydroelectric potential of the Thjorsa and Hvita Basins which were presented in our Advisory Report of March 1960. These general studies indicated that Burfell, with its great flow and high head concentration, might be the most attractive large hydroelectric potential as a single development in Southwest Iceland. Somewhat more detailed investigations and studies in 1961 and early 1962 led to the decision by the State Electricity Authority (SEA) to proceed with the investigations and studies which are summarized in this Report.

Concurrently, the need to industrialize in Iceland became apparent to the extent that the Government opened preliminary negotiations to attract an aluminium smeltering load as a first large step in developing Iceland's huge hydroelectric resources. Further, it was apparent that additional resources were required to meet the normal load growth of the Southwest Iceland System.

Selection of Size of Installation

During the late months of 1962, we appraised a development of 60,000 kilowatts at Burfell which was designed only to meet the normal load growth, but which could be expanded readily to supply a large industrial load. Even this relatively small initial development appeared to us to be attractive economically in comparison to other and smaller developments which we have studied in similar detail in Iceland.

The preliminary negotiations with aluminium interests indicated that an initial smelter in Iceland might have from one to two potlines in half-potline increments, with the smallest possibly enlarged within a few years after initial operation. The demand for each half-potline might vary between about 25,000 and 30,000 kilowatts depending on plant design. Studies by SEA of normal system load growth pointed to the need for 30,000 to 60,000 kilowatts of additional capacity within a few years. Using the higher of these estimates we selected an installed rated capacity of 180,000 kilowatts in six units as the basic design for the initial hydroelectric development at Burfell. The Burfell Project thus is planned to serve two maximum size potlines plus a large increment of normal load.

Because the first smelter installation might be smaller than the above maximum and because the normal load would grow progressively, we made cost estimates of initial installation of four units and of five units in the basic six-unit plant. These last units would be added in the vacant bays as required. Pertinent data with respect to these installations is as follows:

Number of Units	Installed Rated Capacity (kw)	Delivered Annual Primary Energy Production (millions of kwh)*	Required Flow (cubic meters per second)	Percent of Time Required Flow is Available
4	120,000	940	116	99.8
5	150,000	1160	145	98
6	180,000	1375	174	91

* With one transmission line.

The power and energy estimates are presented in Chapter VI.

Description of Project

The Burfell Project will be located approximately 86 kilometers upstream of the mouth of the Thjorsa where the river falls about 120 meters in 13 kilometers as it circles the south end of the mountain, Burfell. The Project will be a run-of-river development with daily pondage only, and the initial stage as presented in this Report will develop the minimum dependable flow of the River. Physical factors of the Thjorsa are presented in Chapter III, and of the site in Chapter IV.

The plan of development is based on the results of extensive field investigations, discussed in Chapter IV, conducted at the selected site beginning early in 1962. These investigations are continuing. The office studies covered a number of alternatives for each Project structure prior to adoption of the selected design. The arrangement of the Project features is discussed in detail in Chapter V.

The Project, as planned, consists of two main components, the power production facilities and the transmission facilities. The former are shown in plan and section on the attached Exhibit A. They consist of three main features: (1) diversion works to divert the river into,(2) the Bjarnalaekur Pond, and (3) the power features. The power features include the intake and penstocks, the powerstation, and the tailrace. The recommended transmission system includes a single circuit 230-kv line from Burfell to the Reykjavik area, sending and receiving substations, and a tie to the existing system in Reykjavik. Alternatives are presented for the terminal substation at Eidi and at Straumsvik. Further, costs are also presented for two circuits by separate routes extending to each of these terminals. A major industrial customer may desire the somewhat greater dependability of two circuits.

River ice represents the only major operation problem which might develop. We are confident that the final designs can solve this problem satisfactorily. A possible cost contingency exists if it develops ultimately that a supplemental supply of ice sluicing water, such as from an initial development at Thorisvatn, becomes necessary. This could increase costs on the order of up to about five percent.

Operating experience with the existing transmission line from the Sog to Reykjavik indicates that no serious operation problems, such as wind or ice, will exist with a line from Burfell. Therefore, we consider that provision of a single 230-kv transmission line is adequate for the planned Burfell Project.

Construction Time

The Burfell Project as planned can be completed within three years after initiation of construction. The planning has been based on unusually thorough and extensive field investigations. No major design or construction problem which would seriously affect costs adversely is apparent or considered probable. The construction of the Project is discussed in Chapter VII.

Cost Estimates

Cost estimates were prepared for the basic six-unit power production plant with four, five, or six units installed initially. Cost estimates were also prepared for the transmission plant with the alternatives of one or two circuits to each of the two terminals, Eidi and Straumsvik--a total of four estimates. The cost estimates are discussed in detail in Chapter II.

Each of the cost estimates is presented to show the total investment. Each total investment was determined by adding allowances for contingencies, engineering and overhead, and construction interest to the estimated direct cost. No allowances were included for one year of interest reserve, which might be desired by some financing agencies, or for working capital. None of the estimates include any allowance for import duties and taxes. All estimates are presented in United States Dollars. An exchange rate of 43 Icelandic Kronur to one U. S. Dollar was used where appropriate in the detail of each estimate.

The total investment required for the various installations with the terminal substation at Eidi was estimated as follows:

	Four Units	Five Units	Six Units
Production Plant	$25,400,000	$26,700,000	$27,700,000
Transmission Plant	3,800,000	4,100,000	4,100,000
Total	$29,200,000	$30,800,000	$31,800,000

These estimates are based on a single circuit transmission line. The addition of the second line, by the Southern route, would increase each of the three totals about $2,600,000. The increase of each with the terminal at Straumsvik would be $300,000 for one transmission line and $3,000,000 for two lines.

Estimates were prepared for items of annual cost not controlled by financing terms. These items include operation and maintenance costs, compensation for water rights, and reserves to provide for extraordinary replacement costs not included in normal maintenance or covered by insurance. These annual costs, based on a single transmission line to either terminal, are estimated as follows:

Number of Units	Annual Costs Other Than Debt Service
4	$745,000
5	840,000
6	910,000

The provision of the second transmission line would add about $50,000 to these annual costs.

The appropriate debt service would be added to each of these above annual costs in order to estimate total annual charges. Inasmuch as financing terms have not been established, it is not possible at this time to estimate debt service exactly. However, we have calculated the annual debt service for the range between the lowest and highest expected terms; i.e., 5 percent and 9 percent of the total estimated project investment.

Using the estimated annual costs other than debt service and the range of debt service shown above, we have computed the estimated unit costs of primary energy for the Project. These energy cost estimates are shown graphically on the attached Exhibit B in the range between 5 and 9 percent. Alternative projects include 4, 5, and 6 units installed initially, and one or two transmission lines for each installation. The estimates of Exhibit B are for the terminal substation located at Eidi. Comparable unit energy costs for Straumsvik delivery would be only about one percent higher, which is negligible for an estimate of this type.

The unit energy costs as estimated on Exhibit B represent to the owner, the Government of Iceland, average costs only. The selling price of the energy should include a further allowance to the owner for reserves needed during the first few years of load development, for bad business years, and possibly to provide cash funds for expansion studies and other system betterments. These further allowances may amount to as much as ten percent of the costs.

Conclusion

We conclude on the basis of our studies that the Burfell Project is feasible technically and attractive economically. This conclusion applies whether the initial development is a relatively small one intended primarily to meet the demands of normal system load growth, or a fairly large one intended to serve, in addition, a large industrial load or loads. Neither size develops the full potential available at the site, and the largest proposed (180,000 kilowatts) can be expanded readily. Our studies, which have extended over the past three and one-half years, of the hydroelectric resources of Southwest Iceland lead us to believe that developments at other potential sites may be somewhat more costly for either relatively small or large installations. A development at Burfell thus appears to be the next logical development of these resources.

Very truly yours,

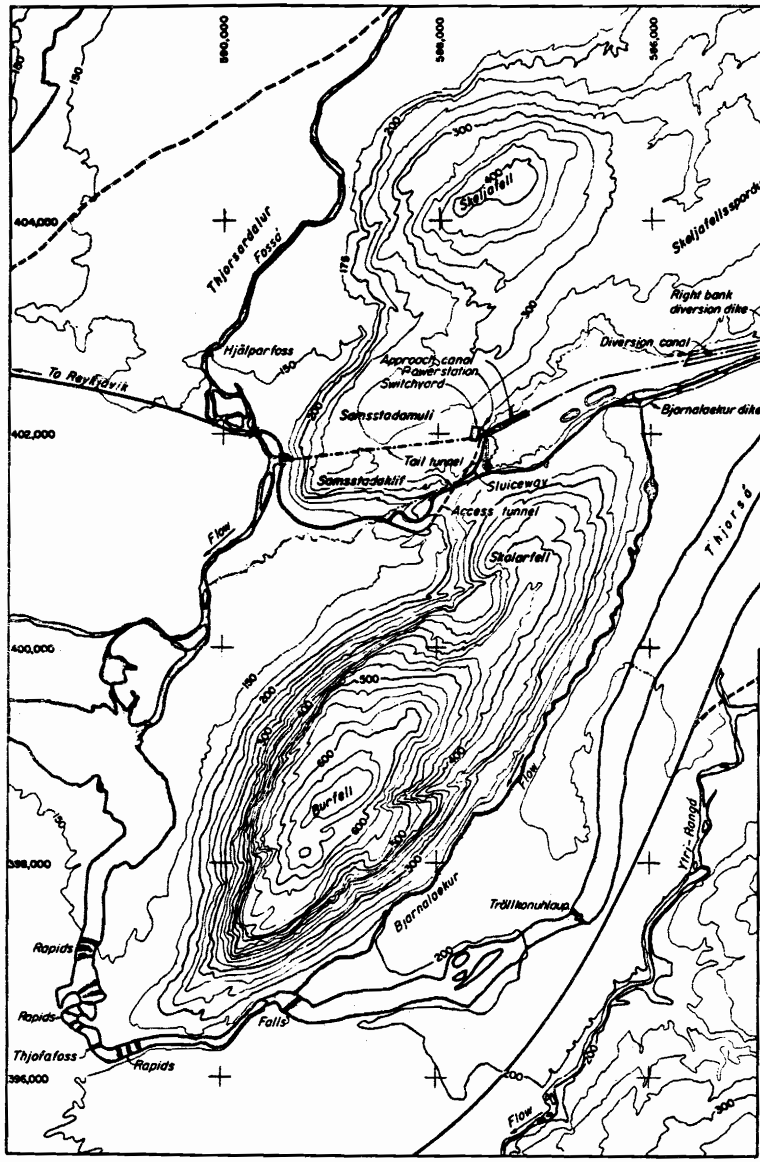
HARZA ENGINEERING COMPANY INTERNATIONAL

E. Montford Fucik

E. Montford Fucik
President

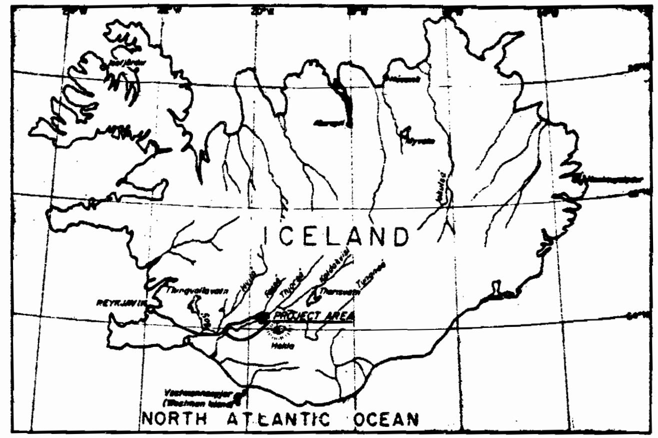
Enc. Exhibits A and B

EXHIBIT A



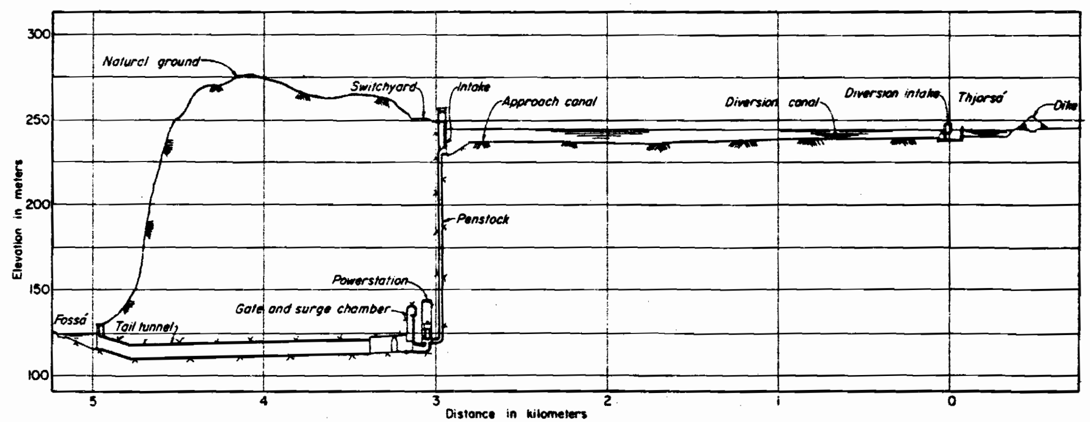
PROJECT PLAN

Scale 0 — 1 Kilometer



KEY PLAN

Scale 0 — 100 Kilometers



PROFILE

Scale distorted

THE STATE ELECTRICITY AUTHORITY
ICELAND

BURFELL PROJECT

LOCATION MAP AND PROJECT PLAN

HARZA ENGINEERING COMPANY INTERNATIONAL

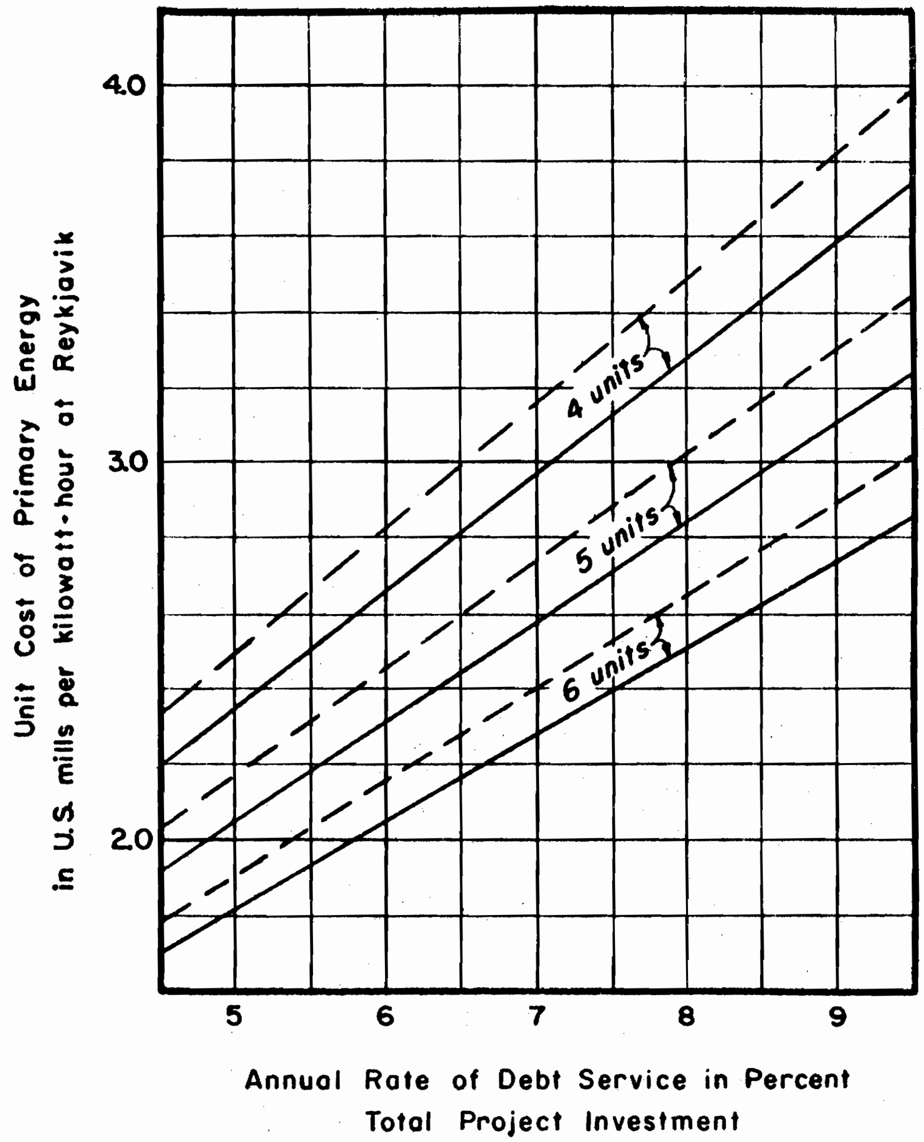
PREPARED BY HARZA ENGINEERING COMPANY

APPROVED ....

REV. NO.	DATE	NATURE OF REVISION	BY	CHKD.	APPD.

CHICAGO, ILLINOIS — DATE JAN. 1963 — DWG. No. 290 P 8

EXHIBIT B



LEGEND

——— *One transmission line*

- - - - *Two transmission lines*

NOTES:

No allowance made for income from sales of secondary energy.

Import duties and taxes not included.

STATE ELECTRICITY AUTHORITY
ICELAND
BURFELL PROJECT

UNIT COST OF ENERGY

HARZA ENGINEERING CO. INTERNATIONAL

PREPARED BY
HARZA ENGINEERING CO., CHICAGO
APPROVED A P Gause

DATE JAN. 1963 | DWG. NO. 290 P 32

TABULATION OF SIGNIFICANT DATA

Drainage area - square kilometers	6380
Discharge - cubic meters per second	
Maximum design flood	7750
Maximum historical	2000
Average	338
Minimum historical	72
Headwater elevation - meters above sea level	
Maximum (at maximum design flood)	248
Normal	244.5
Minimum	243.5
Tailwater elevation - meters above sea level	
Maximum with ice jam in Thjorsa	130 ±
Normal maximum (flood in Fossa)	126.5
Normal	125.5
Minimum	125 ±
Minimum after assumed degradation in Fossa	123 ±
Diversion dam	
Crest elevation of overflow section - meters above sea level	244.5
Height of overflow section from foundations - meters	7
Dikes	
Total length - meters	5300
Maximum height from foundations - meters	30
Total volume of fill - cubic meters	1,300,000
Canals	
Total length - meters	2,100
Total volume of excavation - cubic meters	750,000
Penstocks	
Type	steel lined vertical shafts
Diameters - meters	3.8
Length - meters	135

TABULATION OF SIGNIFICANT DATA (continued)

Powerstation	
Type	underground
Length - meters	115
Width - meters	16
Height - meters	33
Tailrace tunnel	
Type	horseshoe, concrete lined
Diameter - meters	7.5
Length - meters	1560
Turbines	
Number	six
Type	Francis
Rating at 115 meters net head - metric horsepower	44,300
Discharge at rated head, full gate - cubic meters per second	32.5
Speed - revolutions per minute	333.3
Generators	
Number	six
Type	vertical shaft, hydraulic turbine driven
Rating - kilovolt-amperes	33,333
Power factor	0.9
Voltage - kilovolts	13.8
Phases	three
Cycles per second	50
Speed - revolutions per minute	333.3
Transformers	
Number	three
Type	outdoor, three-phase, OA/FA/FOA
Rating - megavolt-amperes	36-36-72
Voltage - kilovolts	13.8-230
Main transmission line	
Length	
Eidi Alternative - one line - kilometers	107
Eidi Alternative - second line - kilometers	112

TABULATION OF SIGNIFICANT DATA (continued)

Main transmission line (continued)	
Straumsvik Alternative - one line - kilometers	118
Straumsvik Alternative - second line - kilometers	118
Voltage - kilovolts	230
Construction	wood poles

TABLE OF EQUIVALENTS AND ABBREVIATIONS

Monetary Equivalents

1 dollar	equals	43 Kronur

Metric Equivalents

1 meter	equals	3.281 feet
1 kilometer	"	0.6214 miles
1 square kilometer	"	0.3861 square miles
1 cubic meter	"	35.32 cubic feet
1 million cubic meters	"	811 acre-feet
1 cubic meter per second	"	35.32 cubic feet per second
1 kiloliter per second	"	35.32 cubic feet per second
1 kilogram	"	2.205 pounds
1 metric ton	"	1.102 short tons

Abbreviations

Million cubic meters	MCM
Cubic meters per second	cms, m^3/sec
Kilowatt	kw
Kilovolt	kv
Kilovolt-ampere	kva
Megavolt-ampere	mva
Kilowatt-hour	kwh
Million kilowatt-hours	Mkwh
Revolutions per minute	rpm
Degrees centigrade	^oC
U.S. Dollars	$
Kronur	Kr.