Ljósafoss in Sog as Water Power Plant for Reykjavik Electricity Works, 1934

Bjarni Benediktsson – Stjórnmál – Ljósafoss – Sog – Raforkuvirkjun – Reyakjvik Electricity Works - 1934

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bjarnibenediktsson.is

Einkaskjalasafn nr. 360
Stjórnmálamaðurinn
Askja 2-4, Örk 4

Bjarni Benediktsson.

REPORT

ON

THE DEVELOPMENT OF LJOSAFOSS IN SOG

AS

WATER POWER PLANT

FOR

REYKJAVIK ELECTRICITY WORKS

MARCH 1934

Jakob Gíslason

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PREPARED IN MARCH 1934

ACCORDING TO AUTHORIZATION FROM
THE MUNICIPALITY OF REYKJAVIK

BY

A. B. BERDAL, Consulting Civil Engineer, MNIF, Oslo
JACOB NISSEN, Consulting Electrical Engineer, MNIF, Oslo

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OSLO

1. Introduction.

In April 1933 the signers of this report, A. B. Berdal and Jacob Nissen, were requested by the Council of Reykjavik to investigate the existing plans for further development of water power plants for Reykjavik Electricity Works and to report upon which of the alternatives was to be recommended for construction.

According to this request we went to Iceland in May 1933. In the course of our journey we inspected the existing plants of the Reykjavik Electricity Works as well as the waterfalls which have been under discussion for development and collected further data necessary for our work.

Upon the conclusion of some ground surveys as arranged during our first visit, A. B. Berdal in September—October 1933 again went to Iceland to undertake further studies and to examine the results of the ground surveys.

After receipt of all the records and data, which we found necessary for our work, and after examination and consideration of the alternatives, we on the 17th January 1934 rendered to the Reykjavik authorities a report concluding with our recommendation of the development of Ljosafoss in the river Sog.

Following this, we were engaged to work out more detailed plans together with description and estimate for the Ljosafoss project.

Before we turn to explain these plans we are going to give an outline of the development of Reykjavik Electricity Works during the past 13 years of power distribution, the necessary power being supplied from a water power plant in Ellidaár, located about 5 km from Reykjavik.

The tables I and II show some data which give an outline of the development of this plant and the consumption of electric energy in Reykjavik.

Table I gives the financial data, table II the technical data and the number of population of Reykjavik.

TABLE I. REYKJAVIK MUNICIPAL HYDRO-ELECTRIC LIGHT & POWER WORKS FINANCIAL DATA

Year	General Balance Sheet: Invested Capital: Town Network, Meters etc. 1000 kr.	Power Plant Ellida River 1000 kr.	Sog Water-rights Preparations 1000 kr.	Total 1000 kr.	Written off 1000 kr.	Booked Power Plant Network etc. 1000 kr.	Cash and Sundries 1000 kr.	Total Assets less Amount written off 1000 kr.	Liabilities 1000 kr.	Net booked Property 1000 kr.
1921	1402	1827		3229		3229	356	3585	3346	239
1922	1586	1879		3465	338	3127	184	3311	3124	187
1923	1745	2042		3787	533	3254	111	3365	3179	186
1924	1818	2157		3975	752	3223	133	3356	3092	264
1925	2028	2208		4236	1187	3049	183	3232	3171	61
1926	2226	2219		4445	1462	2983	159	3142	3039	103
1927	2388	2369		4757	1803	2953	149	3102	3003	99
1928	2501	2452	14	4967	2138	2829	163	2992	2863	129
1929	2683	2511	150	5344	2494	2851	207	3058	2812	246
1930	2916	2531	168	5615	2889	2726	257	2983	2613	370
1931	3079	2776	172	6027	3290	2737	191	2928	2435	493
1932	3254	2801	174	6229	3700	2529	247	2776	2160	616
1933	3410	3105	250	6765	3863	2902	352	3254	2115	1139

Year	Revenue Account: Gross Receipts: Sale of Electricity 1000 kr.	Meterhire and Miscell. 1000 kr.	Total 1000 kr.	Gross Receipts in % of Capital Investment %	Expenses: Operation 1000 kr.	Interest Exchange 1000 kr.	Total 1000 kr.	Surplus 1000 kr.
1921								
1922	482	94	576	16·6	116	173	289	287
1923	540	68	608	16·1	160	244	404	204
1924	644	65	709	17·8	166	241	407	302
1925	711	60	771	18·2	188	251	439	332
1926	745	61	806	18·1	253	222	475	331
1927	750	68	818	17·2	244	220	464	354
1928	791	80	871	17·6	297	198	495	376
1929	847	88	935	17·5	261	201	462	473
1930	940	83	1023	18·2	305	200	505	518
1931	985	73	1058	17·5	328	206	534	524
1932	990	83	1073	17·3	362	178	540	533
1933	1065	103	1168	17·3	358	124	482	686

TABLE II. REYKJAVIK MUNICIPAL HYDRO-ELECTRIC LIGHT & POWER WORKS TECHNICAL DATA

Year	Number of Population	Power Plant: Installed Generating Power kW.	Max. Output[1] kW.	Annual Production[1] million kWh.	Period of Use hours	Network: 3 × 6000 V Transmission and Distribution: Length km	Copper-weight 1000 kg	Distrib. Transformers: Number of Transformer Stations	Transformer Capacity kVA.	3 × 220 V Distribution: Length km	Copper-weight 1000 kg
1921	18218	1032				13·4	10·0	12	1290		
1922	19194	„	920	3·04	3300			„	„	21·2	17·3
1923	20148	1720	1080	4·93	4570			13	1440		
1924	20657	„	1295	6·16	4760			15	1740		
1925	22022	„	1330	6·37	4780			„	„		
1926	23190	„	1310	5·85	4470			„	„		
1927	24304	„	1280	5·04	3930	16·7	13·4	18	2090	36·8	28·4
1928	25217	„	1365	4·92	3600	16·6	13·0	19	2180	37·9	31·5
1929	26428	„	1440	5·05	3510	17·0	12·9	21	2380	47·3	36·3
1930	28182	„	1620	5·57	3440	21·2	20·8	24	2730	49·4	40·2
1931	29477	„	1620	5·44	3360	22·7	23·7	25	2940	51·0	41·9
1932	30565	„	1840	5·88	3190	23·9	25·1	27	3140	56·9	46·8
1933	31500	3160	1995	6·59	3300	25·4	27·4	„	3440	61·6	50·5

Year	House Service Connections Number	Metering Apparatuses Number	Connected Load: Lighting including Street Lighting kW.	Motors 3-phase kW.	Heating and miscell. Purposes kW.	Total kW.	Notes on main Extensions
1921	773						First development.
1922	1116	2494	1019	250	ca. 1500	ca. 2770	
1923	1424	3418	1222	403	- 1700	- 3320	A new set of machines installed.
1924	1556	3926	1353	541	- 2000	- 3890	
1925	1736	4599	1487	677	- 2300	- 4460	
1926	1895	5488	1731	830	- 2500	- 5060	Reservoir at Ellidavatn.
1927	2058	6439	1919	1090	- 2600	- 5600	
1928	2207	7298	2135	1267	- 2700	- 6100	
1929	2412	8236	2419	1478	- 2900	6800	Árbærdam completed.
1930	2587	9303	2776	1895	- 3100	- 7770	A new hightension transmission line.
1931	2736	10261	2972	2381	3300	8653	A new conduit pipe.
1932	2885	11271	3192	2503	3320	9016	
1933	3050	12041	3392	2914	3510	9816	A new set of machines installed.

[1] The decline in output and production 1926—1928 is due to the fact that the use of electricity for cooking and heating purposes has decreased owing to changes in the tariff ratings.

In table III, below will be seen the maximum output and the annual production of the power station, as well as the gross receipts of the Electricity Works, all set out per head of the population.

TABLE III.

Year	Number of Population	Connected Load		Maximum Output		Annual Production		Gross Receipts	
		Total kW.	Per Head Watt	kW.	Per Head Watt	Million kWh.	Per Head kWh.	Total 1000 kr.	Per Head kr.
1921	18218								
1922	19194	ca. 2770	ca. 144	920	48	3·04	158	576	30·00
1923	20148	- 3320	- 164	1080	54	4·93	245	608	30·30
1924	20657	- 3890	- 188	1295	63	6·16	298	709	34·50
1925	22022	- 4460	- 202	1330	60	6·37	290	771	35·00
1926	23190	- 5060	- 218	1310	57	5·85	254	806	35·00
1927	24304	- 5600	- 231	1280	53	5·04	207	818	33·70
1928	25217	- 6100	- 242	1365	54	4·92	195	871	34·70
1929	26428	- 6800	- 258	1440	55	5·05	191	935	35·40
1930	28182	- 7770	- 275	1620	57	5·57	197	1023	36·40
1931	29477	8653	293	1620	55	5·44	185	1058	35·90
1932	30565	9016	295	1840	60	5·88	192	1073	35·00
1933	31500	9816	311	1995	63	6·59	208	1168	37·10

Compairing now the above data with the development of the electricity works of Norwegian towns where the conditions are in many respects similar to the conditions in Reykjavik, we in the above mentioned report of the 17th of January 1934 arrived at the conclusion, that in Reykjavik there is a demand for substantially more electric energy, providing always that it can be supplied at lower rates, which would render a more general utilization of the energy for cooking and possibly also for heating purposes, economic feasible. Whether it can be assumed, though, that the electric power in Reykjavik will be utilized for heating to the same extent as in Norwegian towns depends also upon whether the proposed utilization for heating purposes of water from the hot springs will materialize.

The result of our investigation of this question is that the consumption of electric energy in Reykjavik already at a number of population of 30 000 must be estimated to rise to such an extent that the power stations would have to produce as follows:

About 50 mill. kWh. with a maximum output of well above 9 000 kW. providing that delivery for heating purposes could be expected, and

about 18 mill. kWh. with a maximum output of 4 500 kW. in the event of the project for utilization of the hot springs being carried out.

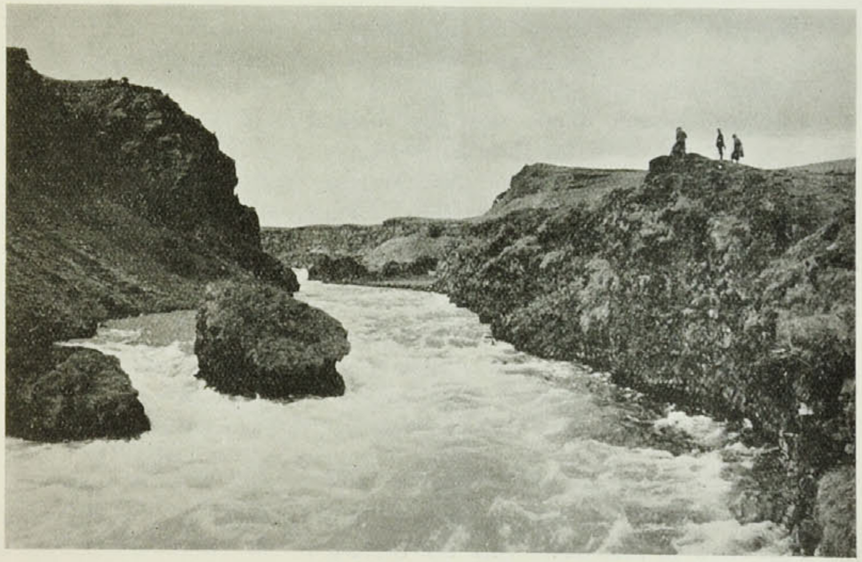
Seeing that the number of population is at present already more than 30,000 and must be assumed to show a further rise in the coming years, a corresponding increase in the above figures must be reckoned with.

The existing power station in Ellidaár has, as will be seen in table II, a generator installation of 3160 kW. incl. the stand-by unit. The possible maximum output is 2240 kW. The maximum annual production of this plant has been about 6·6 mill. kWh with a maximum output of 1995 kW. (in 1933). The existing water reservoir at the lake of Ellida will, however, according to our investigations, not be of sufficient capacity for this production in years of water scarcety.

Plans for a further water regulation, whereby the efficient flow will be increased so as to give an annual production of about 7·3 mill. kWh have been prepared. By the construction of a new power plant at the upper falls of the Ellidaár the total annual production from the Ellidaár could be increased to say 10·6 to 11·5 mill. kWh.

Thus the water power of the Ellidaár will not be sufficient for the estimated consumption even if hot water-supply from the springs was to be realized.

In the river Sog, about 45 km from Reykjavik, there are—as will be seen in the following—several larger water falls where plants can be developed of capacities sufficient for the present estimated consumption and suitable for extensions at low cost as the demand arises.



UPPER FALLS IN SOG

VIEW FROM THINGVALLAVATN

2. The Water Power of the Sog.

The river Sog flows from the lake Thingvallavatn, which has an area of 83 km². It is passing through two smaller lakes, the Ulfljotsvatn and the Alftavatn before joining the river Hvitå.

Discharge records of the river have been taken since 1919. As will be seen in fig. 1 the flow of the river is remarkably even. Thus the highest mean monthly discharge is 99·4 m³ per sec. (February 1922) whilst the lowest is 78·4 m³ per sec. (Sept. 1924). The highest discharge which altogether has been recorded during these years is 109 m³ per sec. and the lowest 74 m³ per sec. The reason for this unusual even flow is firstly that the lake Thingvallavatn is acting as an accumulating reservoir and secondly that the porous, volcanic rock in the catching area of the lake will have a regulating influence, at first sucking up the moisture and later gradually discharging it. Hence the tributaries of the Thingvallavatn are mostly sub-structural and the total measurable tributaries are quite unimportant compaired with the discharge through the Sog.

THE REGULATION OF THE FLOW

The large lake Thingvallavatn makes a fine reservoir for a regulation of the water flow in accordance with the demand of the various seasons. By a draw-down of the level of about 2·5 metres the flow can be regulated accord-

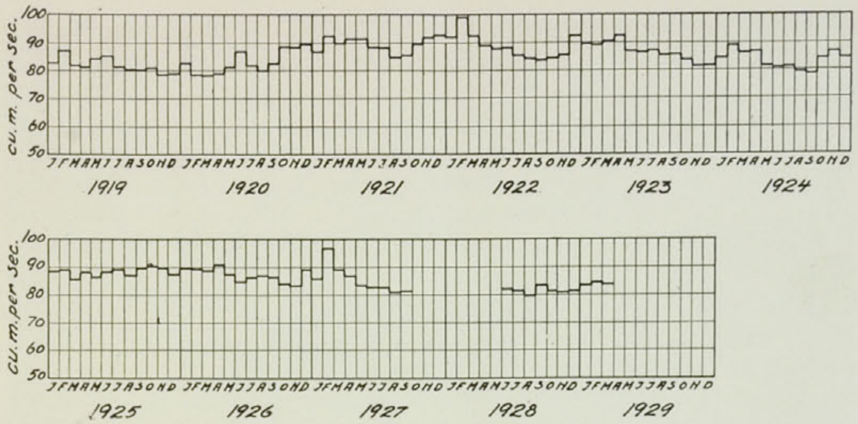


Fig. 1. Monthly mean discharge records.

ing to the load in such a way that all the water of a dry year can be utilized. In this calculation we have assumed that the annual use of the power will at full development of the Sog amount to 5650 hrs. The maximum turbine discharge will then be 124 m³ per sec.

THE WATER FALLS OF THE SOG

The river Sog in its flow from the lake Thingvallavatn to the lake Alftavatn has a total head of 83 metres. This fall is from natures hand divided into two divisions, namely:

1. The Upper Falls between Thingvallavatn and Ulfljotsvatn with a head of about 23 metres, and
2. The Lower Falls below Ulfljotsvatn of about 60 metres head.

The latter stretch of falls includes the three concentrated waterfalls of Ljosafoss, Irufoss and Kistufoss as well as a number of rapids above, between and below these falls.

After a general survey of the various ways in which these falls could be developed we came to the conclusion that the falls should be utilized in three divisions, namely:

1. Upper Falls, gross head about 23 metres.
2. Ljosafoss „ „ „ 17 „
3. Irufoss-Kistufoss „ „ 38 „

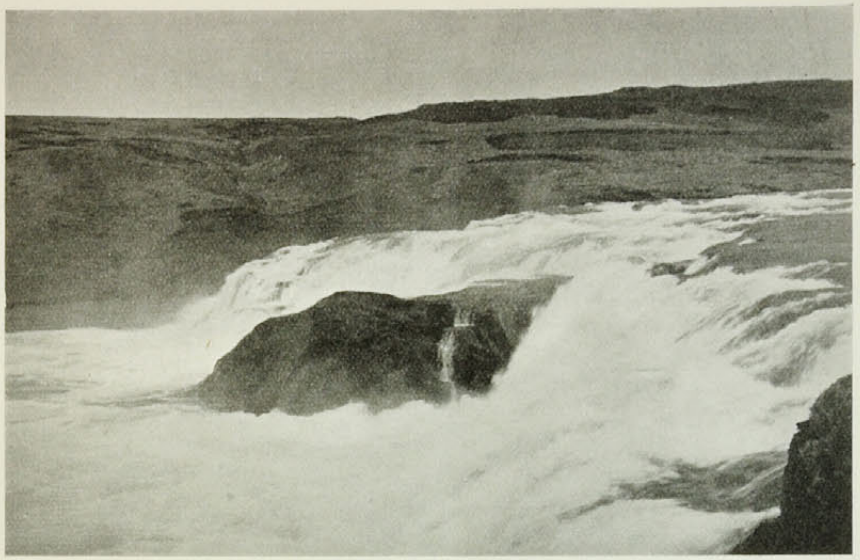
The rapids below Kistefoss—of about 5 metres head—can not be developed to any advantage.

In the attached drawing Pl. I "Situation Plan of Sog River Developments" the above projects are indicated. The drawing also shows a longitudinal section of the river. Head and output of the plants at maximum development is shown in the following table IV.

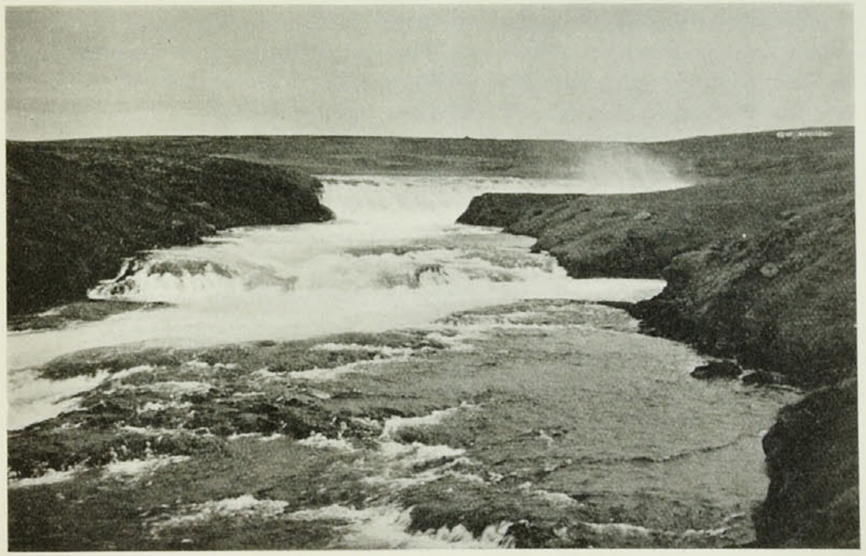
TABLE IV.

1. UPPER FALLS:	Turbine discharge in m³ per sec.	120
	Gross head, maximum, in metres	23·4
	—„— minimum —„—	21·1
	—„— mean —„—	22·2
	Loss of head, maximum —„—	1·1
	Net head (mean) —„—	21·1
	Output in turbine HP. (metric)	*30,000*
2. LJOSAFOSS:	Turbine discharge in m³ per sec.	124
	Gross head, maximum, in metres	17·6
	—„— minimum —„—	16·8
	—„— mean —„—	17·2
	Loss of head, maximum —„—	0·25
	Net head (mean) —„—	16·95
	Output in turbine HP. (metric)	*25,000*
3. IRUFOSS—KISTUFOSS:	Turbine discharge in m³ per sec.	124
	Gross head, maximum, in metres	38·4
	—„— minimum —„—	37·4
	—„— mean —„—	37·9
	Loss of head, maximum —„—	1·9
	Net head (mean) —„—	36·0
	Output in turbine HP. (metric)	*53,000*

The previously mentioned general investigations have given as result that, for the consumption of electric power with which we here are concerned, it will be the most desireable for technical as well as for economical reasons to decide on Ljosafoss.



IRUFOSS



KISTUFOSS

3. Ljosafoss Power Development.

THE WATER FLOW

The regulation of the lake Thingvallavatn must be carried out in connection with the construction of the Upper Falls Development. Until such time as this can be undertaken, we therefore calculate with the unregulated water flow, this being assumed to be 78 m^3 per sec., as the very few days during which the records are lower, can be dispensed with. During the 10 years of the river flow recording there are only 30—40 days on which the flow has been lower than 78 and the very lowest flow recorded is—as previously stated—74 m^3 per sec.

We have assumed that the load factor for the peak loaded 24 hours—when the Ljosafoss Plant is on maximum load—will be 0·83, and we thereby arrive at a maximum turbine water discharge of 94 m^3 per sec. The maximum output, therefore, of the plant,—before the regulation of the lake Thingvallavatn has been carried out—will be 18,800 turbine H. P.

GENERAL ARRANGEMENT OF THE PLANT

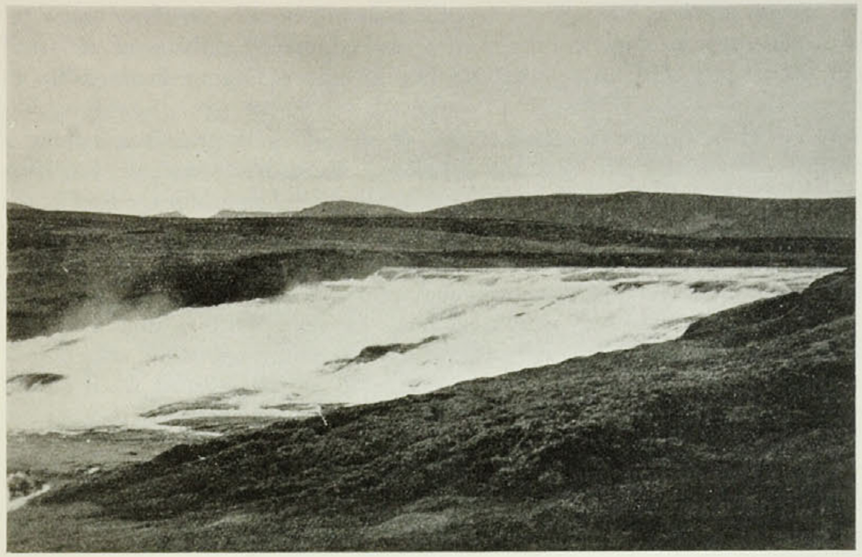
Near the outlet of the lake Ulfljotsvatn the river forms some rapids of about 4 metres head. About 1 km further down the river are located the falls of Ljosafoss with a concentrated head of about 13 metres. Our scheme of development, now, is to construct a dam across the river just above the falls, thereby raising the head water level to El. 81·0, *i. e.* 0·8 metres above the present level of the lake Ulfljotsvatn. Thus a reservoir is created, sufficient for the flow regulation corresponding to the variation of the load during 24 hours.

The Reykjavik Electricity Works have laid out a map of the development sites and surveyed a number of cross sections of the foundations and also made some ground drillings. These field works and surveys are forming the basis of our present plans.

All structures of the power plant will be placed on rock foundations. The rock in the river bed is composed of a very close breccia with a fairly even, horizontal surface. At both sides of the river there are comparatively thin layers of a basaltic rock called dolerite. This rock is rather cracked and one has to assume that certain measures will prove necessary on that account at the dam abutments as well as at the intake. As we have not as yet undertaken exact geological surveys, the extent of the various rock specimens has not yet been fixed.

BRIEF DESCRIPTION OF THE VARIOUS ITEMS OF THE PLANT

The dam is, as will be seen in the attached drawing Pl. II & III proposed to be constructed as a straight buttress dam of reinforced concrete. This design has



LJOSAFOSS

been adopted, firstly on account of cheapness, and secondly on account of it being the safest design under the conditions prevailing at the site.

It is proposed that waterproof concrete without any special tightening layer should be used.

The dam is provided with 3 bottom outlets fitted with gates, and one spillway which we propose fitted with roller gate. At the down-stream side of the spillway an apron is to be arranged, to prevent erosion of the river bed.

The dam has been furnished with a back wall, protecting the back of the concrete wall against frost.

Intake. The left hand side of the dam has been carried forward towards the intake at a curve, thus forming an intake canal. At the intake space has been reserved for altogether 5 pipeline intakes, fitted with trash racks and hydraulically (oil pressure) operated gates, which will automatically close in the event of a failure in the power station.

The 3 intakes which are not wanted in the first stage of construction are to be closed by means of simple gates.

Each turbine unit is having its separate pipe line of an internal diameter of 3·5 metres. It is proposed that the pipe lines should be built of wood staves with straps of rustresisting steel.

Power station. The general arrangement will be seen on Pl. IV and V. It is proposed to use single runner, vertical shafted, Francis turbines of a normal output of 5000 HP at 150 R.P.M., but capable of taking overloads up to 6250 HP.

To each turbine is coupled a 3-phase, 50 cycle generator, having a normal output of 4400 kVA and capable of being overloaded to 5500 kVA in the winter, when low air temperatures are prevailing whilst the load of the Electricity Works is at its highest.

In the first stage of construction it is proposed to install 2 units and, with one of these as a stand-by, the maximum output of the plant will be 4 350 kW.

The transformer- and switchgear house has been placed in direct extension of the power house. Here will be installed 2 transformers, of the same output as the generators, to transform the voltage to 66 kV., further all apparatus necessary for the generators and transformers as well as for station lighting etc.

The transmission line to Reykjavik is to be built for a voltage of 66 kV. with 3 conductors each of 50 mm² and suspended by suspension type insulators on poles of re-inforced concrete or possibly of impregnated timber.

The length of the 66 kV. transmission line will be about 45 km.

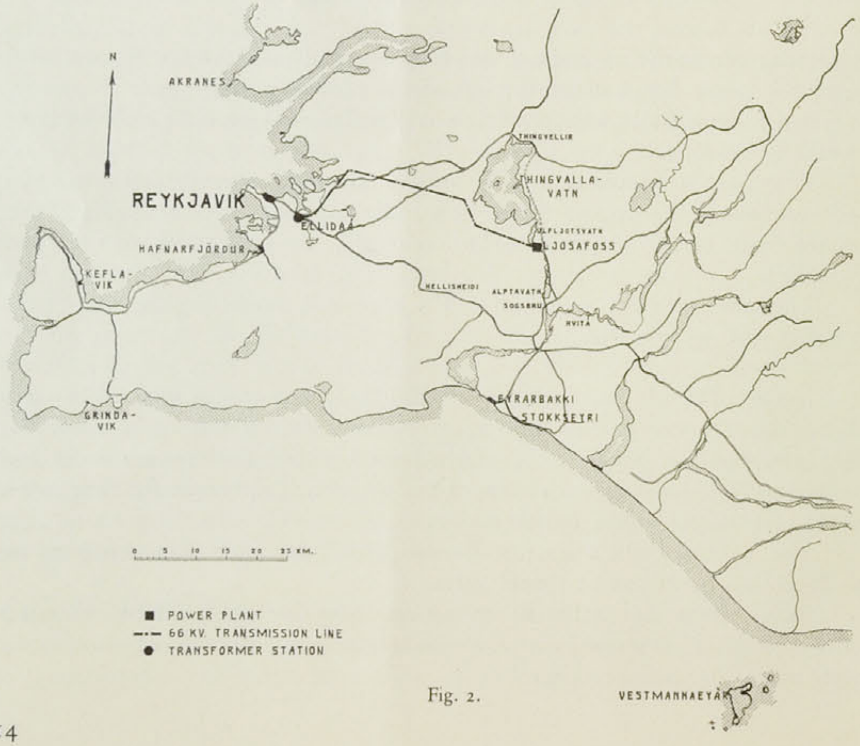


Fig. 2.

The transformer station is supposed to be built at Ellidaá, near the existing power station of the Reykjavik Electricity Works.

The installation will consist of 2 transformers with the necessary apparatus for transforming the voltage to 6 kV. for the Reykjavik supply, possibly also — by means of a 3rd winding — to 20 kV. for transmission to Hafnarfjördur or other towns and districts outside Reykjavik.

These transformers are supposed to be built for the same output as the units of the power station.

CONDITIONS FOR TRANSPORT

From Reykjavik a highroad is leading over Hellisheidi to Sogsbru, a bridge across Sog a little distance below the lake Altftavatn, and another road is leading to Thingvellir, at the north end of Thingvallavatn.

A new road is now under construction on the east side of the river Sog from Sogsbru to Thingvellir. When this is completed there will be two access-roads to the plant. The southerly one is the shortest but is not as yet suitable for the heaviest transports, as a certain part of the road is very curved. Also, the Sog bridge will not stand heavy loads.

Most likely, however, the bridge will have been reconstructed and the road repaired during the summer this year. In the event of this work not being completed in time, the heaviest loads will have to be transported over Thingvellir. On that road as well, some smaller bridges have to be temporarily reinforced, but this is comparatively minor work.

TEMPORARY POWER FOR THE CONSTRUCTION

In order to supply the necessary power for the constuction work, Reykjavik Electricity Works are considering the building of the transmission line in advance, so that electric power can be delivered from the existing plant in Ellidaár. In case of this plan not being carried out, the necessary power will have to be generated by means of one or more oil-electric units.

THE BUILDING MATERIALS

The sand for the concrete is supposed to be supplied from the sand layers at Ingolfsfjell, about 14 km from the plant. Natural layers of sand of any magnitude have not—as far as is known—been found anywhere nearer the construction site. The coarser rock aggregates for the concrete are supposed to be produced of dolerite, near the dam site.

The sand from Ingolfsfjell has been examined by the Reykjavik Electricity Works and found to be very pure. Complete tests of its suitability as a concrete material, however, have not as yet been carried out.

COFFERDAMS

For cofferdams we have supposed the use of timber dams of simple design as there is surface rock everywhere at the site.

TIME OF CONSTRUCTION

As the flow of the river is so even, the construction plan can be worked out regardless of possible floods. On the other side, one has to observe that the weather conditions in the winter very often will be a hindrance to certain work. More especially this applies to the preparatory work, so that the construction work should be started in the summer.

We are of the opinion that a construction time of about 2½ years—*i. e.* 3 summers and 2 winters—has to be allowed for.

4. Cost Estimate.

The construction cost for Ljosafoss Power Plant with transmission line and transformer station we have estimated as follows:

1. *Road repairs, bridges and baracks*			kr. 207,000
2. *Dam with canal and intake*			
a) *Cofferdams, pumping*		kr. 150,000	
b) *Excavation and blasting for dam foundations*			
Earth excavation 3300 m³	kr. 13,200		
Blasting of cutoff channel 350 metres	„ 28,000		
Rock cleaning	„ 31,800	„ 73,000	
c) *Excavation and blasting for canal and intake*			
Earth excavation 7500 m³	kr. 30,000		
Rock excavation 4500 m³	„ 67,500		
Duct for drain outlet	„ 3,500		
Rock cleaning	„ 27,000	„ 128,000	
d) *Concrete and reinforced concrete*			
Concrete in the reinforced concrete structures 1700 m³	kr. 110,000		
Concrete in the bulky structures 3700 m³	„ 222,000		
Reinforcing iron 143 tons	„ 60,000		
Scaffolding and forms 11,600 m²	„ 87,000	„ 479,000	
		kr. 830,000	kr. 207,000

		kr. 830,000	kr. 207,000
e) *Miscellaneous work.*			
Gatehouses	kr. 22,000		
Treatment of concrete surfaces	„ 10,000		
Additional for expansion joints	„ 10,000		
Additional for tightening of defect rock where necessary	„ 50,000	„ 92,000	
f) *Miscell. steel structures for dam and intake.*			
Bottom gates with lifting gear and guiding frames	kr. 50,000		
Intake gates with hydraulic operating gear	„ 58,000		
Pipe cones 28 tons	„ 21,000		
Roller gate 20 × 1·7 metres with gear	„ 35,000		
Trash racks	„ 17,000		
Railings, miscell. minor steel structures	„ 24,000	„ 205,000	„ 1,127,000
3. *Pipe line.*			
Excavation and blasting.			
Earth excavation 4000 m³	kr. 16,000		
Blasting 1500 m³	„ 22,500		
Cleaning up before concreting, finish levelling	„ 10,500	kr. 49,000	
Pipe line foundation blocks incl. forms		„ 20,000	
Wood stave pipe line 3·50 metres dia. 122 metres		„ 61,000	„ 130,000
4. *Power station with transformer house.*			
a) *Coffer dams and pumping*		kr. 60,000	
b) *Excavation and blasting*			
Earth excavation 3000 m³	kr. 12,000		
Rock excavation 2500 m³	„ 37,500		
Rock excavation for tailrace 2850 m³	„ 57,000		
Cleaning up before concreting	„ 13,500	„ 120,000	
c) *Concrete and reinforced concrete &c.*			
Concrete for bulky structures 1200 m³	kr. 66,000		
Concrete for reinforced concrete structures 1000 m³	„ 60,000		
Reinforcing irons 110 tons	„ 46,200		
Forms 12000 m²	„ 96,000		
	kr. 268,200	kr. 180,000	kr. 1,464,000

	kr. 268,200	kr. 180,000	kr. 1,464,000
Indoor plastering and white washing 4500 m^2	„ 22,500		
Front surface treatment	„ 12,000		
Tiles and floor finishing	„ 9,000		
Roof covering 725 m^2	„ 10,900		
Temporary walls and floor for unit no. 3	„ 8,000		
Staircase railings, rails in transformer house, miscell. minor steel structures	„ 10,000		
Doors, windows and sanitary installation etc.	„ 44,400	„ 385,000	
d) *Miscell. steel structures for the power station*			
Draught tube plate liner 24 tons	kr. 18,000		
Stop logs frame 3·3 tons	„ 2,000		
Generator room crane beams . .	„ 10,000	„ 30,000	„ 595,000
5. *Machines.*			
2 turbines of 5000 to 6250 HP. incl. freight to Reykjavik, custom duties and erection . . .		kr. 290,000	
2 generators of 4400 to 5500 kVA. delivered as above		„ 360,000	
2 transformers 66 kV. delivered as above . . .		„ 90,000	
Switchgear —„—		„ 210,000	
Transportation from Reykjavik and rough labour		„ 100,000	kr. 1,050,000
6. *Travelling crane and miscell. tools*			„ 51,000
7. *Dwelling houses at Sog*			„ 80,000
8. *Transmission line* for 66 kV. from Ljosafoss to transformer station at Reykjavik, a distance of about 45 km.			„ 380,000
9. *Transformer station* at Reykjavik comprising 2 transformers for 4400 to 5500 kVA. as well as apparatus for transformers and power distribution			„ 300,000
10. *Construction plant*			„ 200,000
11. *Management* (about 6 %), *unforeseen* (about 12 %), *interest* in the construction period (about 10 %) total 28 % . . .			„ 1,150,000
Total cost of development: Icelandic kronur			5,270,000

To the above estimate is to be remarked:

The unit cost prices which we have used have been fixed as a result of studies of the conditions at site and are based on the present wages.

We have assumed that all plant and structures should be of a plain design without undue fittings. We have, however, included everything necessary for a safe and technically satisfactory plant.

5. Estimated operating accounts.

In tables II and III it will be seen that the number of population of Reykjavik has been steadily increasing.

1922—1933	from 19,200 to 31,500—	in the mean	1120	annually
1928—1933	„ 25,200 „ 31,500—	—„—	1260	„
1930—1933	„ 28,200 „ 31,500—	—„—	1100	„

There is every indication that this development will continue and we are of the opinion that a moderate estimate would be the placing of the towns increase in population somewhere near 1000 annually. Thus the number of population in 1937—which may be the first year of operation of the new plant, providing that the construction work is started this summer—would have risen to about 35000.

The data of the tables II and III also show how the electricity consumption of Reykjavik has increased, namely

for the maximum output in

1922—1933	from 920 to 1995 kW.,	in the mean	98 kW.	annually
1928—1933	„ 1365 „ 1995 „	—„—	126 „	„
1930—1933	„ 1620 „ 1995 „	—„—	125 „	„

for the annual production in

1922—1933	from 3·04 to 6·59 mill. kWh.,	in the mean	0·323 mill. kWh.	annually
1928—1933	„ 4·92 „ 6·59 „ „	—„—	0·334	—„—
1930—1933	„ 5·57 „ 6·59 „ „	—„—	0·340	—„—

It has to be assumed that the rise in the consumption of the coming years will continue at about the same rate as in recent years, viz. the maximum output with 125 kW. annually and the annual production with 0·34 mill. kWh. annually.

Hence in the year of 1937 one will have arrived at a maximum load of about 2500 kW. and an annual production of 6 mill. kWh.

As will be seen of the above introductory remarks this will be more than the existing plant in Ellidaár—in years of water scarcety—can produce. Should the coming years be scarce of water it therefore may appear necessary to undertake some restriction of the supply for short periods.

Such occasional restriction will to some degree reduce the income for the year in question but will, howewer, not have any influence on the development of the demand for electric power, so that the above mentioned maximum load of about 2500 kW. and annual production of about 8 mill. kWh. will have been reached when Ljosafoss Power station is being put into operation in 1937.

The receipts of the sale of electricity have—as will be seen in table I—increased as follows

1922—1933 from kr. 482,000 to 1,065,000,	in the mean	53,000	annually
1928—1933 „ „ 791,000 „ 1,065,000,	—„—	54,800	„
1930—1933 „ „ 940,000 „ 1,065,000,	—„—	41,700	„

This income must, for the above mentioned reasons, also be supposed to increase at about the same rate as in recent years, and we are of the opinion that an annual increase of kr. 40,000 can be reckoned with.

Thus in the year of 1937 the annual income of the sale of electricity will have reached kr. 1,225,000. The remaining income of the Electricity Works—meterhire and miscellaneous—has, as will be seen in table I, also been increasing, but as these accounts include some items which may vary from year to year, they should, at a cautious estimate, not be booked at more than kr. 75,000 or at about the lowest figure of the last 6 years.

The operating expenses of the Electricity Work will, with extending distribution network and increasing sale of electricity, show some increase.

For the years 1934—1937 we are of the opinion that an annual increase of kr. 22,000 must be reckoned with.

According to the above considerations we have in the following table V entered the prospective income and expenses for 1934 and the years forward to 1937, including also interest charges on the liabilities resting on the existing plant as well as repayments on same for the respective years as arranged.

TABLE V.

Gross Receipts.	Year	1934	1935	1936	1937
Sale of Electricity	in 1000 kr.	1105	1145	1185	1225
Meterhire and miscell.	„ 1000 „	75	75	75	75
Total	in 1000 kr.	1180	1220	1260	1300
Expenses.					
Operation	in 1000 kr.	381	403	425	448
Interest	„ 1000 „	123	100	85	72
Total	in 1000 kr.	504	503	510	520
Surplus	in 1000 kr.	676	717	750	780
Repayments on loan	„ 1000 „	389	266	210	200
At disposal	in 1000 kr.	287	451	540	580

The amount placed at disposal—totalling for the years 1934—1936 kr. 1,278,000—may for the greatest part be used for extension of the network in Reykjavik and will then make it capable of distributing also the quantity of power from Ljosafoss with which we have calculated in our estimates.

After these extensions it will in 1937 and following years be sufficient to set aside for further extension of the network a sum of kr. 100,000 annually, to meet the increasing demand for power.

Thus there remain kr. 480,000 of the amount which was placed at disposal from 1937. This amount may then be used for covering the expenses at the Ljosafoss Plant.

We estimate the *operating expenses* for this plant in the first years as follows:

Care and operation	kr. 40,000
Maintenance	„ 20,000
Sum	kr. 60,000

To cover interest charges and depreciation, therefore, there remain in the first year of operation at disposal kr. 420,000.

As will be noted, we have in the above estimate allowed for a continued rise in the sale of electricity at the same rate, only, as has been recorded in Reykjavik in recent years, a rise whereby in 1937 the annual production will have reached a total of about 8 mill. kWh., and a maximum load of 2500 kW.

The proposed first development of the Ljosafoss Power Plant will, however, together with the existing plant in Ellidaár, be capable of a maximum output of 6500 kW., and a production in kWh. fully sufficient to cover the demand.

Thus, when the Ljosafoss Plant has been put into operation the Works will be able to sell considerable more electric energy than allowed for in the above estimate. As will be seen from the introduction of this report, the presumption for such increase of the sale would be that the electric energy could be supplied at lower rates, thereby rendering feasible a more general utilization of the energy for cooking, and may be also for heating purposes.

Even if the projected plant for utilization for heating purposes of hot water from the springs should be carried out, we have—as stated in the introduction, when comparing the conditions in Reykjavik with those of some Norwegian towns—arrived at the conclusion that the consumption of electric energy in Reykjavik at a number of population of 30,000 must be estimated to rise to such an extent that the power stations would have to produce about 18 mill. kWh. with a maximum output of 4500 kW.

At a number of population of 35,000—this being the figure which we in the foregoing found was to be estimated with in Reykjavik in 1937—the corresponding production will be 21 mill. kWh. with a maximum output of 5250 kW.

This production would, with the tariffs at present in force at the electricity works of Norwegian towns, yield a total annual income of kr. 1,450,000.

Our investigations show that there is reason to expect that Reykjavik may obtain a higher annual income from this quantity of power. Estimating cautiously, though, we are not putting it higher in the following estimate of *expected receipts and expenses when the Ljosafoss Plant has been in operation for some years.*

For Reykjavik Electricity Works.

Total income incl. meterhire and miscell.		kr. 1,450,000
Expenses:		
Operating expenses and interest charges on previous loans of the Electricity Work	kr. 550,000	
Repayments on previous loans of the Electricity Works of which loans—after repayments as per table V — at the end of 1936 remain kr. 1,250,000. On these will in the first of the following years have to be repaid	„ 200,000	
Extensions of the network	„ 100,000	„ 850,000
At disposal for covering the expenses at the Ljosafoss Plant		kr. 600,000

For the Ljosafoss Plant.

The expenses after some years of operation we estimate as follows:

Care and operation	kr. 40,000	
Maintenance	„ 40,000	kr. 80,000
At disposal for the Reykjavik Electricity Works for covering interest charges and depreciation for the Ljosafoss Plant		kr. 520,000

The repayments on previous loans of the Electricity Works will after 5 years be reduced to annually kr. 80,000 and after further 3 years the redemption will be completed, whereby the above amount placed at disposal will increase by kr. 200,000.

With the above assumed load of 5250 kW. for Reykjavik there still remain for supply to Hafnarfjördur and other towns and districts 1250 kW.

When this supply is effected the income of the Ljosafoss Plant will increase, without appreciable increase of the operating expenses of the plant.

6. Future Extension of the Ljosafoss Plant.

When the consumption of energy rises above the combined capacities of Ellidaár and the first development of the Ljosafoss, further energy may, at very low costs, be supplied by the installation of a further unit at the Ljosafoss Plant.

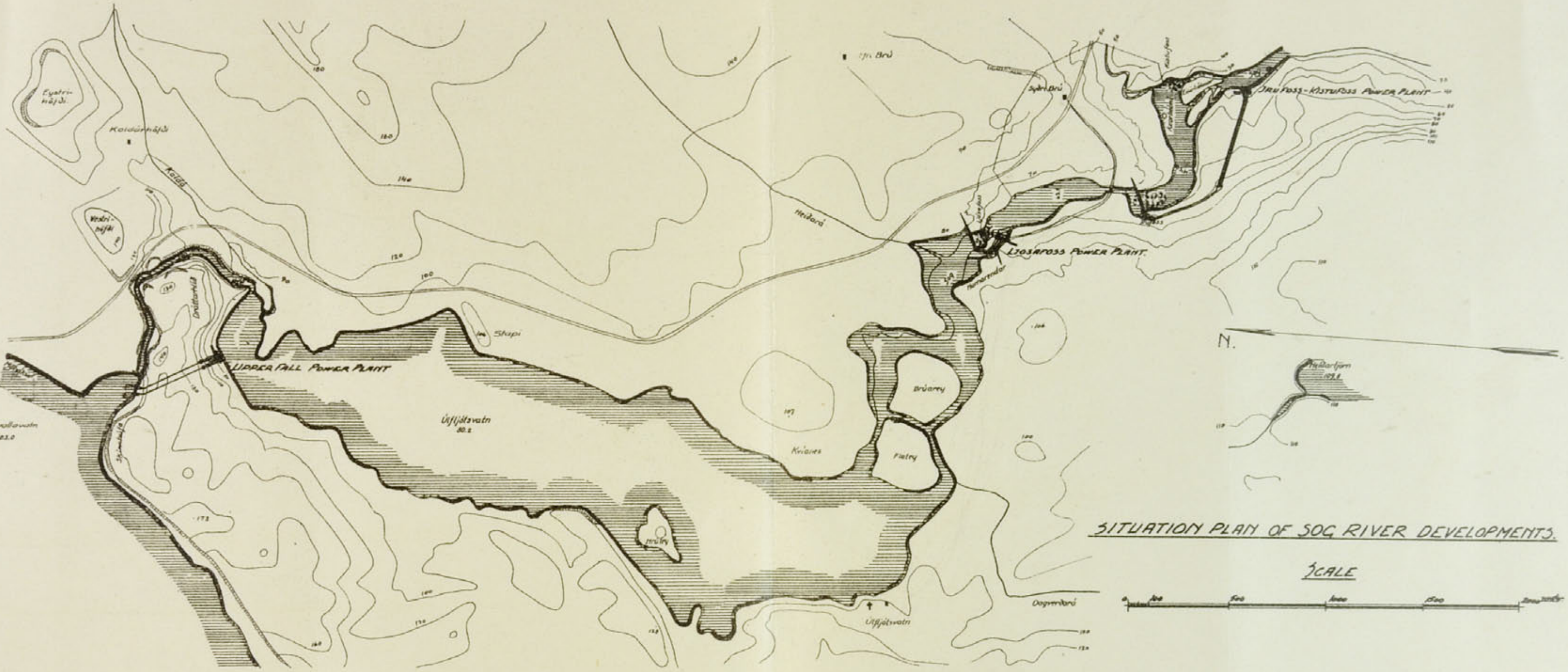
ESTIMATED COST OF INSTALLATION OF THE 3rd UNIT:

Intake with gate and trash rack	kr. 43,000
Pipe line and foundations	„ 45,000
Foundations for machinery	„ 37,000
Machines:	
1 turbine as specified on page 18	kr. 145,000
1 generator —„—	„ 180,000
1 transformer —„—	„ 45,000
Extension of the switchgear	„ 60,000
Transport and rough labour	„ 45,000
Transformer Station:	
Extension and 1 transformer etc. as specified on page 18	kr. 140,000
Management, unforeseen and interest in the construction period, total about 15 %	„ 110,000
Grand total for the extension	kr. 850,000

By this extension a further 4350 kW. can be supplied. The unit cost of this additional energy will thus be very low.

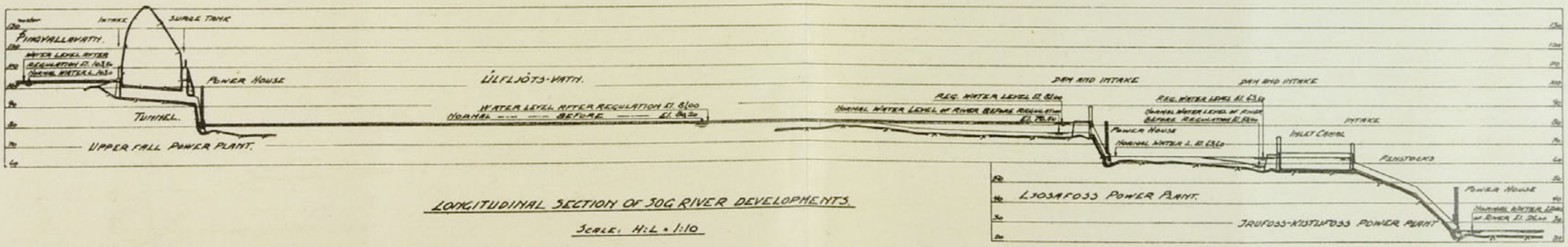
Oslo the 28th March 1934.

A. B. Berdal. *Jacob Nissen.*



SITUATION PLAN OF SOG RIVER DEVELOPMENTS.

SCALE

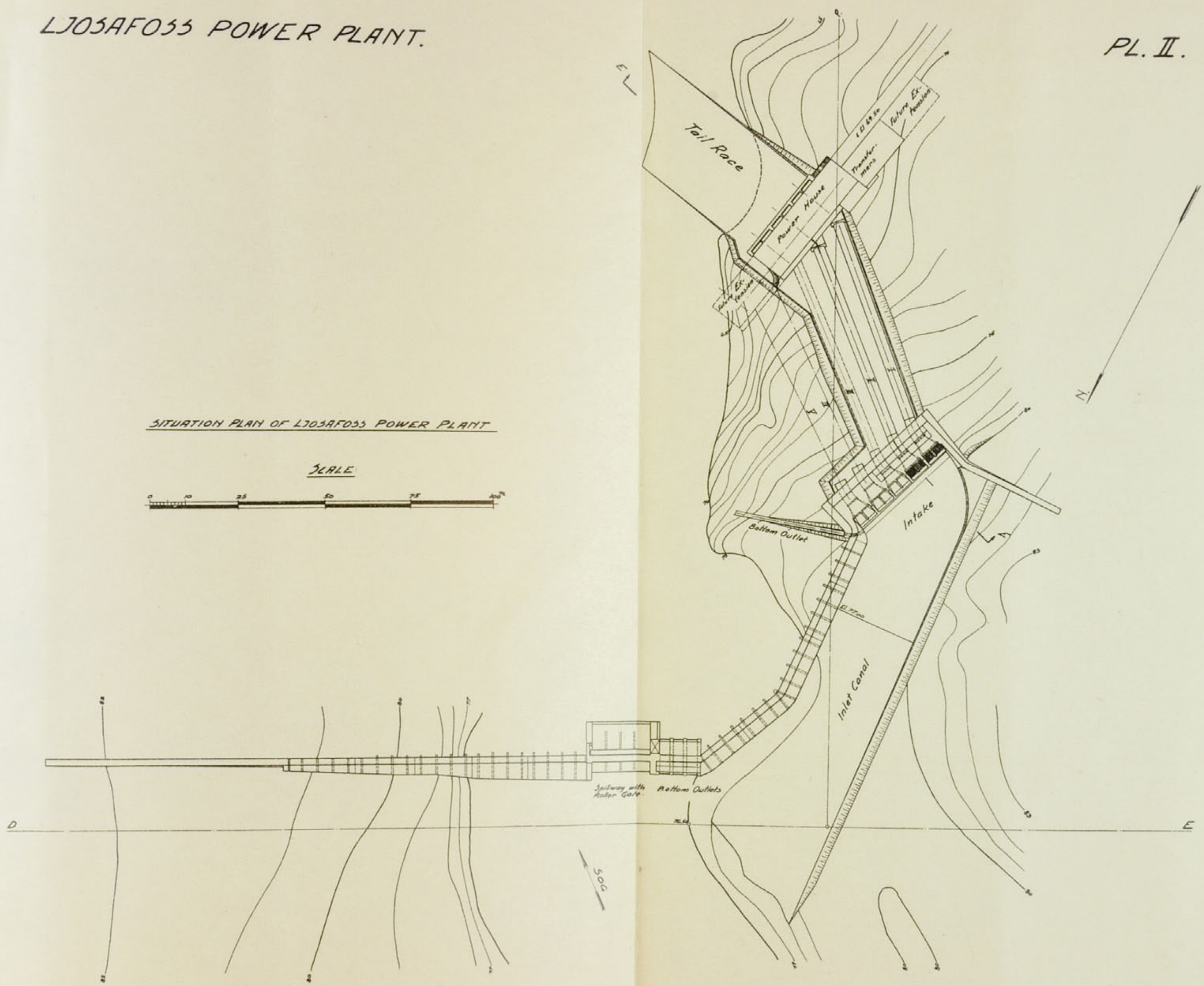


LONGITUDINAL SECTION OF SOG RIVER DEVELOPMENTS

SCALE: H:L = 1:10

LJOSAFOSS POWER PLANT.

PL. II.

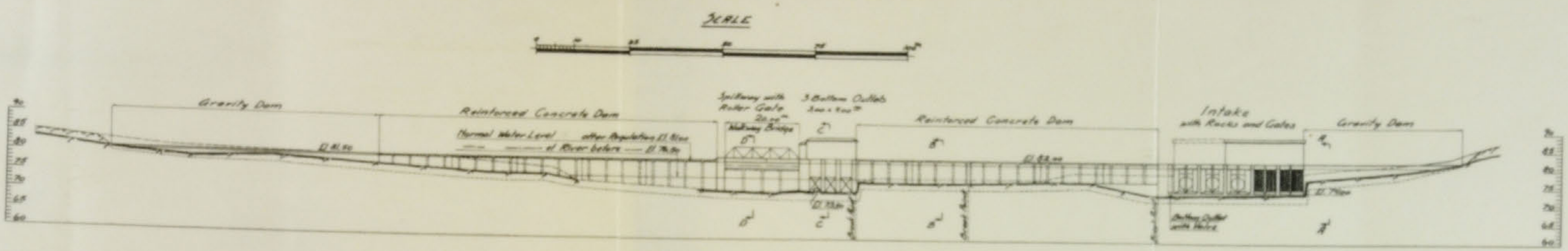


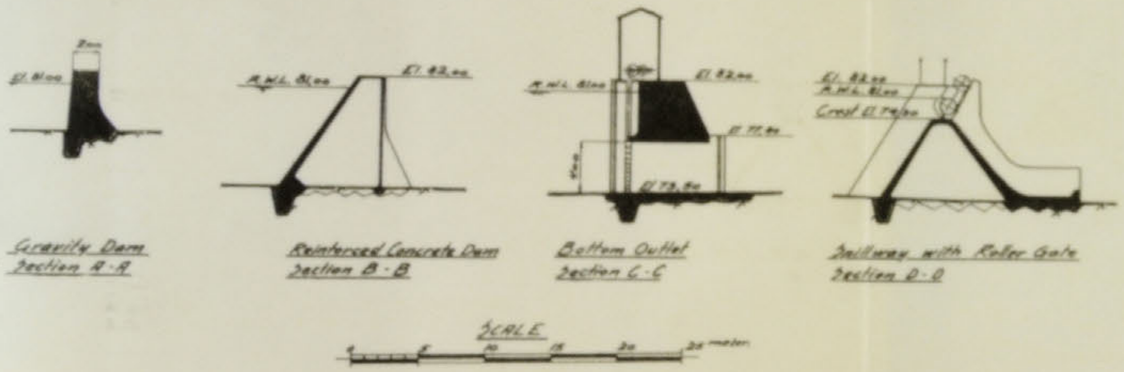
LJOSAFOSS POWER PLANT.

DAM, INTAKE AND PIPELINE

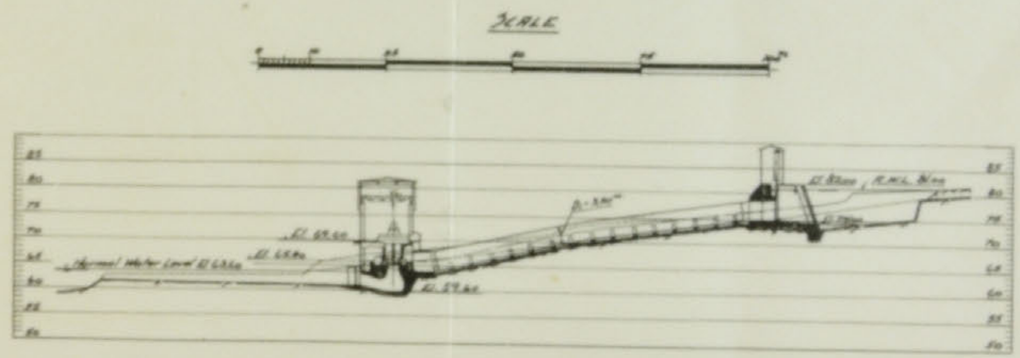
PL. III.

ELEVATION OF DAM LOOKING DOWN STREAM





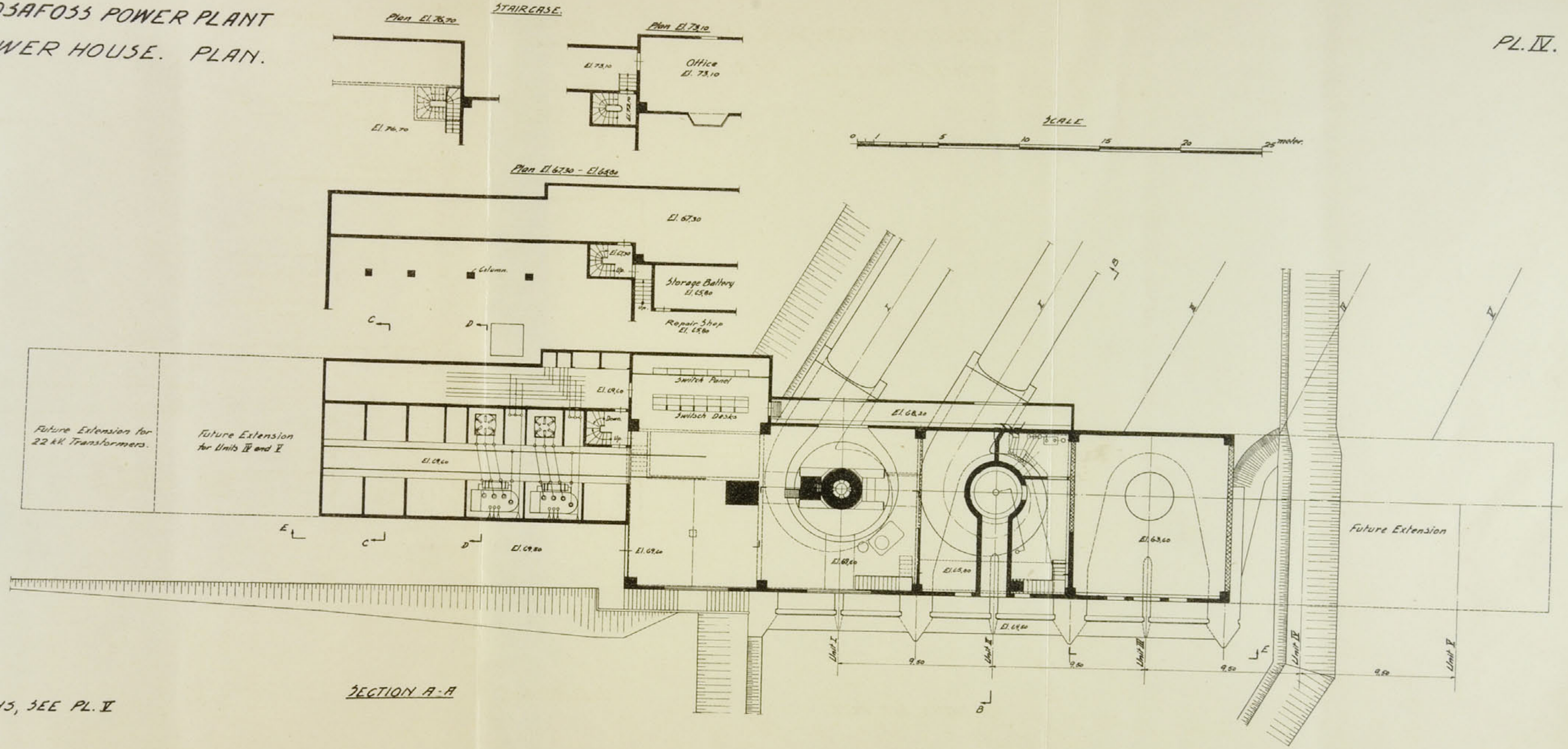
SECTION E-E. INTAKE, PIPELINE AND POWER HOUSE



SITUATION PLAN, SEE PL. II.

LJOSAFOSS POWER PLANT
POWER HOUSE. PLAN.

PL. IV.



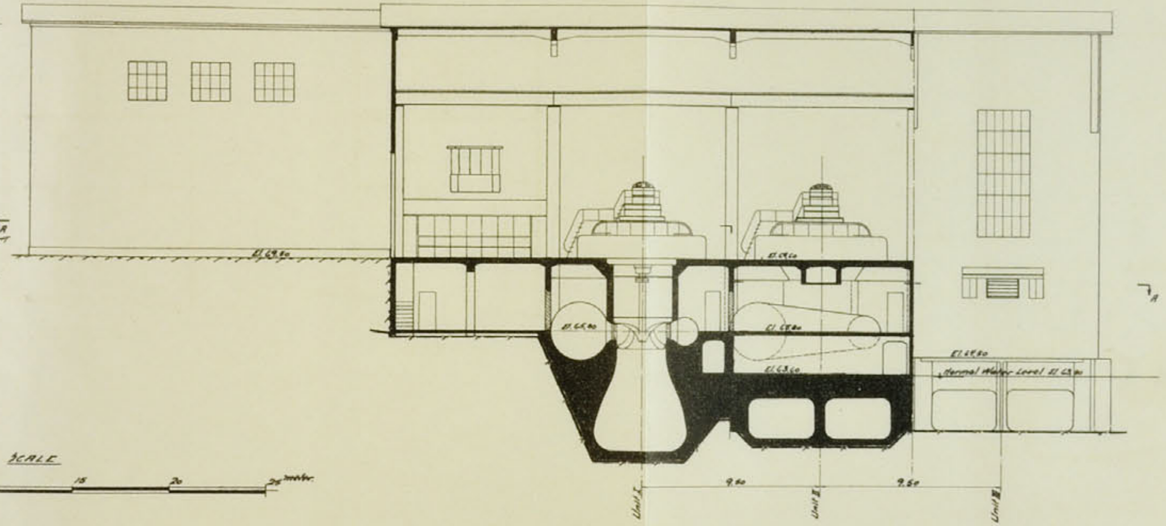
SECTIONS, SEE PL. V

LJOSAFOSS POWER PLANT

POWER HOUSE. SECTIONS.

PL. V.

SECTION E-E.



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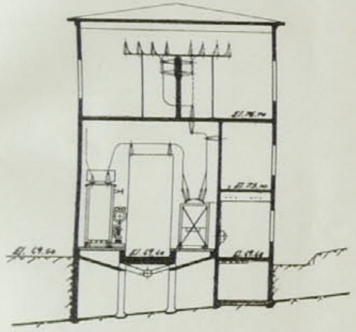
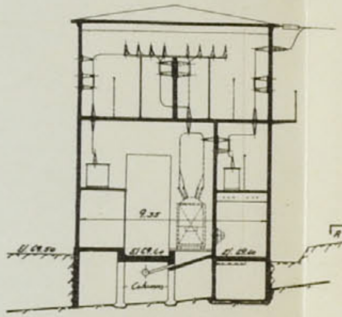
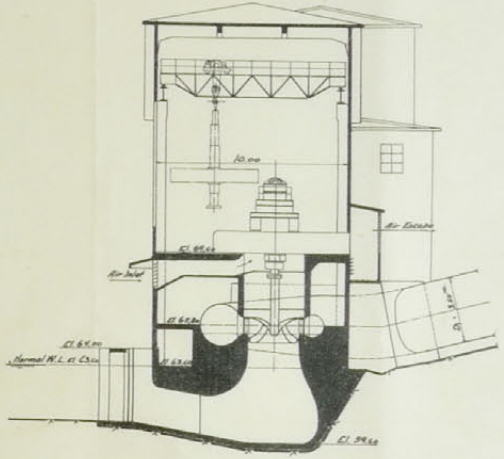


SECTION C-C.





SECTION B-B.

SCALE

SECTIONS, SEE PL. IV.

KIRSTES BOKTRYKKERI, OSLO