SR 76-5

Special Report 76-5

UTILITY DISTRIBUTION SYSTEMS IN ICELAND

H.W.C. Aamot

May 1976

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Special Report 76-5	2. GOVT ACCESSION NO.
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): UTILITY DISTRIBUTION SYSTEMS IN ICELAND	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): H.W.C. Aamot	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: DA Project 4A762719AT06, Task 03, Work Unit 003
11. CONTROLLING OFFICE NAME AND ADDRESS: Directorate of Military Construction, Office, Chief of Engineers, Washington, D.C.	12. REPORT DATE: May 1976
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

District heating	Iceland	Water
Domestic	Public utilities	Water supplies
Geothermal energy	Sewage	
Heat pipes	Sewage disposal	
Heat transmission	Transmission lines	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The study reports on new developments and special problems or solutions in water distribution systems, sewage collection systems, heat distribution and electric transmission systems. Cold weather considerations are highlighted. For water and sewage transport, the use of ductile iron, concrete and plastic materials is reported. Utility lines are generally placed individually, utilidors are too expensive for most installations except in some city center locations. Heat distribution with hot water from geothermal wells is mostly

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (cont'd).

one-way piping. After heating, the water is discharged through the sewage system. Street heating is being expanded. With electric distribution, the use of self-supporting aerial cables is becoming popular because it is very cost-effective and reliable. Within the city, all distribution is under ground. Arcing of isolators on high voltage transmission lines due to salt from the ocean atmosphere is being reduced with silicone fluids.

PREFACE

This report was prepared by Dr. Haldor W.C. Aamot, Research Mechanical Engineer, Construction Engineering Research Branch, U.S. Army Cold Regions Research and Engineering Laboratory.

The work was funded by the U.S. Army Corps of Engineers under DA Project 4A762719AT06, Task 03, Work Unit 003: Utility Distribution Systems in Cold Regions. The objective is to develop new or improved criteria for design and construction of utility transport systems in cold climates.

The warm welcome given by all the people and offices visited during the trip and their exceptional cooperation in providing available information is gratefully acknowledged.

The citation of commercial products and company names in this report is for information only and does not constitute endorsement or approval. Also, the citations are given merely as examples, not as the complete range of available choices.

INTRODUCTION

This report presents information on utility distribution systems gathered on a study trip to Iceland in January 1975. The information concerns new technology and materials and cold weather related problems and solutions. The systems involved are water and sewage transport, heat distribution and electric transmission and distribution.

The distribution systems studied are those of the capital city of Reykjavik which contains about half of Iceland's population. The city engineer and the heads of the various departments provided all the desired information and gave inspection tours of their facilities. The severity of the subarctic climate presents problems, including particularly those caused by high winds. Extreme cold is not a great problem, however, and permafrost is only found in some inland mountain areas.

The exploration and development of geothermal resources for heating is particularly noteworthy. Early wells were drilled 12 miles from the city but newer wells have been drilled right in the city.

UTILITY DISTRIBUTION SYSTEMS IN ICELAND

1. Background

Iceland is located between 63 and 67°N latitude in the North Atlantic, 155 naut. miles from Greenland and 430 naut. miles from Scotland. The size of the island is about 40,000 square miles. Figure 1.1 shows Iceland including its four glacial snowfields. The population is about 200,000; about 100,000 live in the capital Reykjavik and adjacent Kopavogur and Hafnarfjördhur. The Gulf Stream passes south of Iceland and the Greenland current passes north. Both influence Iceland's climate. In Reykjavik the mean annual temperature is 40°F, the mean January temperature is 31°F, the mean July temperature is 52°F. The Mid Atlantic Ridge crosses through the middle of Iceland and is responsible for geologic activity. In 1963 the island of Surtsey was created off the north coast as a result of volcanic eruption and in 1973 an eruption on the island of Heimaey (about 10 miles from Surtsey) covered 1/3 of the island. There are many geothermal springs or ponds and some geysers on Iceland, the best known being the Great Geysir.

Iceland's main export trade is in fish and fish products. The availability of hydroelectric power supports production and export of aluminum, fertilizer and cement. Agriculture produces sheep's wool for knit and woven export products.

All of Reykjavik is served by the city's water distribution and sewage collection system. The whole city is served by the city's district heating system, using geothermal hot water, and electricity is distributed throughout by the Municipal Electric Works. The only other utility network is the telephone system; there is no gas distribution.

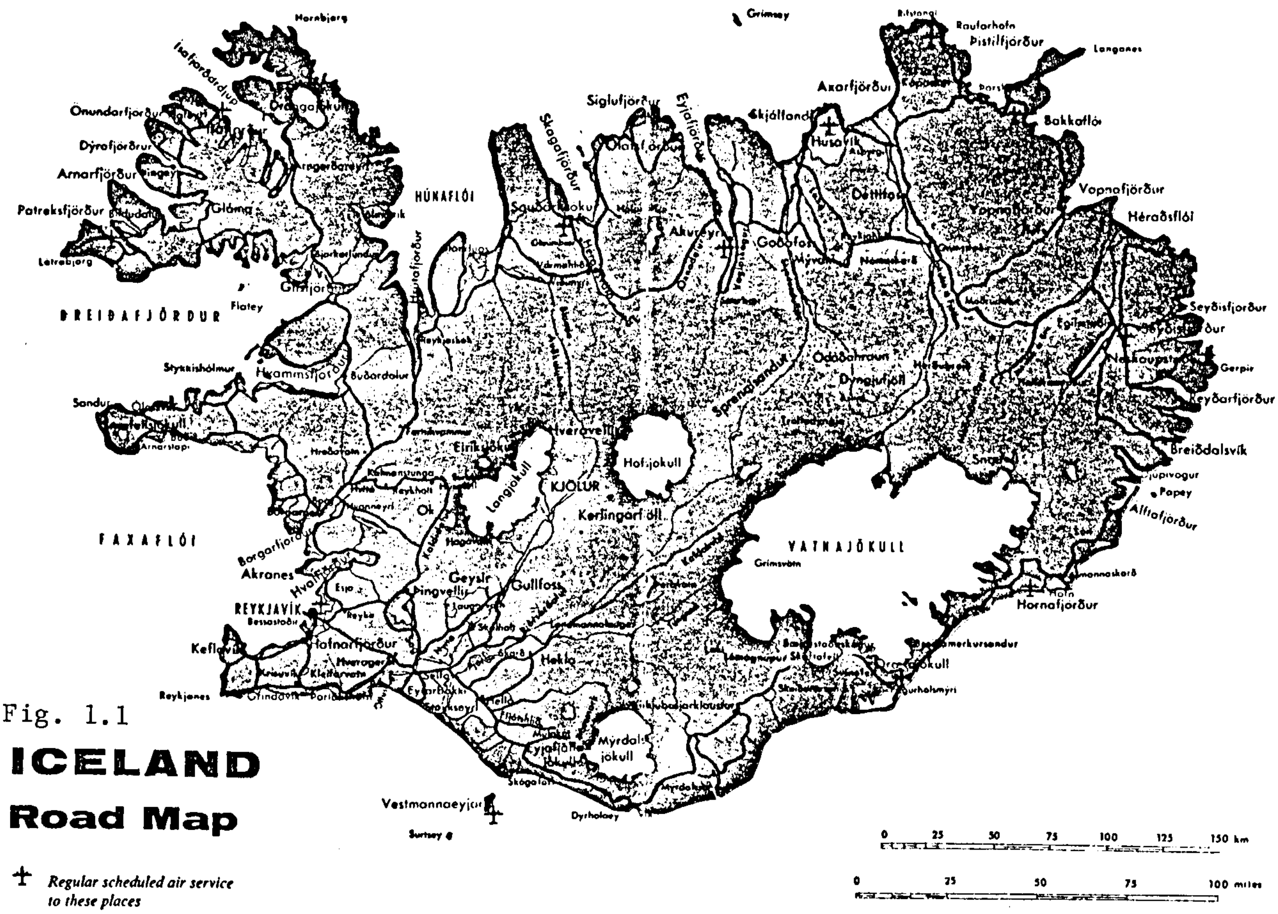


Fig. 1.1

ICELAND
Road Map

2. Sewage Transport

Reykjavik has about 325 km (203 miles) of sewer lines serving the whole city. All lines are laid for gravity flow drainage with discharge into the ocean at many points. Figure 2.1 shows the sewer lines on the city map. A study by the Danish Isotope Center determined the coliform count in 1970 (Figure 2.2) and the projected coliform count in 2000 (Figure 2.3) with continued use of the existing system. Six alternative proposals for sewage management were prepared by the Center. Proposal 1 provides for transport of all sewage through an extended straight pipe to a single discharge point, including the use of lift stations. Figures 2.4 and 2.5 show the present discharge points and the proposed single discharge point. Figure 2.6 shows the anticipated effect of the single discharge point. The cost of Proposal 1 with primary treatment is estimated at $10 to 20 million over ten years. The present annual budget for sewers is about $2 million and the total budget for the city's street and sewer systems is $8 million.

Sewer lines are buried under the centers of streets, sometimes under the grass shoulder, below a frost safe depth of 4 ft. Figures 2.7 and 2.8 show typical street and sewer cross sections. The sanitary sewer is in the lowest position below the storm sewer. Minimum sizes are 200 mm (8 in.) and 250 mm (10 in.) with minimum slopes of 1%. Larger pipes may use lower slope (0.4%). The largest pipe size available is 1.60 m (63 in.) diameter. The pipes are ordinary concrete pipe with rubber seals, formerly asphalt hemp seals.

There is concern about alkali reactions in the concrete pipes. The lowest reaction rates appear to be at 10°C (50°F) with higher rates at lower as well as higher temperatures. The sewage temperature is typically near 15°C (59°F) because the sewage contains the wasted hot water from the geothermal district heating system.

Manholes for the sewage lines are constructed efficiently with prefabricated elements (Figure 2.9). Only the base with the pipe connection is poured in place. Cylindrical sections are then stacked on top to complete the manhole (4 ft. outside diameter).

For an extended pipeline, as for the single discharge of Proposal 1, lift stations and higher flow velocities will be used. Gravity drainage will be in concrete pipe with rubber seals. Pressure lines will be polyethylene pipe with max. flow velocities of 1.5 m/s (5 ft/sec). The final discharge line is 900 m (3000 ft) long (Figure 2.5) and is also made of polyethylene with max. velocities of 2.5 m/s (8.2 ft/sec). Figure 2.10 shows a brochure page describing Norwegian continuously extruded polyethylene piping.

The used hot water from the district heating system is discharged into the sewer lines. Recently work has been started to use this geothermal water leaving the buildings at about 38°C (100°F) to heat sidewalks and even streets for snow and ice removal. This is proving to be successful. The cost of sidewalk construction is increased by 70%. The frost protection problem is reduced. The polyethylene piping is laid as shown in Figure 2.11, which depicts an installation in Sweden. Then, the piping is covered with sand and sidewalk pavers are laid without mortar. The melt water drains through the sand. Figures 2.12 and 2.13 show a heated pedestrian mall in the center of the city and icy conditions on streets and sidewalks beyond.

The city has about 236 km (147 miles) of streets. There is very little snow plowing and salting. There is never much snow accumulation because of frequent winds. The traffic wears its own tracks on the streets. Ice conditions on sidewalks are common and hazardous. One waits for the next rain to wash the ice away. All cars use studded tires. The wear rate on the pavement is 1 mm annually per 1000 cars per day on 2 lanes. The aggregate is very wear resistant but its only source is now depleted. Other available aggregates wear faster. Concrete has only 60% of the above wear resistance.

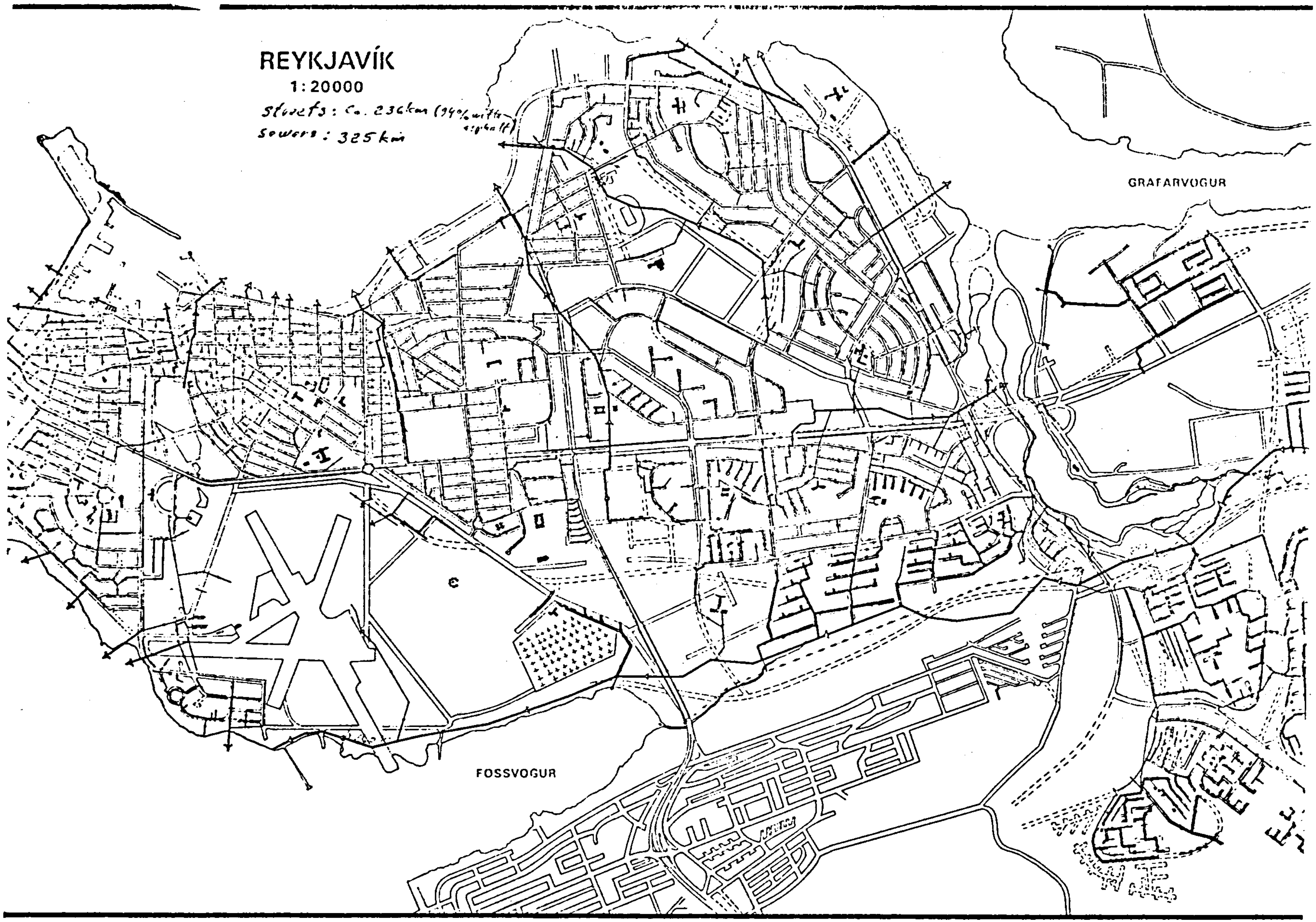


Figure 2.1 : Sewage transport system of Reykjavik.

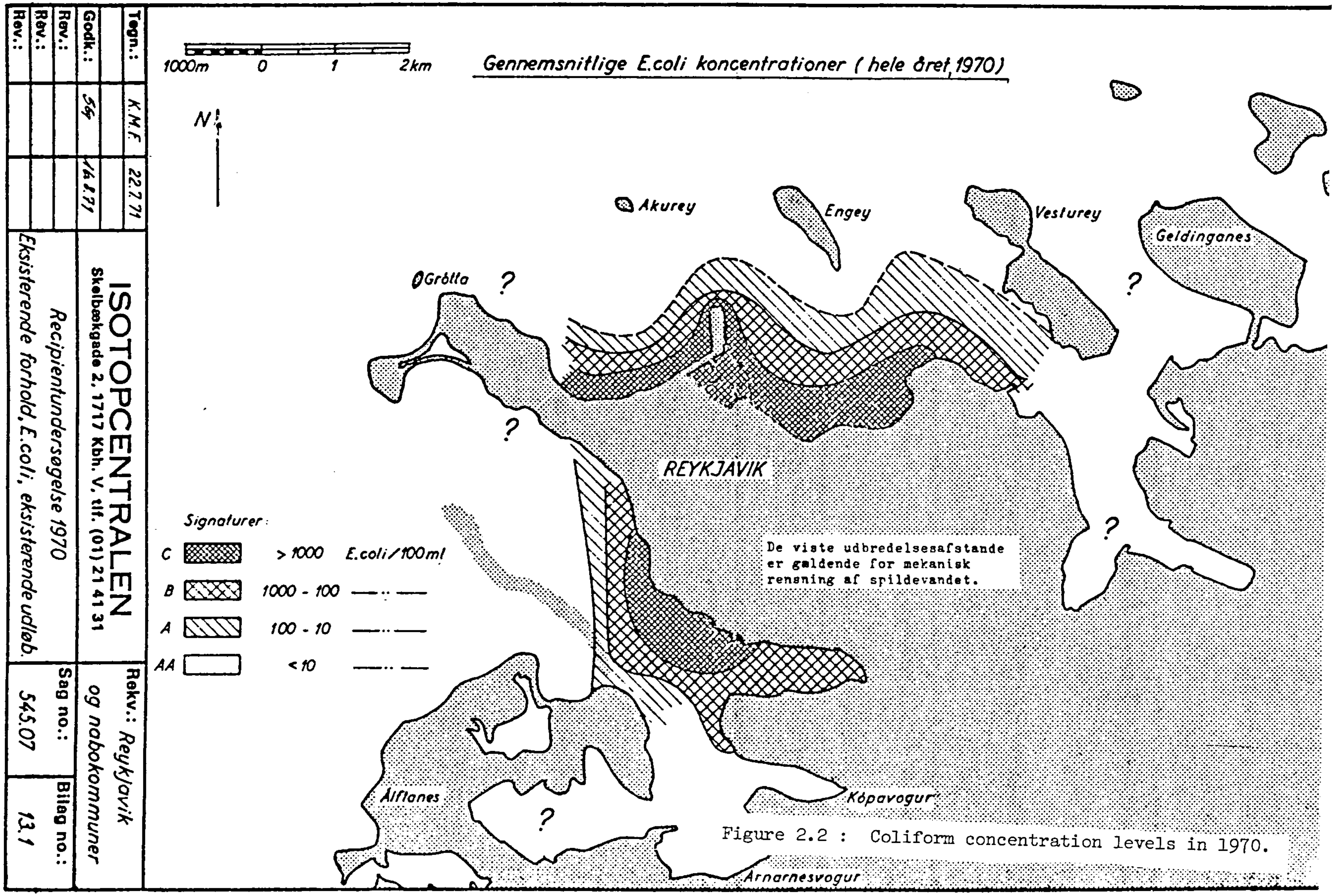


Figure 2.2 : Coliform concentration levels in 1970.

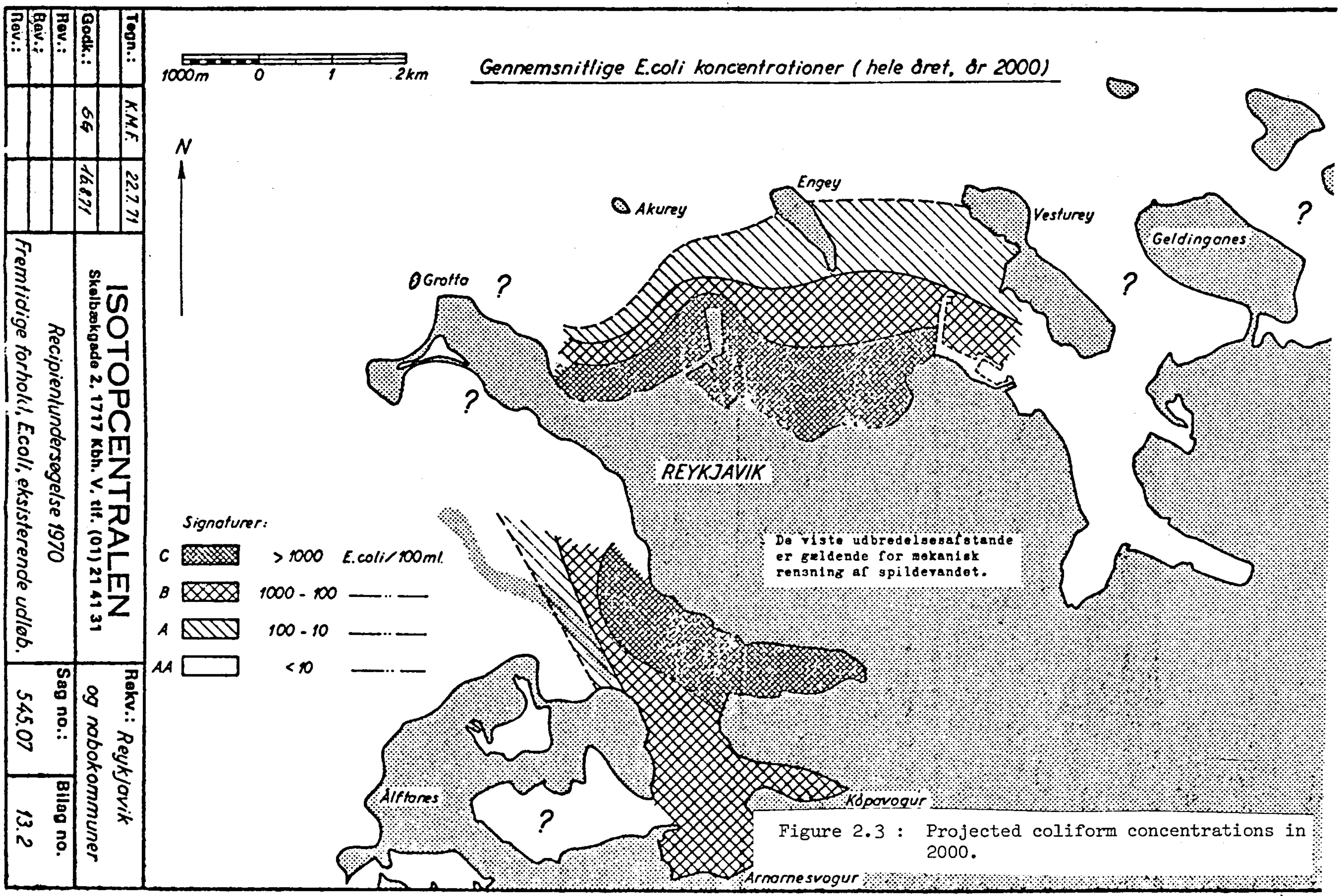


Figure 2.3 : Projected coliform concentrations in 2000.

3	740		18	80	
4	2000	1230	19	150	
5	1500		20	2100	
6	250		21	240	
7	2400	940	22	240	
8	470	220	23	530	
9	1550		24	530	600
10	280	810	25	240	
11	490		26	240	200
12	530	940	27	760	
13	60	210	28	760	800
14	160		29	380	
15	160				
Sum	12360	4600	Sum	6990	1600
Personer	65000	24000	Personer	37000	8000

Spildevandsmængder er gennemsnitsværdier
En person sættes i 1971 til 190 l/døgn.

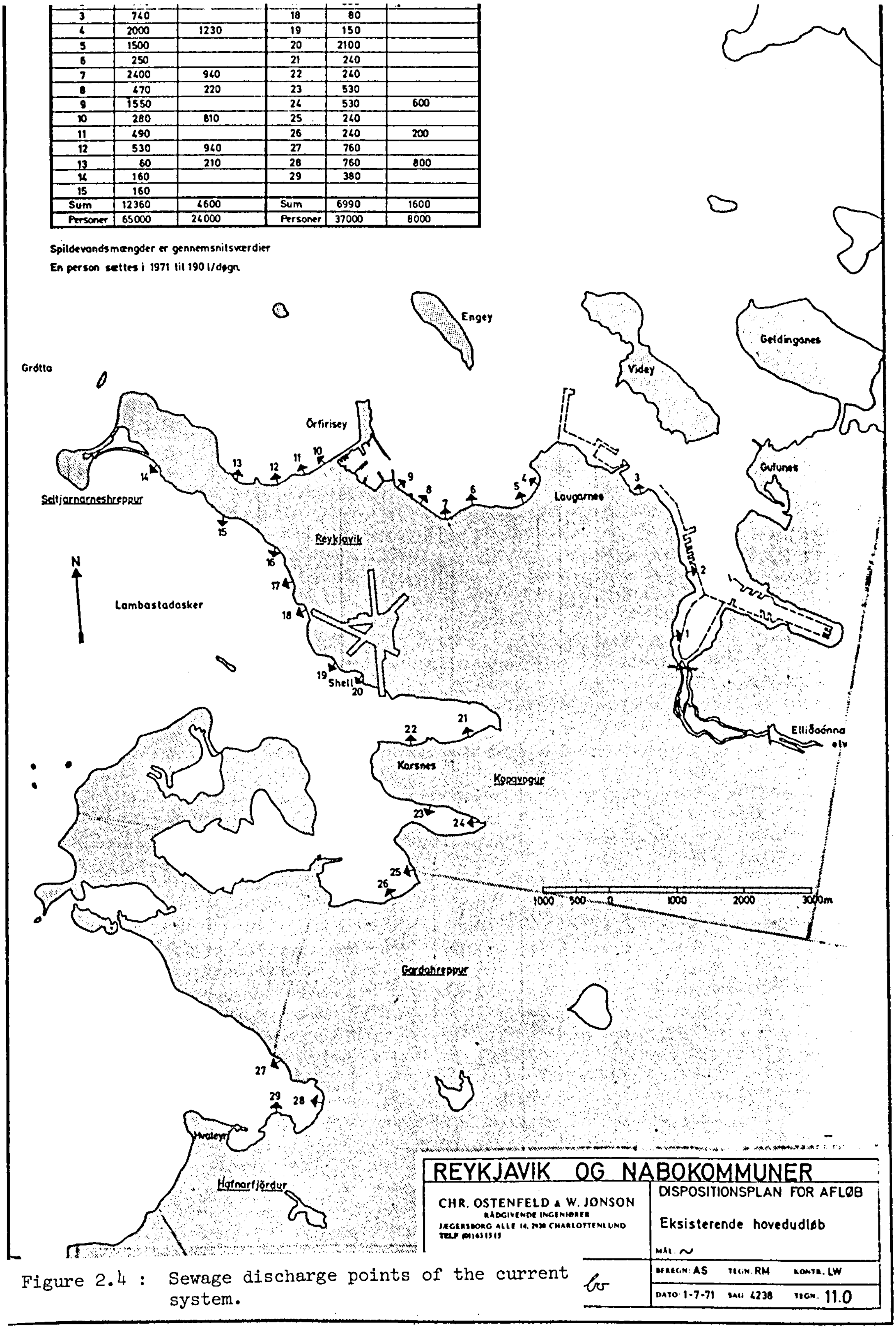


Figure 2.4 : Sewage discharge points of the current system.

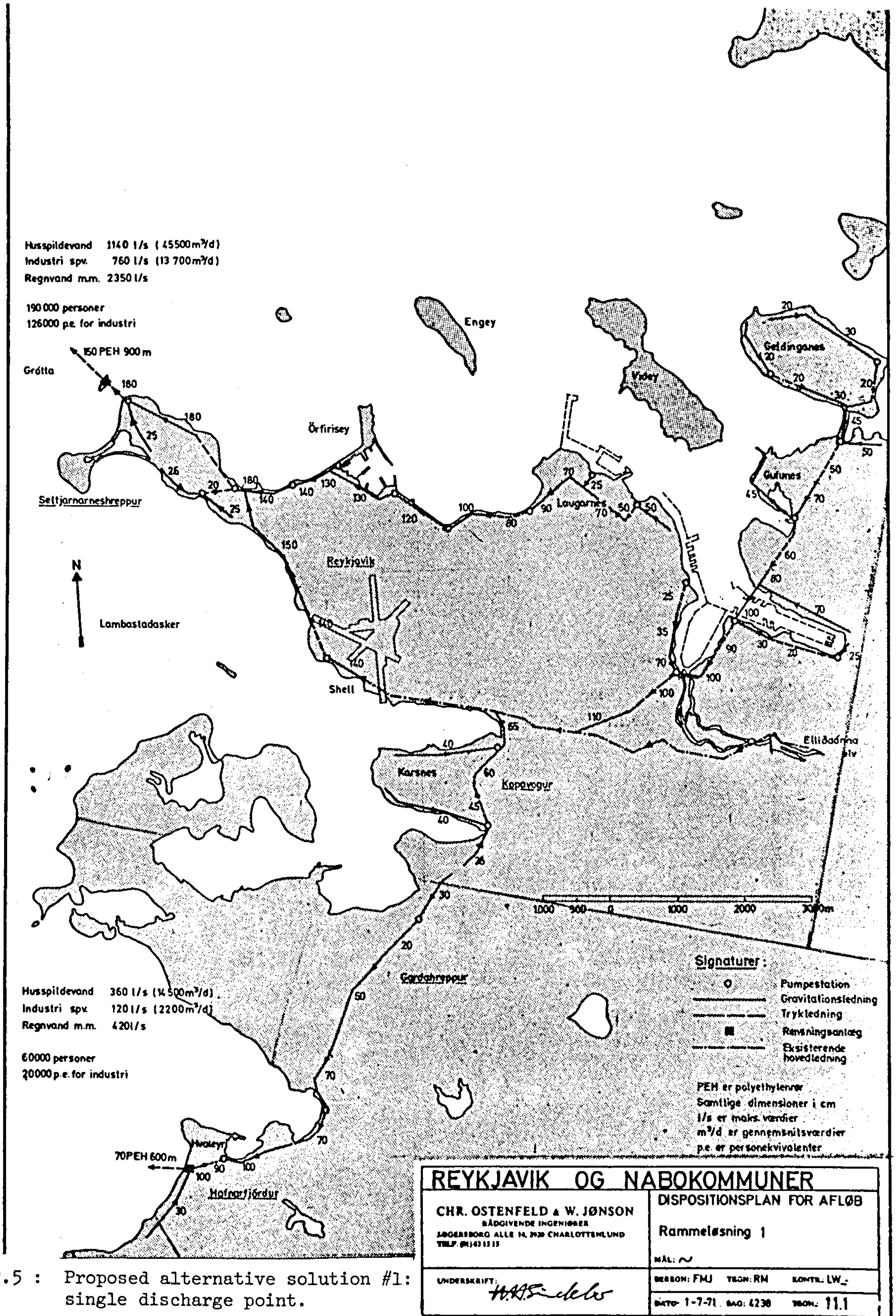


Figure 2.5 : Proposed alternative solution #1: single discharge point.

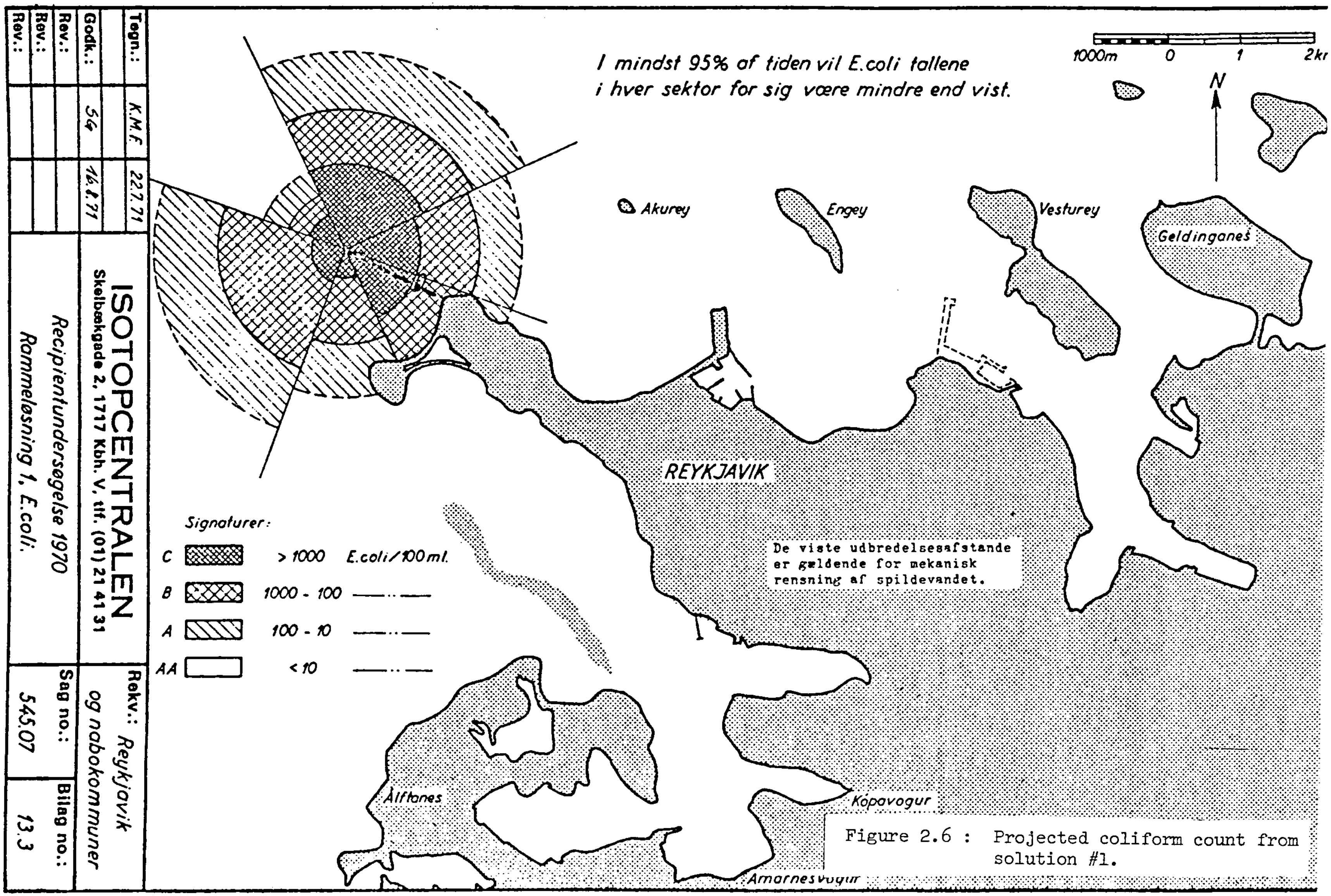
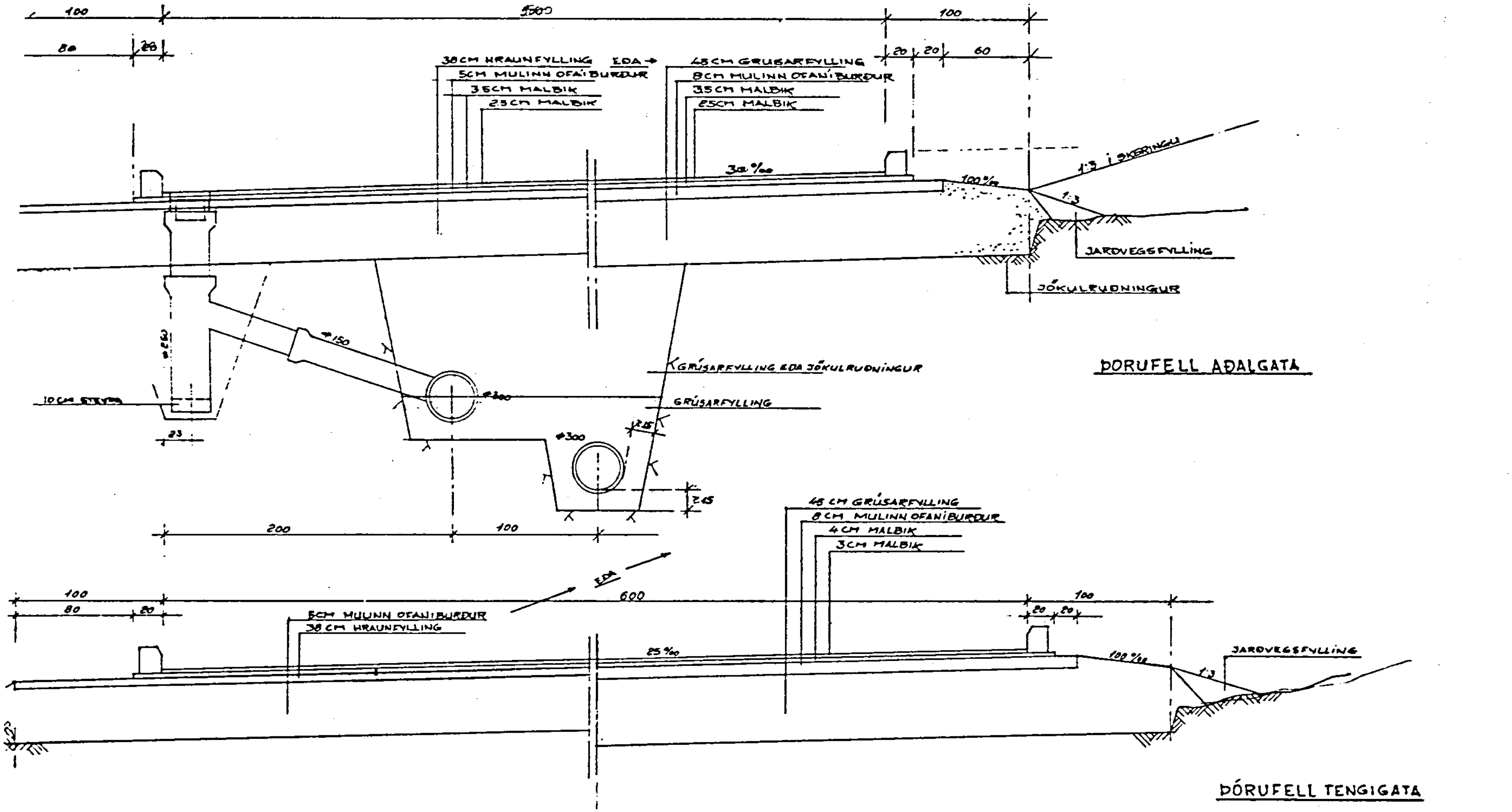


Figure 2.6 : Projected coliform count from solution #1.



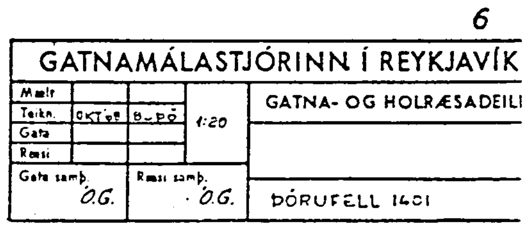


Figure 2.7 : Detail of sewer line installation.

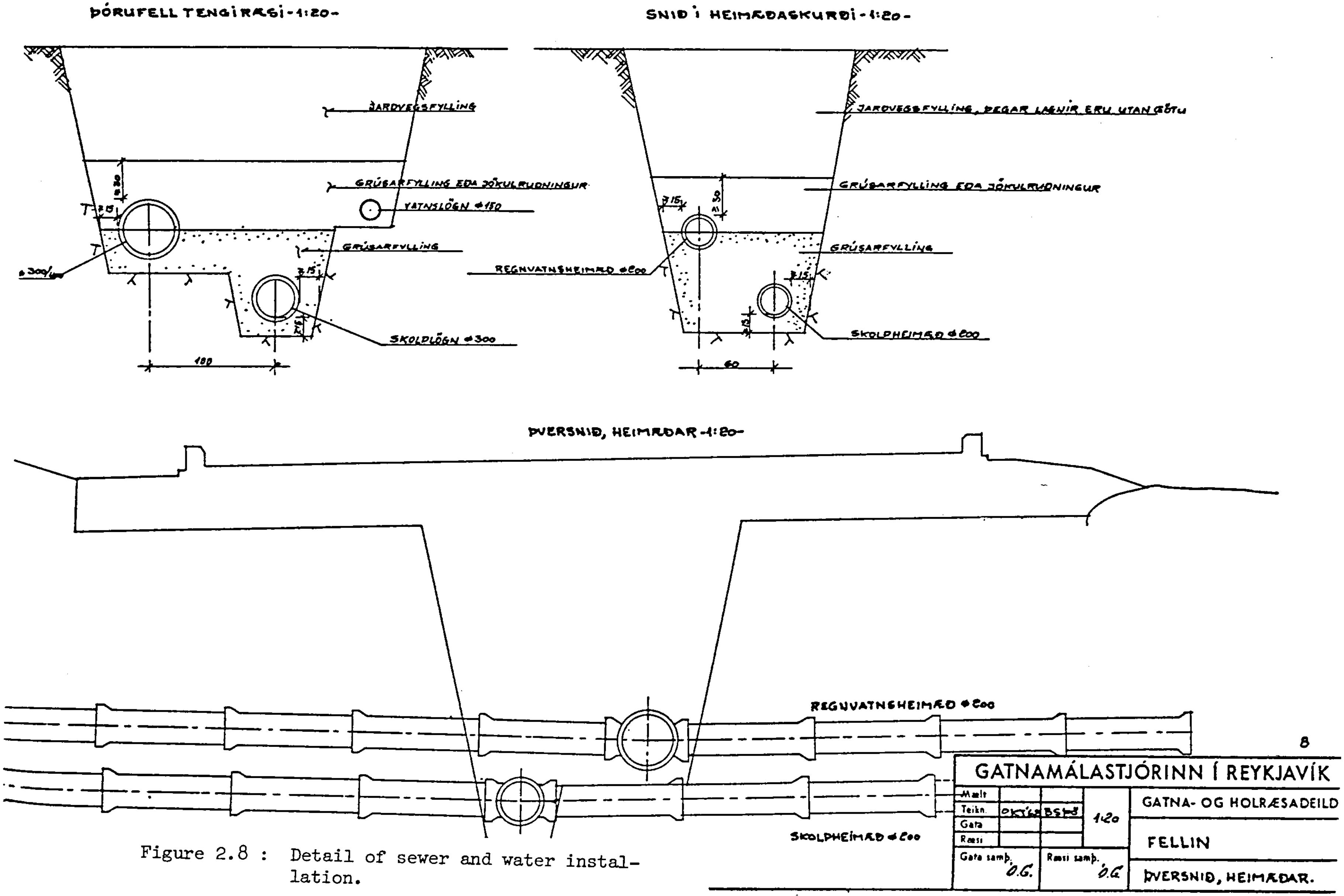


Figure 2.8 : Detail of sewer and water installation.

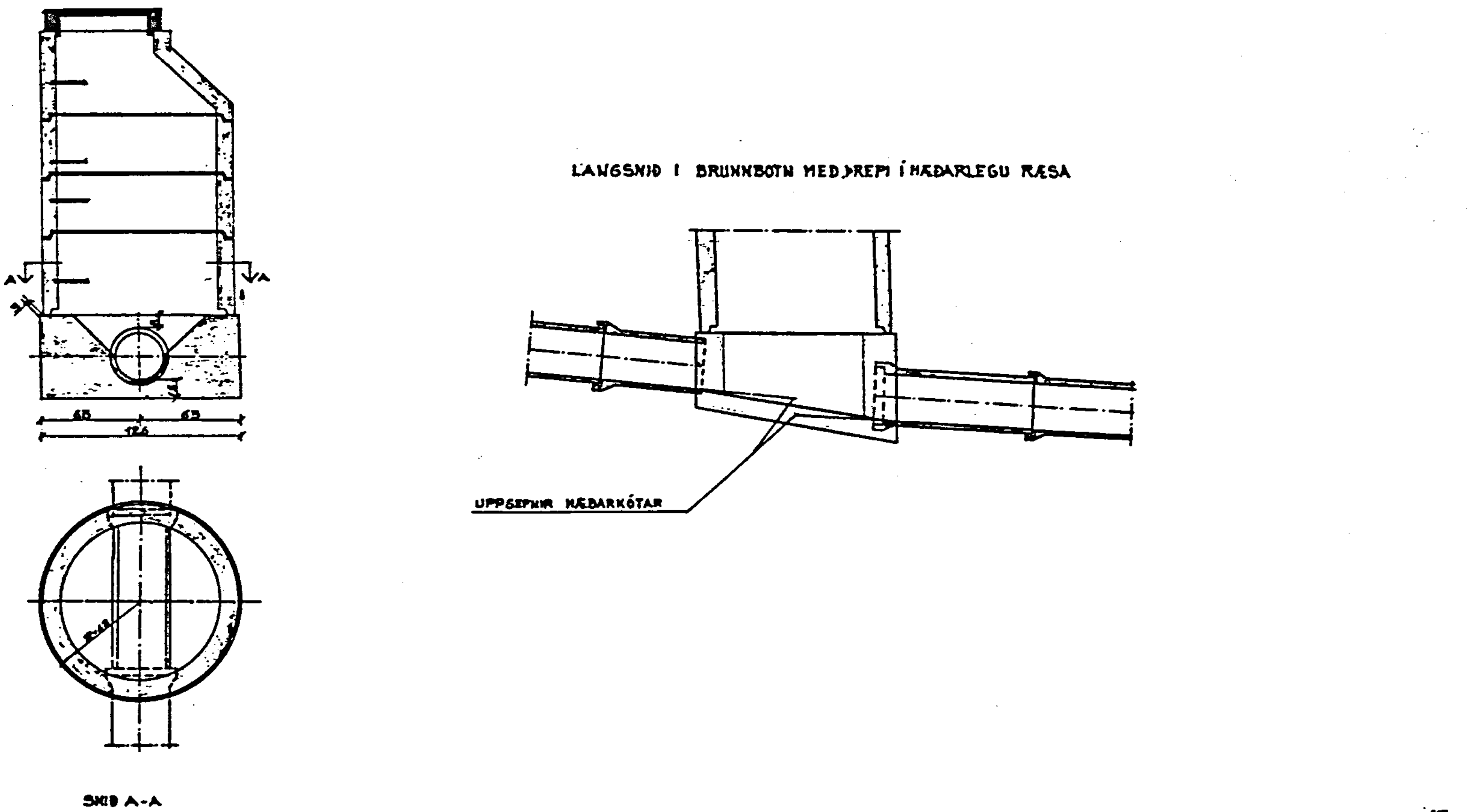
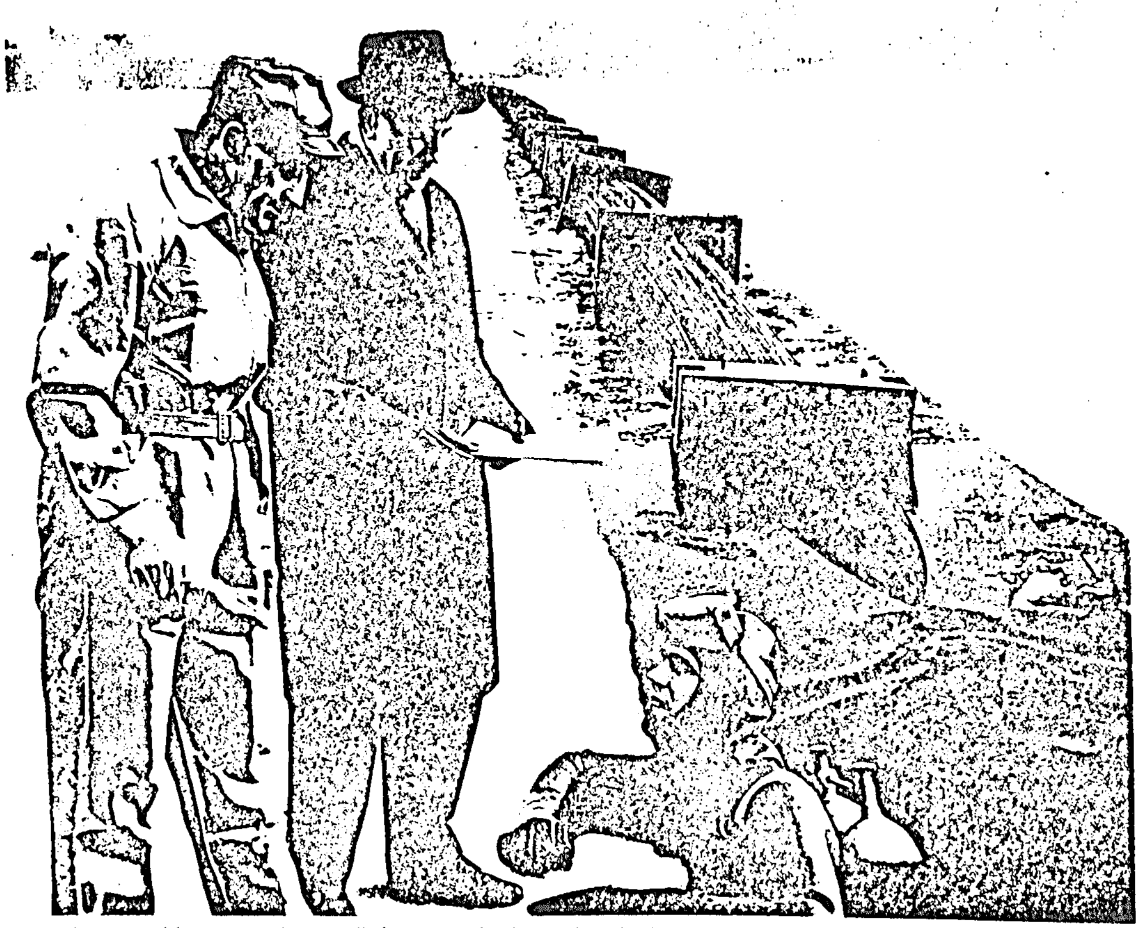


Figure 2.9 : Detail of sewer manhole installation.

Technical Information from VA Section, ESSEM Plast

ESSEM VA

EP 168
Aug. 1968
SfB In 6



A special team of frogmen make a preliminary examination and assist in the work of pipelaying.

Large-bore polyethylene piping — the solution to your water /sewage problem?

The resources and experience of ESSEM Plast are at your disposal

ESSEM High-Density Polyethylene Pipe has introduced new possibilities in water and sewage engineering. Corrosion-resistant, generously proportioned, simple and rapid laying provide good economy for buried or submerged pipe lines.

Talk it ower with ESSEM Plast...

We supply polyethylene piping in sizes up to 1000 mm outside diameter in short or long lengths. Our mobile tube mill can manufacture long pipes up to 400 mm o.d. at the site.

...we supply more than piping

We give you advice on technical questions, we undertake inspection and supervision of the work, and we provide **a guarantee for the delivery.**

Figure 2.10: Page from Norwegian PE pipe manufacturer's brochure.

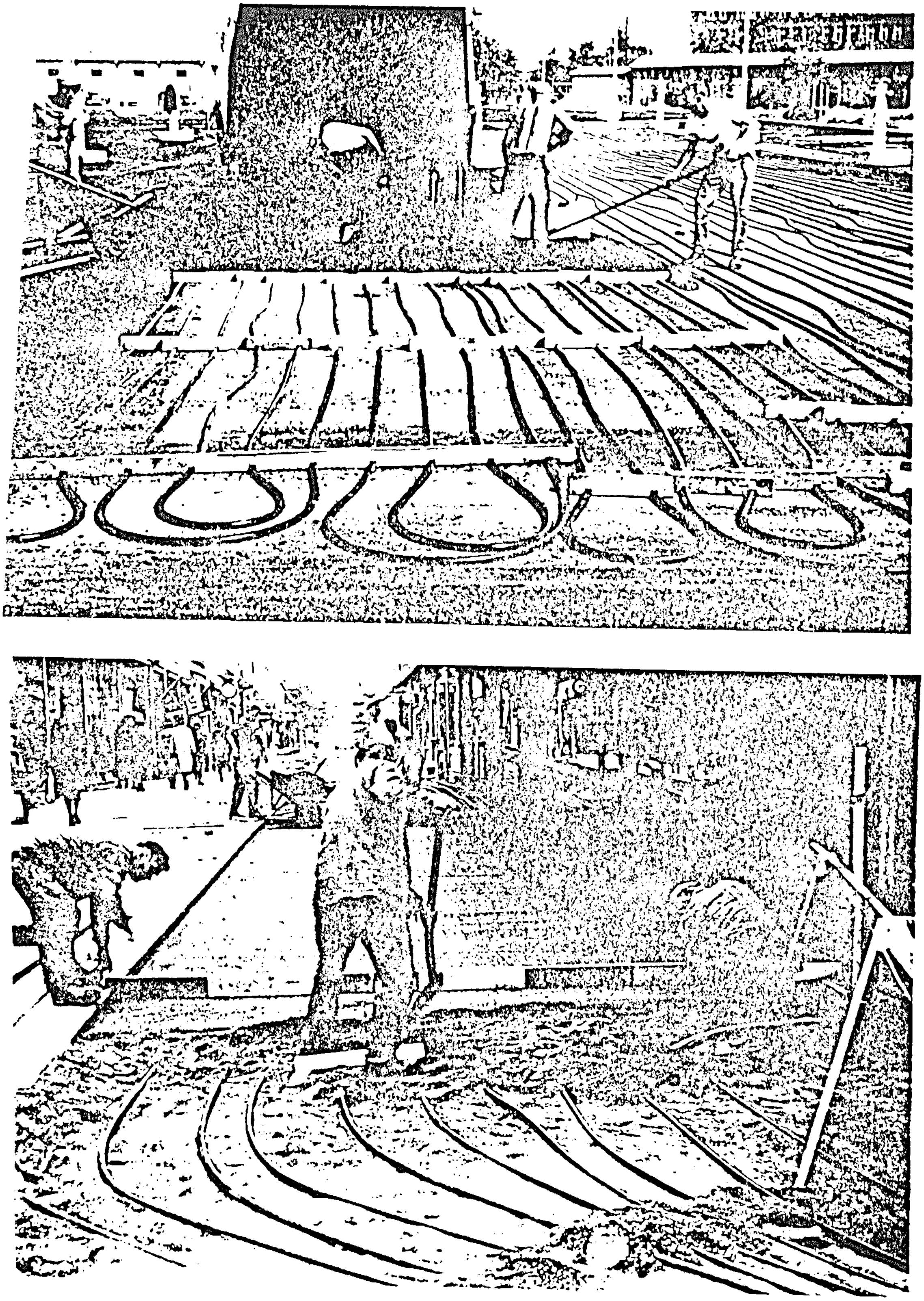


Figure 2.11: Swedish installation of PE pipe for street heating.

Figure 2.12: Pedestrian mall in Reykjavik with subsurface heating for snow and ice control.

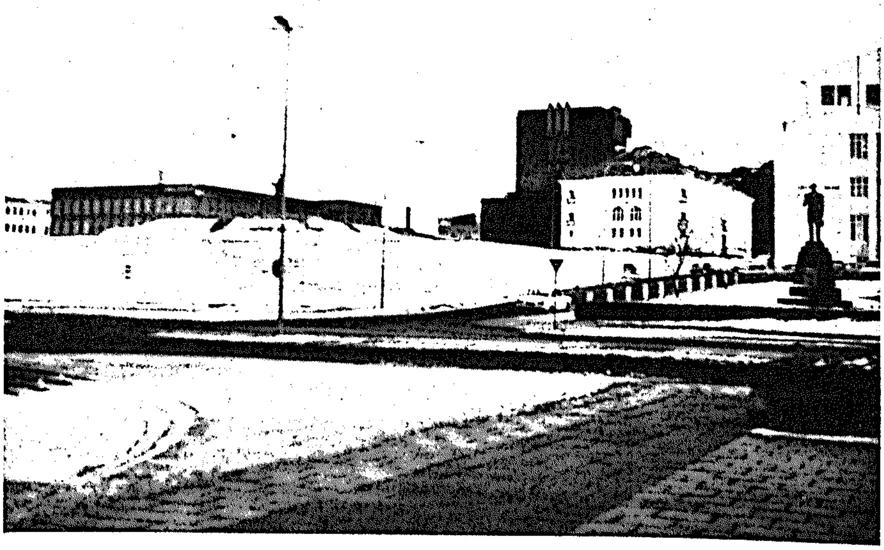


Figure 2.13: Heated pedestrian mall and icy streets in background.

3. Water Distribution

Reykjavik draws its water from wells 15 km (about 10 miles) east. The water is clean, needs no treatment or chlorination. The oldest well delivers 200 l/s (3,170 gpm), newer ones 570 l/s (9.035 gpm) and 150 l/s (2,378 gpm) for a total supply of 920 l/s (14,583 gpm).

Some of the old (1923) pipes made of wood staves are still in use. Other old pipes are cast iron but they have given some problems with splitting (poor casting quality). Today, reinforced concrete and ductile iron are used successfully. Some calcium in concrete goes into solution with soft water but stops after some time. Figure 3.1 shows a supply of concrete pipe stored near one well.

There are three storage tanks in the city. The first which holds 2,000 m^3, is made of concrete, coated with asphalt and covered with earth. The second holds 10,000 m^3, is of the same construction, but only the walls are banked with earth. The third holds 4,000 m^3, is circular, and is insulated with pumice and air space around the sides, and gravel and grass on top.

Distribution in the older city is with cast iron mains and galvanized steel service pipes. Since 1965 ductile iron mains and polyethylene service pipes have been used. Ductile iron resists impact of construction equipment on buried pipes. Earthquake resistance is not a reason for the choice but may be beneficial. Water lines are usually installed at the same time and together with sewer lines as shown in Figure 2.8 (above the sewer lines). Installation is normally in a new residential area when building construction is started and the streets are built. District heating lines are usually laid separately later. Only one installation was ever made using a tunnel (utilidor) for all utilities in 1942-43. Its length is about 100 m. The method proved to be too expensive.

The normal maximum water usage of the city is about 65,000 m^3/day or 650 l/day per capita. Subtracting the estimated leakage the normal max. usage is about 520 l/day (137 gpd) per capita. Other measurements of normal usage indicate 325 l/day (86 gpd) per capita.

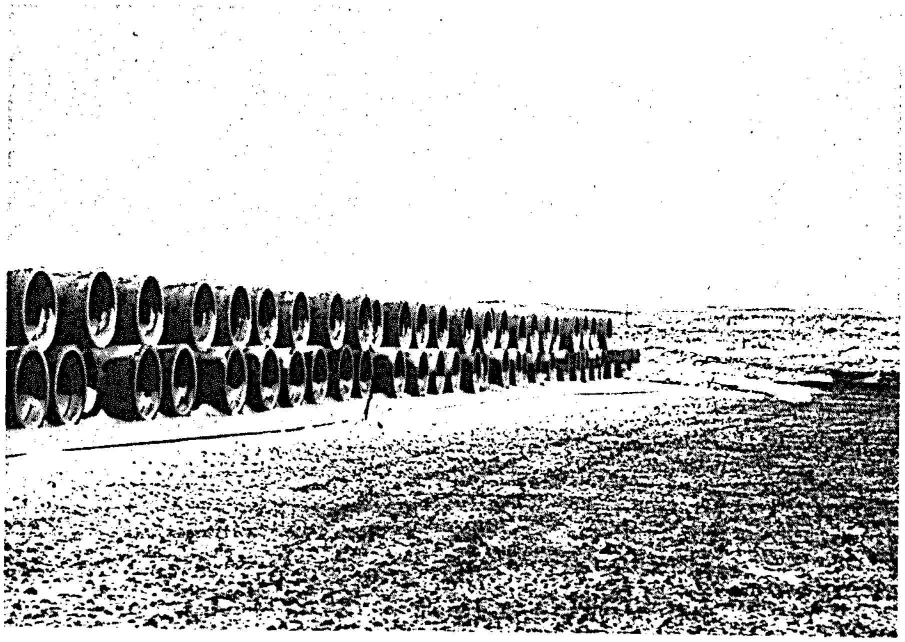


Figure 3.1: Reinforced concrete pipe for main water supply line.

4. Electrical Distribution

The National Power Company is a partnership of the Icelandic State and the City of Reykjavik. The Company generates electric energy and delivers and sells it wholesale for public and industrial use. Figure 4.1 describes the Company in more detail.

The Reykjavik Municipal Electric Works distributes electricity in Reykjavik and adjacent communities. It purchases electricity from the National Power Company and generates a small amount at its Ellidaar Hydro Station (in Reykjavik). Figure 4.2 shows the overall system, including the incoming lines and main substations A1 to A10. Figure 4.3 is a schematic distribution diagram. It shows the principal connections between the main stations at Geithals and Ellidaar and the 10 main substations.

The plan is to complete the whole system with 132 kV and 11 kV lines in place of the older 30 kV, 60 kV and 6 kV lines. It is further planned to increase the reliability of the system by completing a 132-kV ring in place of radial lines. As part of this ring an oil-filled 132-kV cable has been laid from Geithals via Korpulfsstadir to main substation A3, partly under water. The principle of this ring is further illustrated in Figure 4.4. The distribution from main substations is also radial to about 500 secondary substations (11-kV lines). Here it is planned to interconnect main substations through certain secondary substations where they adjoin in order to increase the system reliability.

The price of electric energy in Reykjavik is high despite the fact that it comes from hydroelectric plants whose low cost electricity is an important factor in the desired development of energy-intensive export industries, such as aluminum. The cost of electricity was raised on 1 January 1974 and on 1 January 1975 to the present level of 7.2¢/kWh (current exchange rate equivalent) at a flat rate for residential customers. Part of the reason for the high price is blamed on the after effect of the suppressed rate during the previous government, part of the reason is the high cost of the distribution system which emphasizes reliable service in a severe climate. All distribution in the city is underground. When service interruptions occur, they usually come from problems with overhead lines outside the city, particularly during storms.

Figure 4.5 shows a new residential area with street lights and underground distribution. The large overhead transmission line is a 220-kV line. (The street lights are shown burning because the picture was taken in twilight about 10:30 am.) Figures 4.6 to 4.8 are examples of underground cable installation specifications. High voltage cables H (11 kV) are laid deeper than lower voltage cables N (1 kV) and service cables G (0.4 kV). Domestic service is 230 V (230/400 V). The buried cables are shielded with pavers 37 x 50 cm and 25 x 50 cm or with a plastic band, as shown, depending on the voltage. Figure 4.7 shows the installation next to a district heating conduit.

Figures 4.9 to 4.11 show examples of overhead wire installations for 11-kV service. Overhead wires are used outside the city because they are less expensive than cables. They would not be accepted in the city by the population for aesthetic reasons.

As an alternative to high cost underground cables and low reliability overhead wires the municipal electric company is introducing overhead (self-supporting aerial) cables, which have been introduced successfully in Scandinavia. These overhead cables are a twisted bundle of (2,3 or 4) insulated wires. They are anchored to poles without insulators and require no mechanical support wire. They are more reliable than overhead wires and less expensive. More information is presented in Special Report 76.2. Figure 4.12 shows overhead wires connected to one side of a pole and the overhead cable to the other side. The cable is used in this situation for a road crossing. Figure 4.13 shows the same cable on the other side of the road where it crosses a second road at an intersection. Thereafter, the line changes to overhead wires again.

Numbers were provided for the estimated cost of various installation methods and those presented in Table 4.1 permit a comparison. The first three lines may be compared with each other and they show the overhead cable to be least expensive. The overhead wires are the most expensive alternative, partly because of the use of copper instead of aluminum; labor is highest for the underground cable installation. The last two lines compare high voltage wires and underground cable. The cable is more expensive for labor and material.

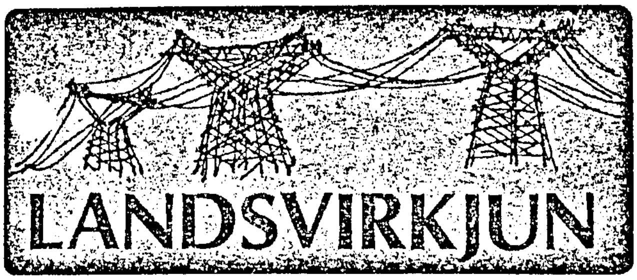
Overhead cables are from IKO Kabelfabrik in Sweden, accessories from Kabeldon in Sweden.

The electric distribution system is monitored through a Supervisory Control System with monitors at the main office and other key locations such as Ellidaar and Geithals. The Control system was built by Leeds and Northrup. The video screen monitors permit schematic display of the whole system or any substation system, showing the position of switches, the load on any line and any problem situation that may develop. A computer controlled typewriter records these conditions for the whole system every hour.

A 22-channel Zellweger ripple control system is attached to the Supervisory Control System. It controls street lighting and certain other loads which may be turned on and off according to schedule or arbitrarily for load management. Only about 6 channels are in use at present. Ripple control is through a 425 Ha wave signal with pulse code modulation for each channel. The wave signal is superimposed on the 30 kV electric power system and detected by receivers at the point of use.

	Labor	Material	Total
Overhead cable (1 kV); 4 x 50 mm^2 Al	300	600	900
Overhead wire (0.4 kV); 4 x 50 mm^2 Cu + 10 Cu	447	1400	1847
Undergrnd cable (1 kV); 3 x 95 Al + 50 Cu + grnd	570	750	1320
Overhead wire (11 kV); 3 x 124 mm^2 Al	356	800	1152
Undergrnd cable (11 kV); 3 x 240 mm^2 Al + grnd	925	2500	3425

Table 4.1: Estimated costs of installed electric lines in Reykjavik. Values are in Icel. Crowns per meter and are grouped for comparison of alternate methods.



Landsvirkjun (The National Power Company) was established on July 1, 1965 by a partnership agreement between the Icelandic State and the City of Reykjavik pursuant to the Act No. 59, May 20, 1965. The concern is jointly owned by these parties, each party owning one half of the company.

The principal objects of Landsvirkjun are to construct and operate electric power plants and main transmission facilities and to sell electric power therefrom wholesale for public and industrial consumption. The company acquired at the outset the Sog Hydroelectric Power System and the thermal power station at Ellidaár in Reykjavik, and the power supply area is initially the same as that of the Sog System, extending from the village Vik in Mýrdalur in the east to the Snaefellsnes peninsula in the west. Approximately 70 per cent of the national population are living within this area.

The Sog System comprises three hydroelectric power plants, viz. the Irafoss, Ljósafoss and Steingrímsstöd Power Plants. The combined capacity of these plants amounts to 89000 kW, while their energy potential in an average year will total 550 million kWh. The thermal power station has a capacity of 19000 kW.

On September 20, 1966, the Government of Iceland and Swiss Aluminium Ltd. closed an agreement on the establishment of an aluminium smelter in Iceland, with Landsvirkjun and ISAL, an Icelandic subsidiary of Swiss Aluminium Ltd., simultaneously entering into a contract for the purchase and supply of electric power for its operation. The agreements call for the development by Landsvirkjun of a 210000 kW hydroelectric power project at Búrfell Mountain on the River Thjórsá and for the construction by ISAL of an aluminium smelter located at Straumsvík Bay south of the Township of Hafnarfjördur and having an annual output of approx. 60000 tons of virgin aluminium. The first stage of these projects, viz. a 105000 kW power plant and a 30000 ton smelter, is to be completed in September 1969. Besides the hydroelectric facilities, Landsvirkjun will erect at Straumsvik a 35000 kW reserve gasturbine station.

In 1967, the energy production of Landsvirkjun was approx. 510 million kWh, having thus increased by 180 million kWh since 1957. It is presently expected that the production will reach 1100 million kWh in 1970 and 2000 million kWh in 1976.

The Board of Directors of Landsvirkjun is composed as follows:

Dr. Jóhannes Nordal, Governor of the Central Bank of Iceland, Chairman; Mr. Árni Grétar Finnsson, Attorney; Mr. Baldvin Jónsson, Attorney; Mr. Birgir Ísl. Gunnarsson, Attorney; The Hon. Geir Hallgrímsson, Mayor of the City of Reykjavik; Mr. Sigtryggur Klemenzson, Governor of the Central Bank of Iceland; and Mr. Sigurdur Thoroddsen, Consulting Engineer.

The General Manager of Landsvirkjun is Mr. Eiríkur Briem, Electrical Engineer. The Head of the Administration Department is Mr. Halldór Jónatansson, Attorney, the Head of the Engineering Department Dr. Gunnar Sigurdsson, Civil Engineer, and the Head of the Technical Operations Department Mr. Ingólfur Ágústsson, Electrical Engineer.

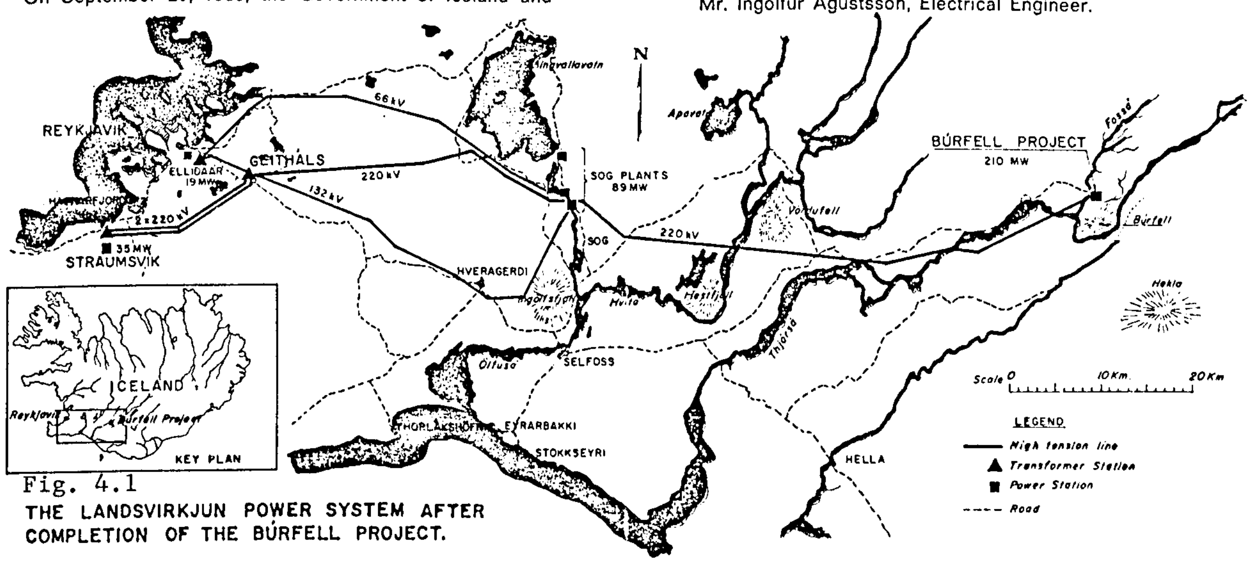


Fig. 4.1
THE LANDSVIRKJUN POWER SYSTEM AFTER COMPLETION OF THE BÚRFELL PROJECT.

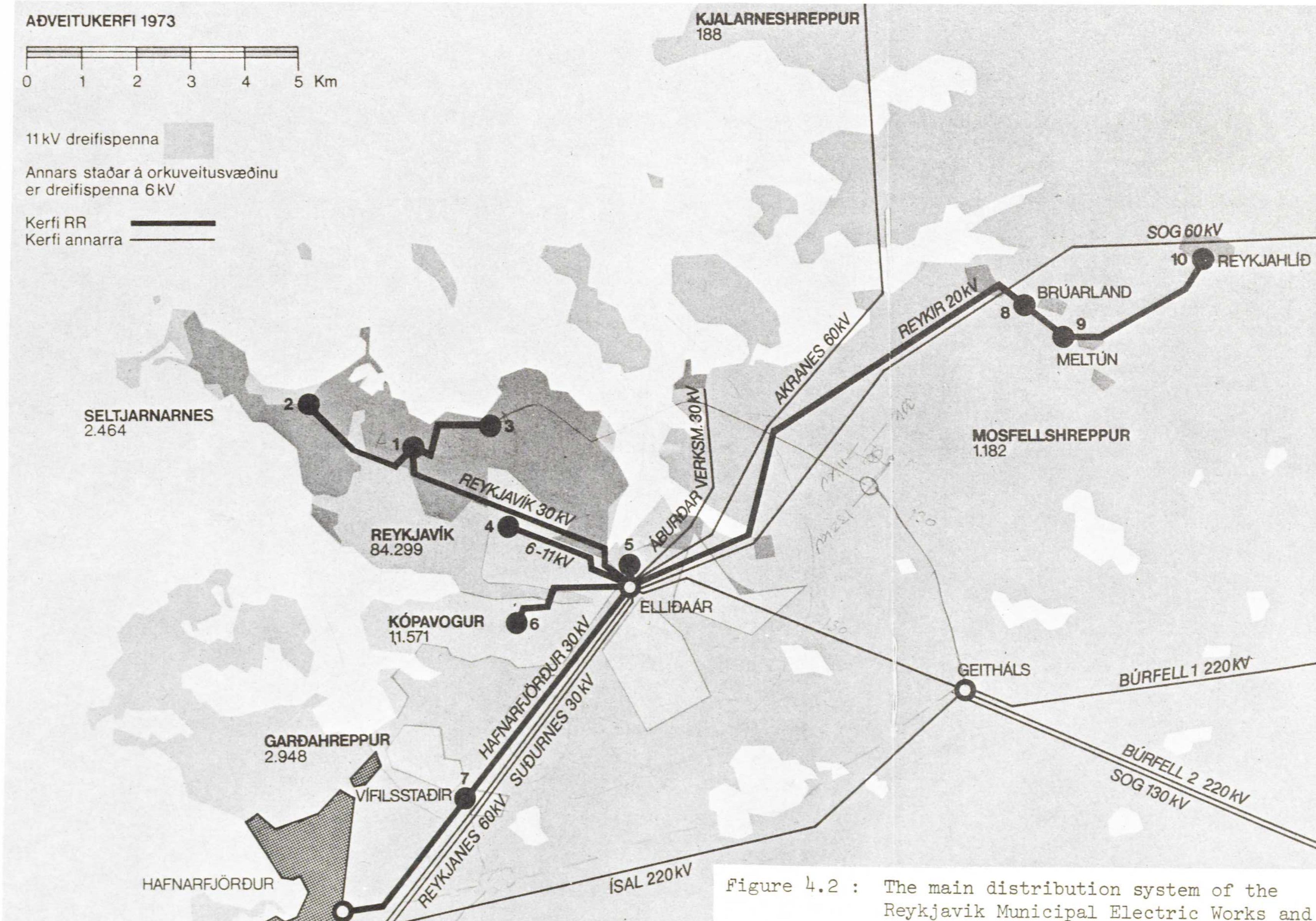


Figure 4.2 : The main distribution system of the Reykjavik Municipal Electric Works and supply lines of the National Power Company.

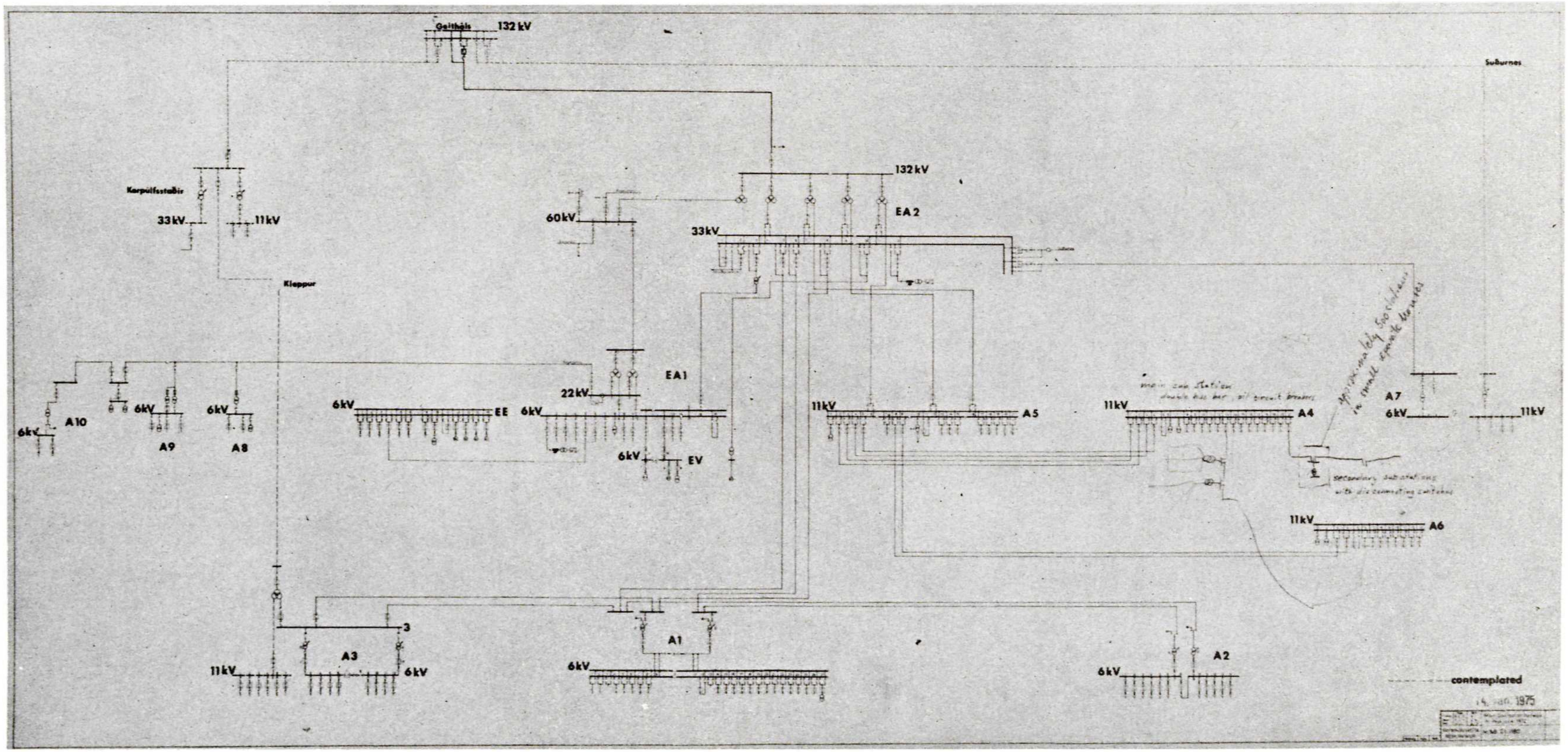


Figure 4.3 : Schematic diagram of the distribution system.

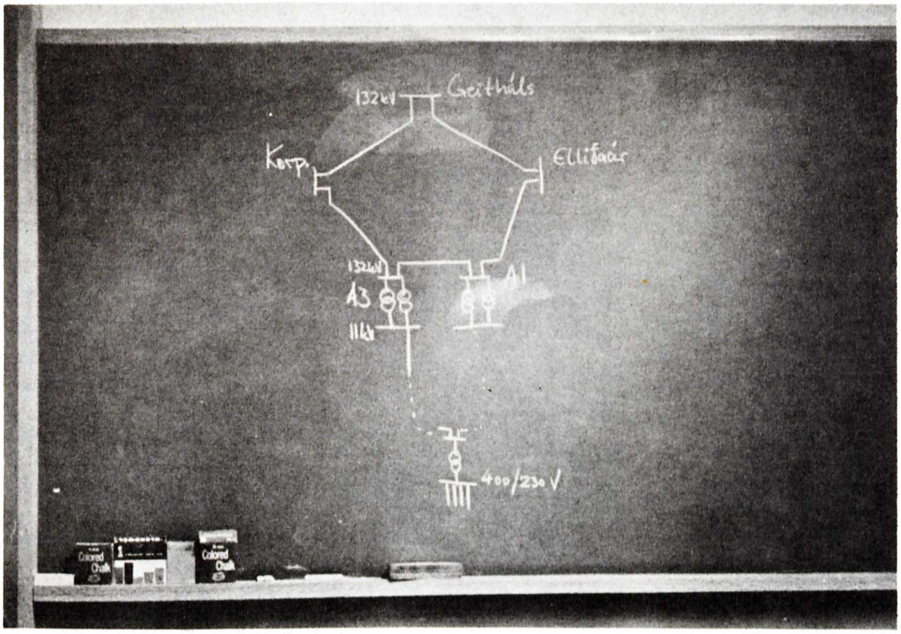


Figure 4.4: Sketch of the distribution ring and the interconnections through secondary substations.

Figure 4.5: Residential area with underground distribution.

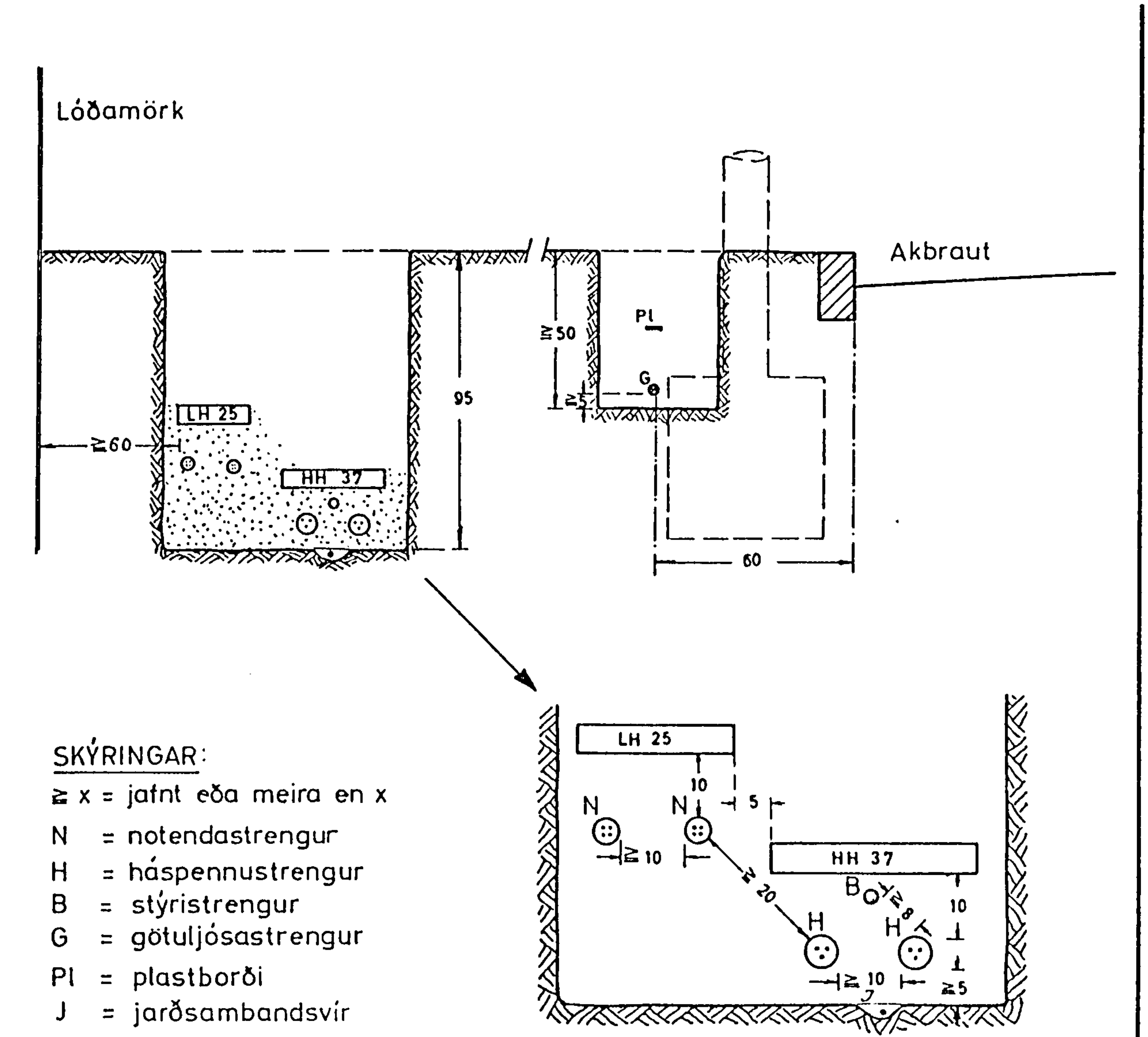
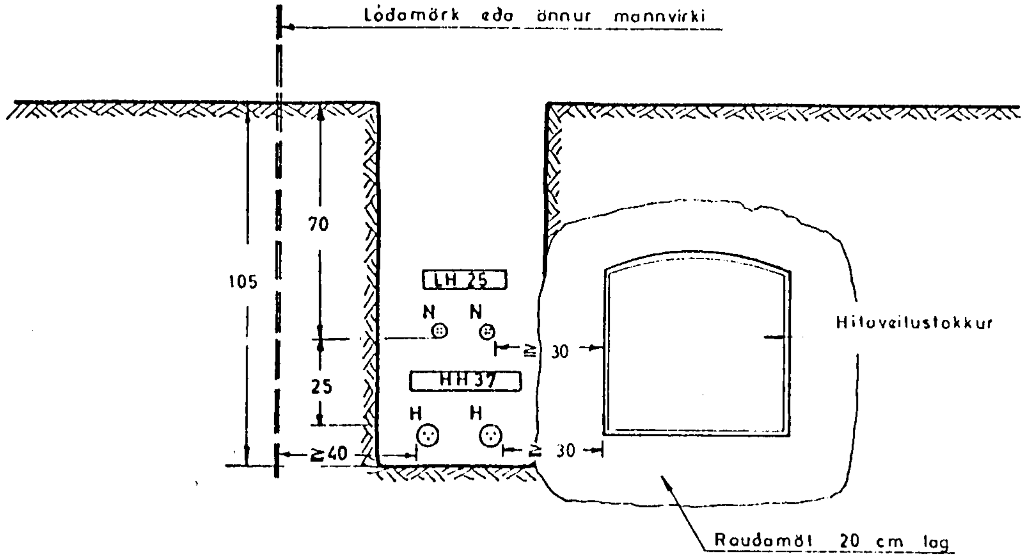


Figure 4.6 : Detail of electrical underground installation.

	Dags.	Nafn	JARÐSTRENGIR FJARLÆGÐ MILLI STRENGJA OG HELLNA	Kvarði : 1:20 1:10
Frumdr.	24.3.66	JOS/ IK		
Teikn.	—	HB		
Yfirf.				
RAFMAGNSVEITA REYKJAVÍKUR			Nr. 62.4.1153	MÁL ERU Í CM

Hallur
Jarðb.vír 10.7.'68 I.K



Skyringar:

≥x Jafnt eða meira en x
N - Notendastrengur
H - Háspennustrengur

Figure 4.7 : Detail of electrical underground installation (near hot water conduit).

	Dags.	Nafn	JARÐSTRENGIR	Kvarði =
Frumdr.	24.3.66	JOS/IK	LEGA VIÐ TAKMARKAÐA BREIDD	1:20
Teikn.	—	HB		
Yfirf.				
RAFMAGNSVEITA REYKJAVÍKUR			Nr. 62. 4. 1154	MÁL ERU Í CM

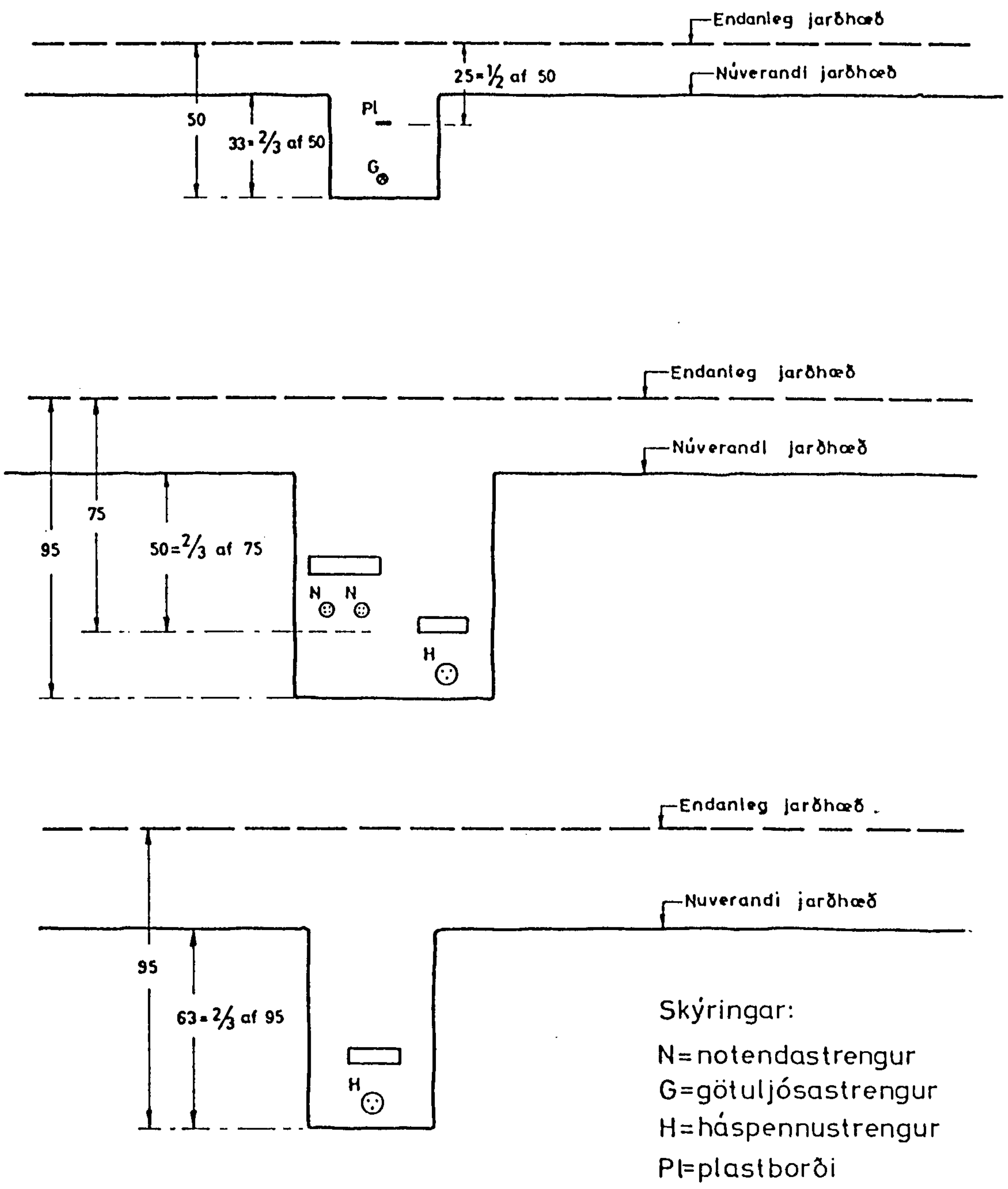
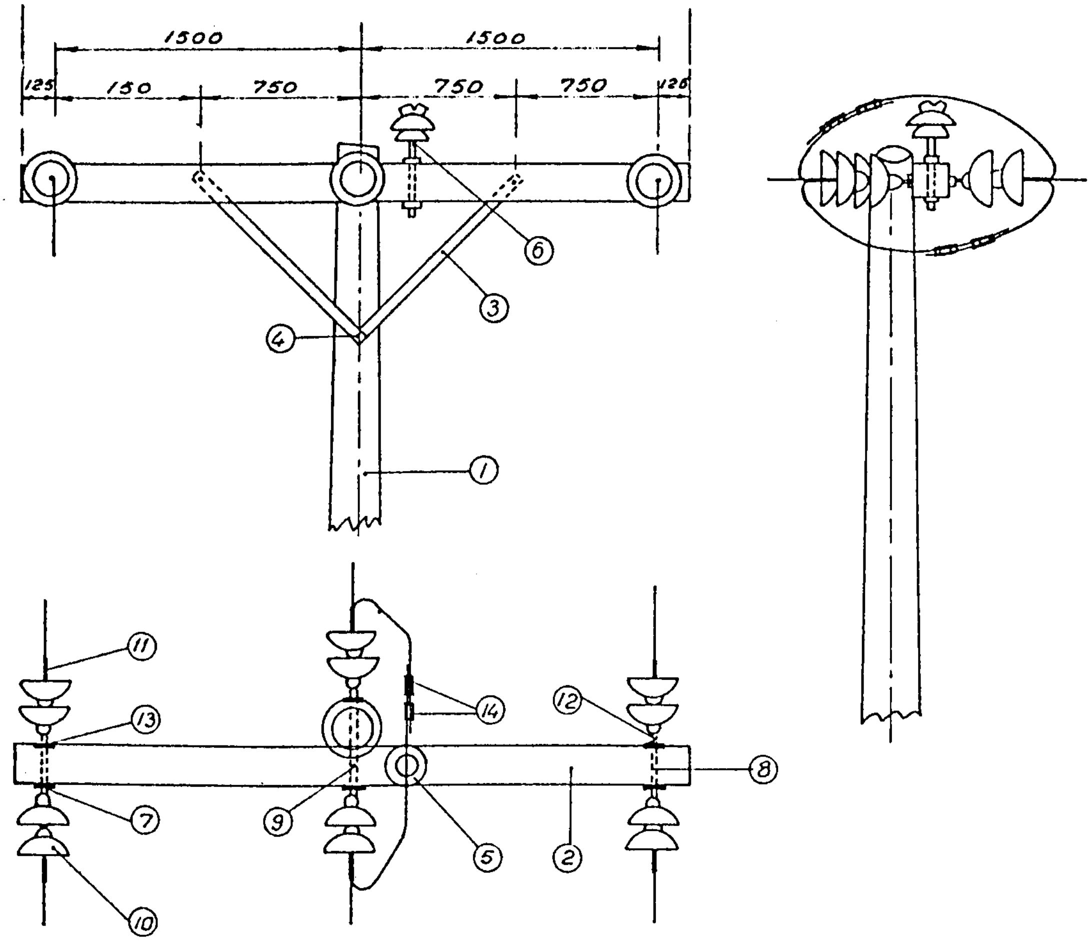


Figure 4.8 : Detail of electrical underground installation.

	Dags.	Nafn	JARÐSTRENGIR LÁGMARKSHÆÐ JARÐVEGS VIÐ STRENGLÖGN	Kvarði 1:20
Frumdr.	30.3.66	JOS/IK		
Teikn.	—	HB		
Yfirf.				
RAFMAGNSVEITA REYKJAVÍKUR			Nr. 62.4.1155	MAL ERU I CM

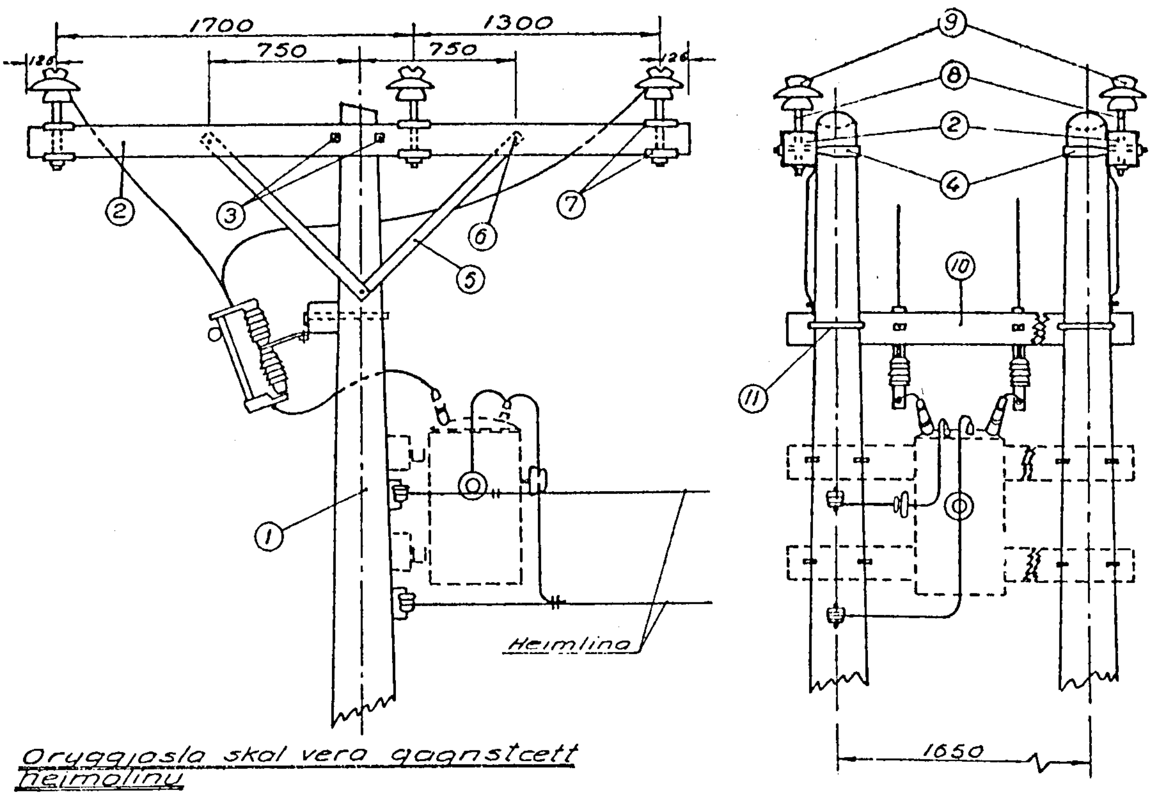


⑭	6	Tengiklemmur	Al – Al
⑬	8	Skífur	f. 3/4"
⑫	6	krokar	3/4"
⑪	6	Endaklemmur	
⑩	12	Einangraskalar	10"
⑨	1	Bolti, alsnittaður	3/4"x24"
⑧	2	Boltar alsnittaðir	3/4"x10"
⑦	6	Augaræ	f. 3/4"
⑥	1	Einangrapinni	15 kV
⑤	1	Standeinangrari	15 kV
④	3	Franskar skrufur	3/4"x4"
③	2	Skábönd	3-fasa
②	1	þverslá	325 cm
①	1	Staur	skv. staural.

Figure 4.9 : Detail of overhead wire installation.

Gert eftir teikningu frá RARIK nr. 4-0939-51

	Dags.	Nafn	Einfaldur burðarstaur fyrir upptak 3 fasa 11-30 kV	Kvarði
Frumdr.	2.10.68	GSJ. HO		
Teikn.	— " —	S. Th.		
Yfirf.	10.10.68	G. S. J.		
RAFMAGNSVEITA			Nr. 63. 4.1474	



Öryggjasla skal vera gagnstætt heimolínu

Onefnd mal mm

⑫	4	Skífur	5/8" 65x65x6galv.
⑪	2	Klafar	5/8"
⑩	1	Öryggjasla	3½"x5"x2,2m
⑨	6	Standeinangrar	11kV
⑧	6	Einangrapinnar	11kV
⑦	12	Söðlar	
⑥	6	Frönsk skrúfa	3/4"x4"
⑤	4	Skábond	3-fasa
④	4	þakjárnssaumar	
③	2	Klafar	
②	2	þverslar	325 cm
①	2	Staurar	Skv. staurolista

Figure 4.10: Detail of overhead wire installation(with transformer for service connection).

Gert eftir teikningu frá RARIK nr. 4-0365-51

	Dags.	Nafn		
Frumdr.	2.10.'68	GSJ.HO	Tvöfaldur burðarstaur fyrir spennistöð	Kvarði
Telkn.	—"—	S.Th.		
Yfirf.	10.10.68	G.S.J.	1-3 fasa 11kV	
RAFMAGNSVEITA			Nr. 63. 4.1467	S1

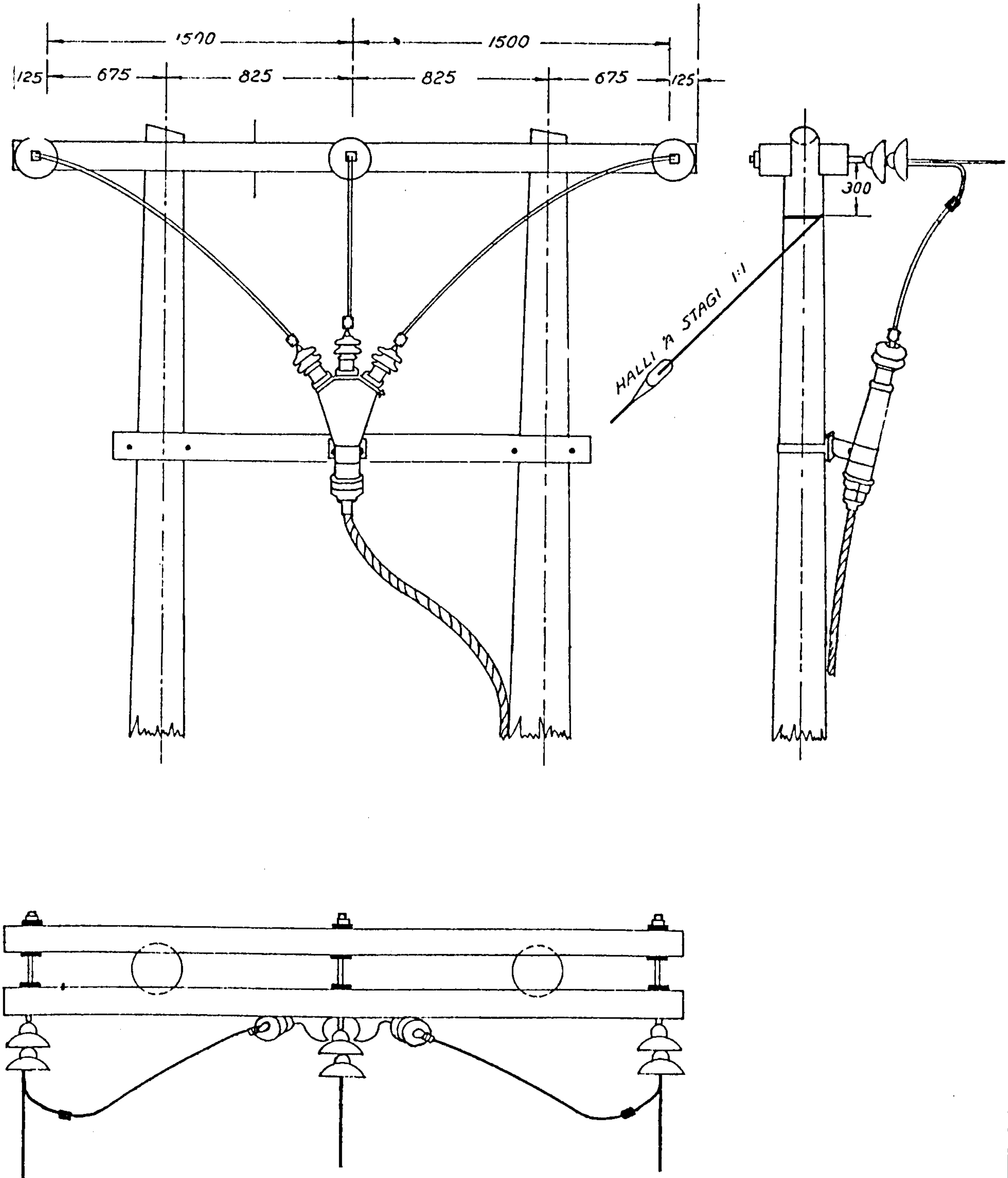


Figure 4.11: Detail of overhead wire installation(cable termination).

	Dags.	Nafn	TVÖFALT ENDAMASTUR MEÐ NIÐURTAKI	Kvarði
Frumdr.	25.8.70	T. Þ.		1:25
Teikn.	—"—	I.E.L.		
Yfirf.	—"—	[illegible]	3 fasa 10 kV	
RAFMAGNSVEITA REYKJAVÍKUR			Nr. 63. 4. 1723	EM-1

Figure 4.12: Transition from overhead wires to self-supporting aerial cable.

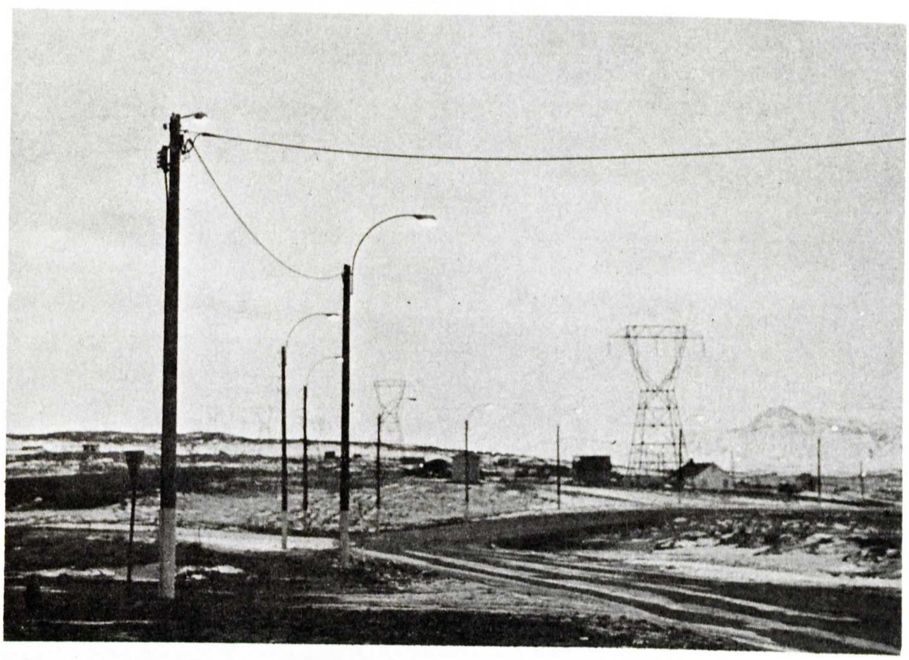


Figure 4.13: Overhead cables, wires and high-voltage transmission line.

5. Heat Distribution

The Reykjavik district heating system is described by Chief Engineer J. Zoëga and Manager of the Technical Division G. Kristinsson in the paper reproduced in Attachment 5.1. The following discussion provides supplemental information and details of interest.

Figure 5.1 shows the hot water storage tanks: 8 x 1000 tons and 2 x 9000 tons. The smaller ones are made of concrete, the larger ones of steel with insulation and aluminum skin.

Figure 5.2 shows the original main supply line leading to the storage tanks. The insulated steel pipe is inside the cast-in-place concrete conduit, covered with concrete plates. Figure 5.3 shows a new main line under construction with G. Kristinsson looking into the conduit. The rock wool insulating boards (staves), placed around the steel pipe and fastened with strapping, are 60 mm (2.35 in.) thick. They are preformed with a resin binder. The density of the material is 150 kg/m^3 (9.4 lb/ft^3). Figure 5.4 shows bellows used to compensate for thermal movement. The short pipe between the bellows is anchored. The pipe ends at each end of the bellows are aligned with guide elements to prevent lateral forces on the bellows.

Individual house connections are made from street mains as shown in Figure 5.5. Thermal movement is compensated by angles in the lines. Figure 5.6 shows details of the street mains in the conduit and the connections of service lines. The current practice of insulating the pipes in the street mains is with rock-or glass wool wrapped around the pipe, as shown in Figure 7 of Attachment 5.1, not with foamed concrete. The foamed concrete has proved not satisfactory, lacking good self-drying characteristics. The service lines are steel with polyurethane foam insulation and extruded polyethylene jackets. They are buried directly in pipe diameter sizes up to 150 mm (6 in.) for single supply lines and sizes up to 100 mm (4 in.) for dual supply lines. Larger sizes are laid in concrete conduits.

Figures 5.7 to 5.9 show details of manholes with connections of service lines to street mains. Figure 5.10 shows details of manholes for service line connections. Note the use of flexible pipe for movement compensation. Pipe dimensions are in millimeters.

Figures 5.11 and 5.12 show a temporary main line laid above ground on supports. The steel pipe is insulated with rock wool as in Figure 5.3 and covered with an aluminum shell. The line serves a new development (background) and will be replaced later by a permanent line in a conduit.

Figures 5.13 and 5.14 show drilling for hot water at Reykir. The pipelines have been installed recently; the insulation is not complete but the resulting heat losses are insignificant. A de-aerating valve is visible in Figure 5.14.

Table 5.1 gives statistics about the district heating system. The equivalent full load operating hours are 3500 per year. The design heating requirements of a house are 17 kcal/h m^3 (19.8 W/m^3 or 1.91 BTU/hr ft^3) at -15°C (5°F) as a 24-hour average. The actual peak is 1.15 times as great and the design peak is 1.25 times as great. The thermal peak load of the system is 300 MW(th). The electrical peak load is 67 MW (on 24 December). The annual hot water use is about 2 m^3 per cubic meter of house volume, which is about 98 kWh/m^3 (9475 BTU/ft^3).

The heating season is about 5500 degree-days Celsius (21°C reference base). The equivalent in degree-days Fahrenheit is not known.

The fee for connecting to the system is a regressive rate based on the size of the building. It is as follows in US Dollars (January 1975):

up to 400 m^3 : \$753

400 to 2000 m^3 : \$0.60 per m^3

2000 to 6000 m^3 : \$0.51 per m^3

The usage charges for the hot water are based on a flat rate of about \$0.27 per m^3 (\$7.68 per 1000 ft^3). The comparative heating cost for hot water vs heating oil and electricity on an energy basis is:

0.55 c/kWh for hot water (\$1.61 per MBTU)

1.90 c/kWh for oil (45.8 c/gal) (\$5.59 per MBTU)

7.20 c/kWh for electricity (Ch. 4) (\$21.08 per MBTU).

6000 to 10000 m^3: \$0.39 per m^3

1. Synopsis

THE Reykjavík District Heating System uses natural heat resources, found in the city and its vicinity, to heat 8,700 of its approximately 10,000 houses, serving some 72,000 inhabitants. (Fig. 1.)

The natural hot water used is obtained by drilling in known thermal areas, and in areas found by various geophysical methods to be promising.

The water used is chemically clean, directly potable and contains only a small amount of dissolved solids, it is also non-corrosive to steel, and ordinary black steel pipes are used throughout in the system. Load density in the city is low, the average being 17 Gcal/hr km², and 1·5 Gcal/hr km of distribution mains.

The maximum heating load is at present 190 Gcal/hr and the available energy 205 Gcal/hr including a 30 Gcal/hr oil fired heat peak power plant.

The climate in Southern Iceland is mild considering latitude, the mean temperature in July being 11°C, and in January - 0·4°C, and the consumption in January is only 2·3 times that of July; thus, due to the relatively cold summers and warm winters, the equivalent hours at peak power for natural heat alone are 5,800 pr. year. (Load factor 66 per cent.) Water-meters are used for billing and the cost of heating averages 65 per cent of the cost of individual fuel oil boiler heating.

The growth of the city, as well as the possibility of supplying neighbouring communities having 30,000 inhabitants, will in the near future necessitate exploration and development of thermal areas further from the city where high temperatures (up to 260°C) have been found.

2. Units

Mks units are used throughout the paper, the heat units being the kilogramme-calorie, Giga-calorie Gcal (1 Gcal = 10^6 Kgcal) and Tera-calorie (A Tcal = 10^3 Gcal).

3. Utilization of natural heat in Reykjavík

Hot springs have been known in Iceland since the time of the first settlers, late in the ninth century; the name of the city is derived from hot springs, but the use of this natural heat was for the first thousand years limited to washing and bathing.

At the beginning of this century, use was first made of it for heating of dwelling houses, and some years later for heating greenhouses.

In 1928, the first boreholes for hot water were drilled close to hot springs in the eastern part of the city; 14 boreholes were drilled to a maximum depth of 400 m and yielded 50 m³/hr of water at 87°C.

In 1930, a distribution system was built, serving some 70 houses together with an open air swimming-pool, a swimming-hall and a schoolhouse.

These undertakings promoted further interest in the utilization of these natural resources, and in 1933 the city authorities purchased drilling rights in a hot spring area at Reykir, some 15 km east of the city, and drilling started that same year.

In the years 1939–1943, collecting mains and a pumphouse were built, together with a main pipeline to the city, storage tanks of 8000 m³ capacity and a single pipe distribution system for the main part of the city, as it was at that time; this system was put into operation on December 1st 1943 and served 2300 houses.

In 1947, additional drilling rights were bought, 3 km north of Reykir, and drilling commenced the same year; the area was developed in the years 1949–1950 and extensions to the distribution system in the city followed.

In all 72 boreholes were drilled in these thermal areas, down to a maximum depth of 770 m; and the total yield amounted to 1200 m³/hr of water at a temperature of 86°C.

In 1958 the municipality, in cooperation with state authorities, purchased a large drilling rig which had until this time been used widely in southern Iceland, mainly in the city, drilling to a maximum depth of 2200 metres.

Scientific methods of exploration were used, such as systematic temperature measurements in boreholes already drilled, and mapping of temperature gradients in these boreholes, measurements of gravity – and magnetic-field, and electrical resistance of rock foundation.

Results were obtained in the same year in a field inside the city limits, and the field was connected by a pipeline to the existing system; two new districts were added to the system in 1957–1961, and drilling continued.

Since 1958 the result of drilling in this field has been 1100 m³/hr of 128°C water together with 600 m³/hr of water at 105°C from a second more recently developed field, also within the city limits.

Since 1962 work has been in progress on extensions to the distribution system according to a general plan made in 1961, to supply all planned districts with district heating. That work is now nearing completion, and the number of houses connected to the district heating system today is 8700, representing a heating load of 190 Gcal/hr.

An oil fired peak boiler plant of 30 Gcal/hr capacity has been added, and storage capacity increased to 26,000 m³.

The system's natural heat resources today are summarized in the following table:

1. Reykir area	1000 m³/hr at 80°C	40 Gcal/hr
2. Reykjavík area	1700 ,, ,, 119°C	135 ,,
3. Peak power plant		30 ,,
4. Electricity Authority peak plant[1]		20 ,,
	Total	225 Gcal/hr

1. Available only at electrical off-peak hours.

4. The District Heating System (Fig. 2)

4.1 Development of Thremal Areas

As stated in the previous chapter the geothermal areas have yielded water at temperatures either below 100°C or above, and different methods are employed in utilizing these areas.

Where water temperature is below 100°C (Reykir Area), the water comes out of the boreholes by gravity flow, and is collected from the various boreholes into a cistern by the main pumphouse, it is then piped to the lower situated pumps, which then pump it through a double 14" pipeline to the storage tanks in the city.

Pumping is regulated by air operated valves on the discharge side of the pumps, controlled by a level control in the collecting cistern.

Where the temperature of the water exceeds 100°C (Reykjavík Area), a certain minimum pressure must be maintained on the water to avoid boiling in the system. This is produced by deep well pumps inserted 110–120 m down the boreholes, connected by drive shafts to surface mounted electric motors, pumping the water through collecting mains to the area main pumphouse. The hot water in these areas contain a certain amount of gaseous nitrogen which has to be expelled; it will otherwise collect in the radiator of the highest situated houses in the system, where pressure is lowest, and thus block the circulation in the houses' heating system.

This nitrogen is removed by piping the water, on arrival at the main pumphouse, through a de-airator, which is a horizontal steel tank with a relatively large surface. The pressure is relieved and the water allowed to boil slightly at the surface; the gas freed by this process is then led to the atmosphere, and the water piped to the suction side of the pumps, which pump it through high temperature mains to the various district stations in the city.

Pumping is regulated in the same manner as before by a level control in the gas separators.

These main supply pumping plants are each equipped with three pumps, any two being of sufficient capacity to pump all the water available, and the third functioning as stand-by.

All pumps are driven by squirrel cage induction motors as speed regulation is not employed.

The total pumping power in the 4 main plants is 3590 HP, and in the 16 boreholes in use in the Reykjavík area 1525 HP.

4.2 District Pumping Plants

The city is divided into a number of districts, each served by its own district pumping plant. In the oldest part of the system, completed in 1943, the distribution system is a single pipe one. It is fed directly from the storage tanks situated on a hill, which then was higher than any structural feature in the city; it does however require booster pumps to take care of higher loads, the pumps adding a lift of 20 mwc.

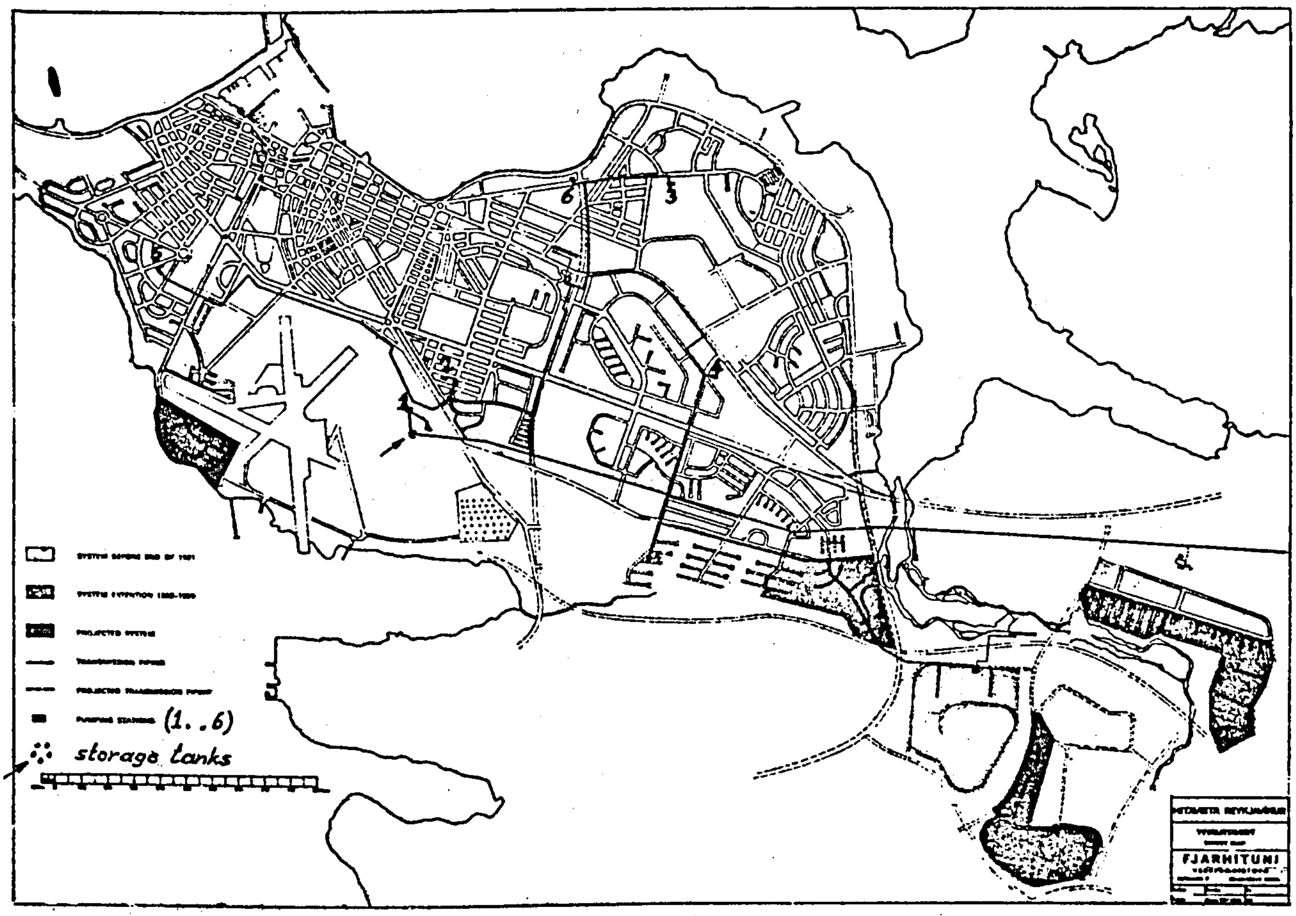


FIG. 1

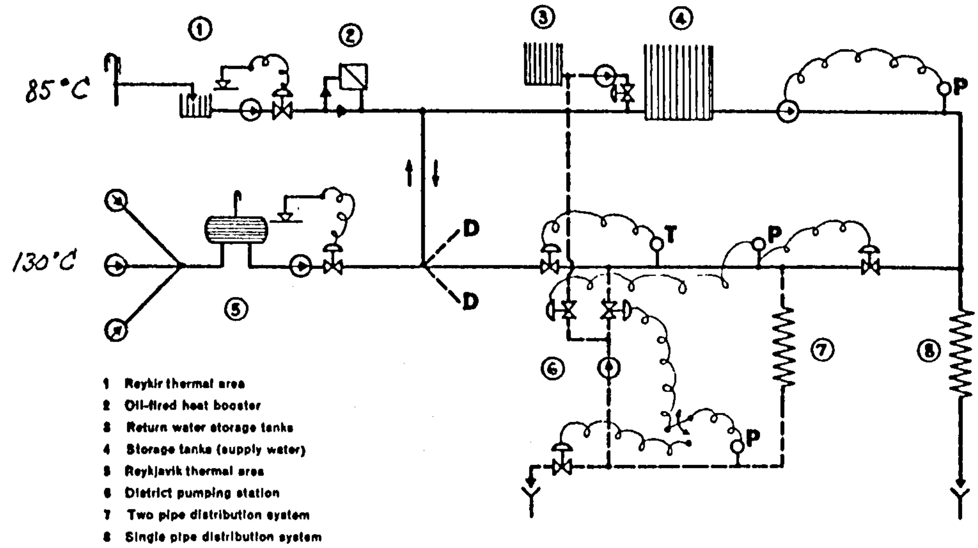


FIG. 2.—*Schematic diagram of system*

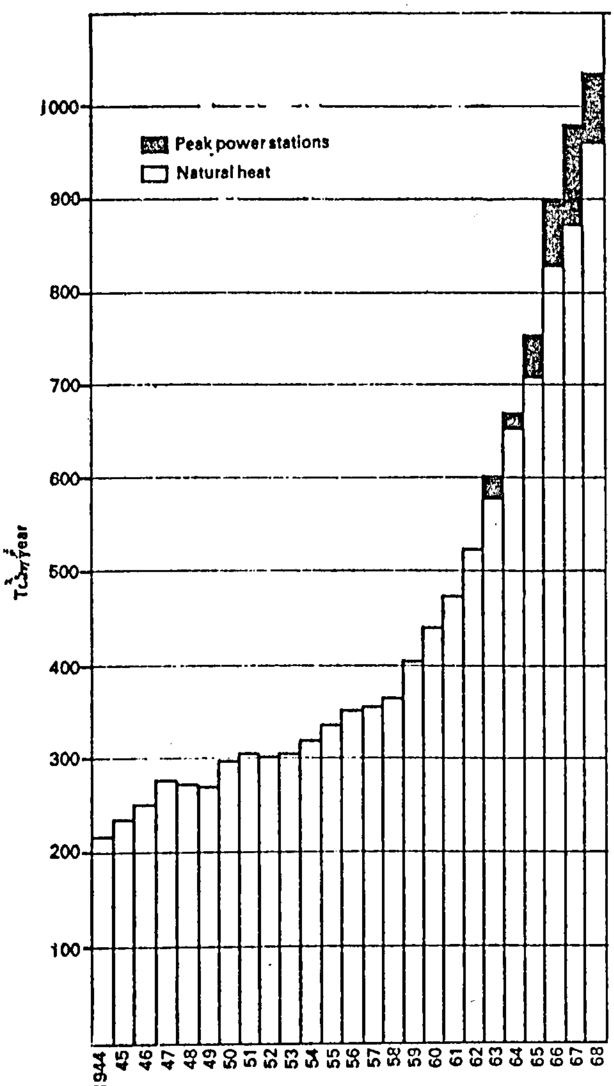


FIG. 3.—*Yearly heat production*

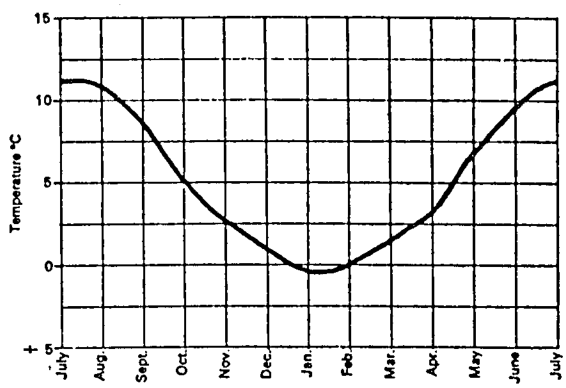


FIG. 4.—*Monthly mean temperature in Reykjavik 1931–1960*

The pumps are regulated (speed regulation) by a pressure controller at a selected point in the distribution system.

In order to utilize water at 120°C and higher, and yet maintain the water supplied to the houses at a suitable temperature for heating and domestic use (80°C), combined single and two pipe systems have been built, making possible mixing of the high temperature water with return water from the two pipe system while at the same time draining the system through the single pipe part of the system.

The piping arrangement in pumping stations serving these combined districts is such (Fig. 2) that only the return water is pumped, the high temperature water being led into the supply main on the pressure side of the pumps.

Temperature of the supply water is regulated by an air operated regulating valve in the high temp. pipe, controlled by a temperature controller in the supply pipe. Pressure in the system, both in the supply and return pipes, is regulated by valves controlled by pressure regulators at suitable points in the system. Each district pumping station is equipped with two pump units, one of which is sized for 100 per cent capacity, the other for 70 per cent.

All pumping stations, apart from borehole pumps, are fully automatic; they do, therefore, not require constant control, but are looked after by 10 engineers visiting each station several times a day. During the winter season a full 24 hours watch is maintained.

At the time of writing (Dec. 1969), an electronic system is being commissioned which enables remote supervision of all pumping plants and borehole pumps from a central control room; a number of other operations can also be con-

trolled, such as the starting and stopping of pumps. Automatic data-logging is also included for all stations, recording e.g. temperatures, pressures, and amount of water pumped by each station.
The total number of district distribution stations is 9 with an overall pump rating of 2576 HP.

4.3 Distribution System

4.3.1 *Heating Load*
The total of houses heated by district heating in the city in terms of volume is 10·3 million m^3, and the corresponding heating load based on $-10°C$ outside and $+20°$ inside temperatures is 190 Gcal/hr, or approx. 19 kg cal/hr m^3:

4.3.2 *Load Density*
The load density of the system is rather low, as many of the houses in the city are single family houses standing in rather large grounds. The average density is 17 Gcal/hr km^2, and 1·5 Gcal/hr km when referred to mains length. House connections from street mains are not included in the latter figure; these are also comparatively long.

4.3.3 *Heat production*
Fig. 3 shows the yearly heat production of the system since 1944 and its division into geothermal heat and that produced by oil boilers. This figure also shows the growth of the system as described in chapter 2; the heat production has nearly trebled in the past 10 years, from 360 Tcal/year in 1958 to 1035 Tcal/year in 1968.

4.3.4 *Load distribution*
The climate in Reykjavík is very suitable for district heating, especially geothermal, as the available heat is consistent and the variable production costs are a very small part of the total production costs.
The mean temperature of the year is 5°C (41°F), the mean of July being 11·2°C (52·2°F) and that of January $-0·4°C$ (31·3°F). Fig. 4 shows the monthly mean temperatures.

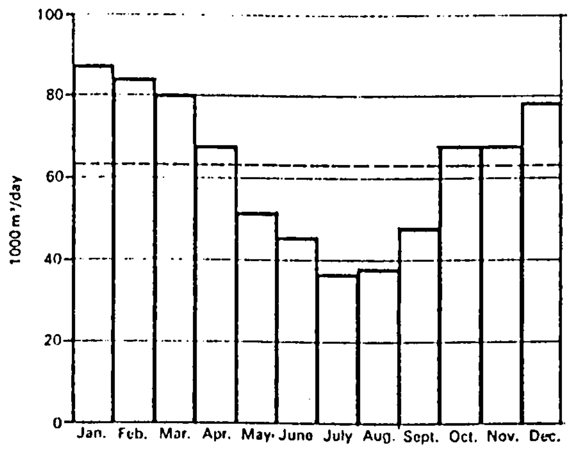


Fig. 5.—*Monthly water production 1968*

The difference between the mean temperature of the hottest and the coldest months is only 11·6°C (20·9°F). Fig. 5 shows the relatively even distribution of load through the year, the January load being only 2·3 times that of July.
These figures reflect the island climate prevailing in the south-western coastal area of Iceland, and the influence of the Gulf Stream balancing the temperatures. Due to the low summer temperatures, the heating season lasts throughout the year.
On the other hand, the weather in Reykjavik is very unstable, as indicated in Fig. 6, which shows the daily mean temperatures during the winter months of 1968–1969, which were exceptionally cold. Wind velocity is no more stable than temperature and can become very high. On average, we have 14 days of storm (wind velocity above 40 knots) each year.
Very low temperatures with high wind velocities do nevertheless not last long at any one time, and days with temperatures below $-5°C$ (23°F) are on average fewer than 10 in any one year.

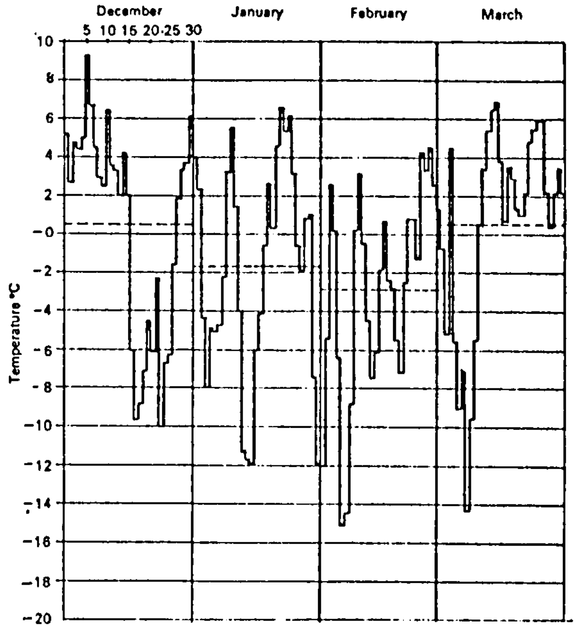


Fig. 6.—*Daily mean temperature Dec–March 1968–69*

As the District Heating System obtains its energy in the form of hot water from the ground, storage tanks can be used to carry it over short periods of cold weather, lasting for a few days only. These tanks are also used to supply peak demand during daytime, which is 15–30 per cent over the mean load for the 24 hrs, the maximum amount produced hourly being even.
Due to these facts described, the number of equivalent hours at full load (load factor) is very high for this system as compared to current figures in Europe or North-America, the average figure being about 5000 hours pr. year, or 57 per cent. The capacity of the system's oil fired peak boiler plant is approximately 15 per cent of its total capacity and the load factor of the geothermal heat alone therefore becomes 5800 hrs/yr or approx 66 per cent.

4.3.5 *Distribution Network*
The pipes used in the system are longitudinally welded black steel pipes to standards DIN 2440 up to 6″ and to DIN 2458 above 6 .
Street mains larger than 3″, supply and collecting mains, are laid in buried concrete channels, and insulated either with rockwool or aerated concrete. Air venting troughs are formed in the insulating concrete, just under the channel cover and drains at the bottom (Fig. 7). The channels are embedded in hard core, together with concrete drain pipes. Minimum inclination of channels is kept at 5 °/oo. At street junctions, the channels meet in concrete chambers, containing valves, fastening bolts, expansion joints, etc. These chambers are ventilated, and either drained from the bottom or, if that is not possible, they have a pump pit. Smaller street mains and house connections from street mains are insulated with polyurethane foam insulation, protected by a water jacket of high density polyethylene. These pipes are prefabricated in lengths of 6 m, the PE jackets joined by sleeves of PVC, sealed at both ends by rubber rings, heat shrunk for further tightness, and foamed in situ.

Figures on pipeline lengths are as follows:

Collecting mains	14·2 km
Supply mains	29·1 km
Street mains	125·2 km
House connection	120·4 km

4.3.6 *Consumers connections*
Central heating has been a general rule for all housing in the city for the past 40–50 years, the vast majority having radiator heating systems, so that direct connection is nearly always employed (Fig. 8).

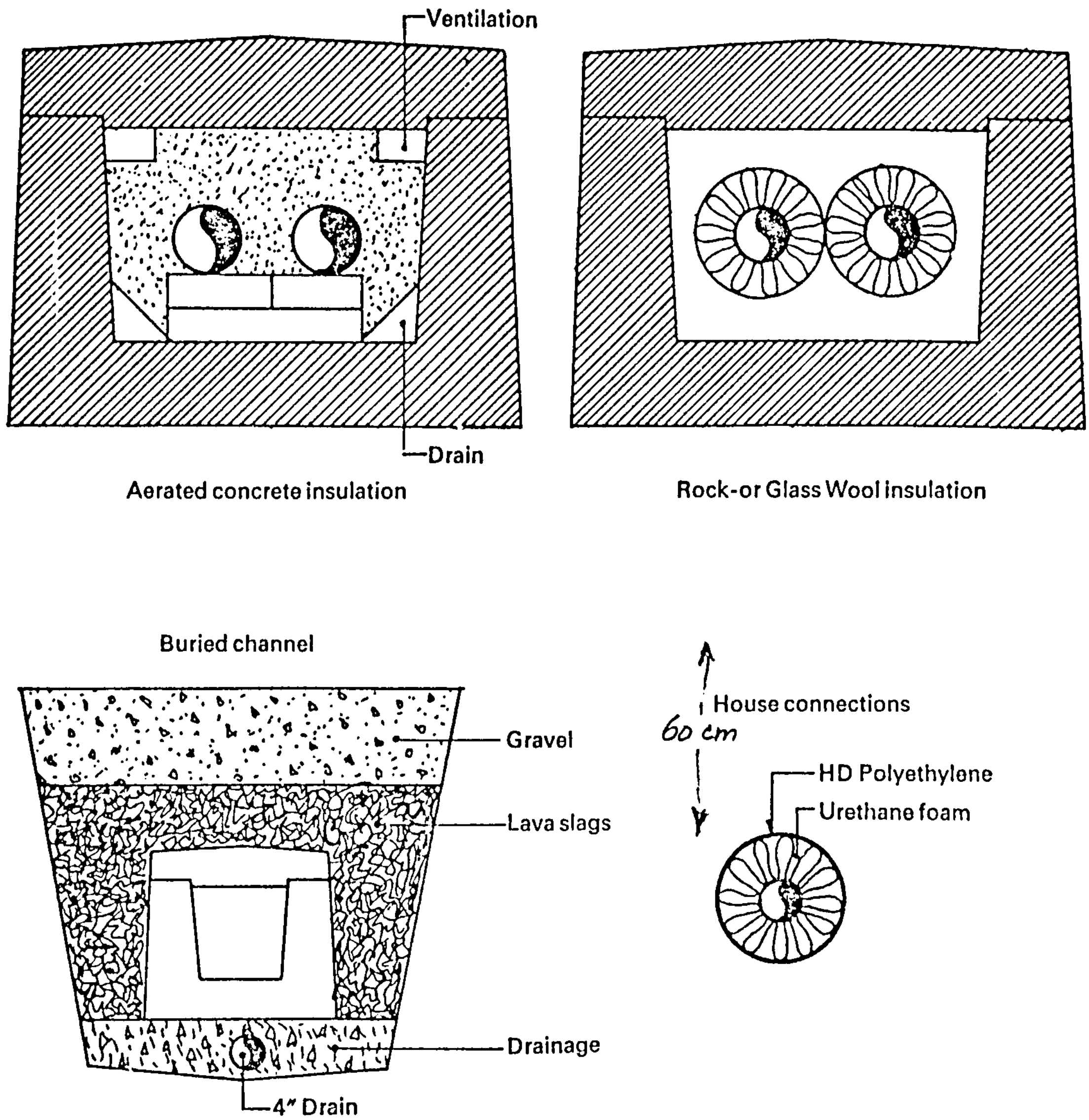


FIG. 7.—*Street main channels*

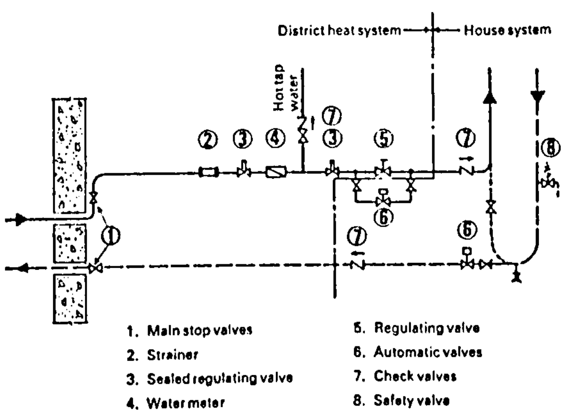


FIG. 8.—*House connection*

Hot domestic water is also supplied directly, and water meters are therefore included in the supply pipe.

Inferential water meters are used, with magnetic coupling between water-wheel and register mechanism. The District Heating System supplies water to each consumer at a certain minimum pressure in a single pipe system, or in a double pipe system; it maintains a certain minimum pressure difference, keeping the return mains pressure within reasonable limits, to supply sufficient back pressure without overloading the house systems.

A minimum of automatic control equipment is mandatory to ensure proper utilization of the water, and supply is limited, by sealed maximum regulators, according to the heat requirements of each consumer.

Generally the control equipment consists of a solenoid valve, connected in series to a room thermostat, and a high limit temperature switch mounted in the return pipe from the radiators. In the last few years, individual thermostatic valves fitted in the return of each radiator have become popular.

5. Costs

5.1 Capital Costs

The capital cost of the District Heating System is usually divided into two main parts, which breakdown as follows:

I. Heat production:
(1) Drilling
(2) Borehole development
(3) Collecting mains
(4) Main Pumping Stations
(5) Supply Mains

II. Distribution System
(1) Distribution Pumping Stations
(2) Street Mains
(3) Service Branches
(4) Consumer Connections

The cost of the various items is very variable. In the first group it varies with the capacity of the thermal areas, the number and distribution of boreholes in the area and the distance of the area from the distribution stations.
In the latter group, the cost varies with the size of the distribution systems, their load density, type of ground in the districts, etc.
As the borehole water is piped directly into the distribution system, it is possible to build a part of it as a single pipe system with the water having spent its heat in consumers' radiators being returned to the drains.
This makes the distribution network cheaper, as the cost of a single pipe network is only about 70 per cent of a two pipe system.
With present day methods and equipment the average capital costs come out as follows:

I. Heat production	2·6 million kr/gcal/hr or 12,400 £/gcal/hr	
II. Distribution System	5·1 million kr/gcal/hr or 24,200 £/gcal/hr	
Total	7·7 million kr/gcal/hr or 36,600 £/gcal/hr	

The total replacement value of the District Heating System today, amounts to approx 1500 million kr. (£7·1 million) without depreciation.

5.2 Operation Costs

The costs of operation for the year 1968 were as follows: (£1·0 = 210 icel. kr.)

Revenue:		
Hot water sales	ikr.	188·0 million
Meter rent charges	ikr.	15·3 „
Total	ikr.	203·3 million
Expenses:		
Pumping plants	ikr.	31·0 million
Peak power plants	„	21·3 „
Maintenances of distributing Network	ikr.	26·6 million
Office costs, billing, collecting	„	10·5 „
Research, social expenditure etc.	„	3·8 „
Depreciation	„	47·1 „
Total	ikr.	139·3 million
Income from operation	ikr.	64·0 million

5.3 Unit Prices

The hot water is sold on a unit volume basis, as metered at consumers' premises by water meters, the charge at present being ikr. 13·92 pr cubic metre, including a purchase tax of 7·5 per cent; to this is added meter rent amounting on average to approx. 7 per cent of the yearly consumption.

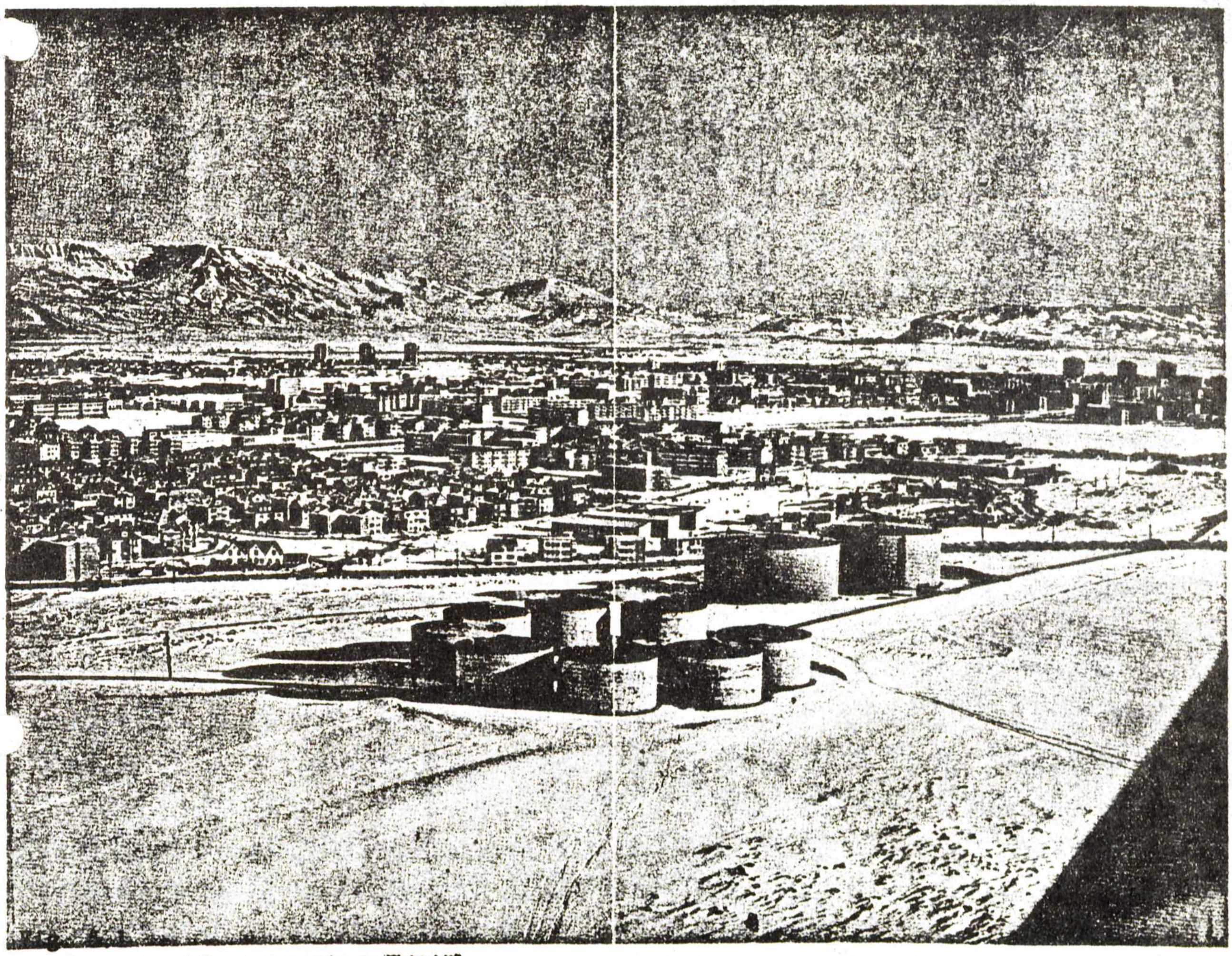
Taking into account domestic hot water, supplied directly from the system's supply pipes, the unit heat price is ikr. 350 pr Gcal (£1·7 pr Gcal). The unit heat price for fuel oil today in Iceland is ikr. 560 pr. Gcal (£2·7 pr Gcal).

6. Future Prospects of the System

The city of Reykjavik has now a little over 80,000 inhabitants, and nearly all its houses are connected to the District Heating System.
Geothermal energy is still very little used for industrial purposes, chiefly for the reason that the supply temperature of the distribution system 80°C is not high enough.
It is believed that the available geothermal energy in the city and its vicinity is now more or less fully utilized.
At a distance of 30 km from the city, there is a thermal area where temperatures of above 260°C have been encountered.
This heat can be transmitted to the city as water at 150°C–200°C, i.e. of a temperature that is sufficiently high for various industrial uses, e.g. the fish and other food industries.
The growth of the city also demands increased energy for heating and in its immediate vicinity there are communities with approx 30,000 inhabitants who do not yet enjoy district heating.
When developing high temperature thermal areas, it is feasible to utilize part of the heat available for the production of electricity via steam turbines.
Such power, among other things, could then be used for pumping water from the field to the city. With the increased development of geothermal energy the prospects of greenhouse manufacture in the city and its vicinity are also enhanced, which is important in view of the proximity of a market.
This will give an idea of the work ahead for District Heating over the next decade.

1968 Cost of building index ~ 350

1974 ~1290



A bird's-eye view of the storage tanks on Öskjuhlíð.

UTILIZED NATURAL HEAT

Thus the Reykjavík District Heating Service receives it's energy from three thermal fields, Reykir, Reykjahlíð and Reykjavík, the amounts of water and its temperature being as follows:

Reykir	250 l/sec. (3900 gpm)	at	86°C (187°F)
Reykjahlíð	130 l/sec. (2000 gpm)	at	86°C (187°F)
Reykjavík	300 l/sec. (4700 gpm)	at	128°C (260°F)
Reykjavík	180 l/sec. (2800 gpm)	at	103°C (218°F)

Due to the higher temperature of the water obtained in Reykjavík, it's useful heat value is more than three times that of the water from Reykir and Reykjahlíð together.

OIL FIRED BOILER PLANTS

When planning the economic use of natural heat for house heating, a certain low outside temperature limit is drawn, at which the natural resources shall be sufficent to meet the demand, and the size (heating capacity) of the distribution system decided upon accordingly. The Reykjavík system is designed to meet the heating load of the city at ÷10°C (÷14°F). In colder periods, the increased load is met in two ways; by storing hot water in storage tanks, and by operating oil fired peak power stations.

In 1967 the service built such a plant at Arbaer, its thermal power being 30 Gcal/hr (120 million BTU's) corresponding to 200 l/sec. (3100 gallons pr. minute) of water at 86°C (187°F). In addition the service can obtain assistance from the Electricity Board's peak electric power

Table 5.1. **Reykjavík Municipal District Heating Service**

Some Statistics

	(1) Production of Hot Water Thousands of tons (metric)	(2) Number of houses Connected at end of year	(3) Number of individual heating systems at end of year	(4) Total volume of connected houses cubic metres x1000	(5) Total no. of inhabitants in Reykjavik at end of year	(6) Number of inhabitants enjoying District Heating at end of year	(7) % of inh tants enjoying District Heating at end of year
1961	9.980	4.429	6.539	5.339	73.388	37.800	51
1962	11.360	4.766	7.603	5.792	74.978	41.142	55
1963	12.825	5.119	8.438	6.367	76.401	43.744	57
1964	14.451	5.644	9.647	7.365	77.220	52.927	68
1965	15.663	6.287	10.836	8.142	78.300	55.793	71
1966	18.643	7.382	12.616	9.336	78.982	64.582	82
1967	21.884	8.058	13.870	10.411	79.813	69.761	87
1968	22.967	8.506	14.657	10.707	80.942	71.182	88
1969	23.982	8.818	15.222	11.183	81.354	73.263	90
1970	24.330	9,279	15.912	12.038	81.561	76.603	94
1971	25.614	9.669	16.525	12.715	82.693	79.331	96
1972	26.967	9.924	16.962	13.174	83.831	81.961	98
1973	30.639	10.510	17.786	14.198	84.299	83.160	98.6

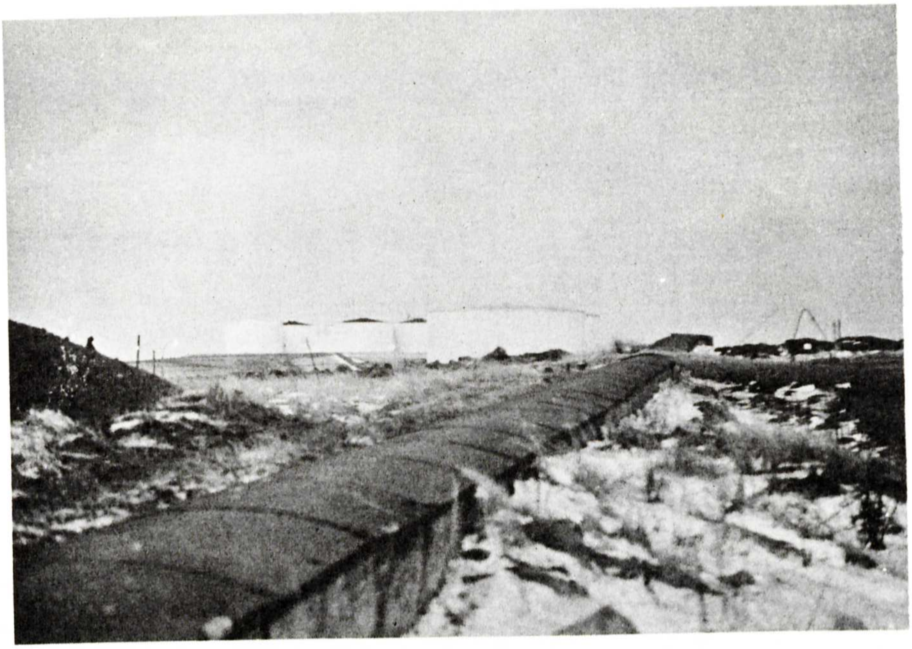


Figure 5.2: Hot water main supply line and storage tanks in background

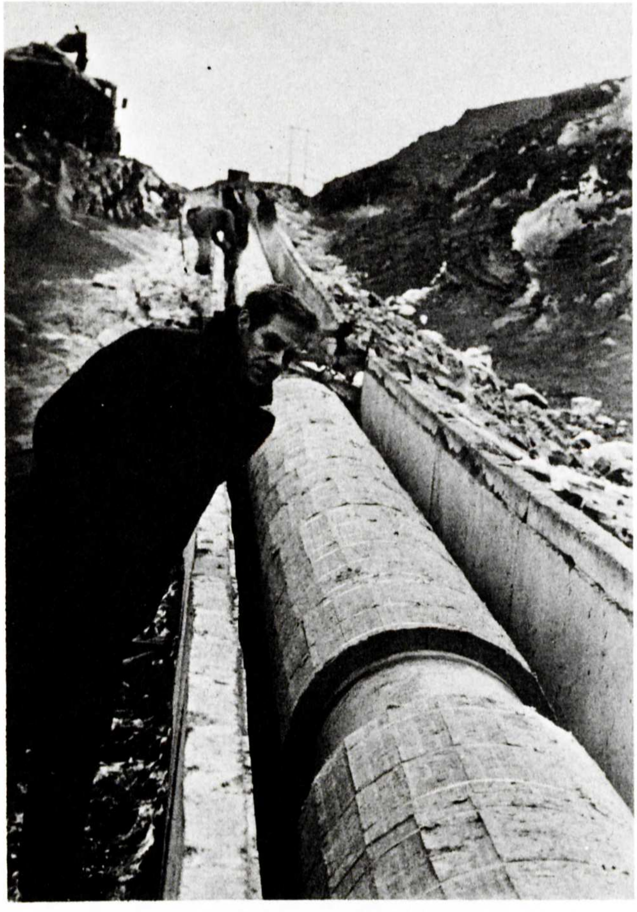
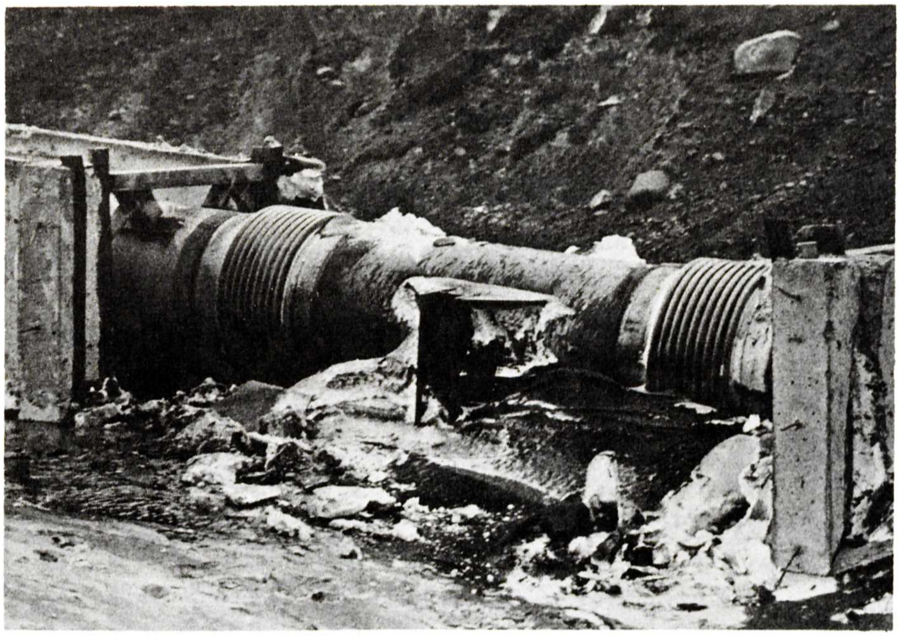


Figure 5.3: New main supply line under construction



5.4: Bellows for compensation of thermal movement

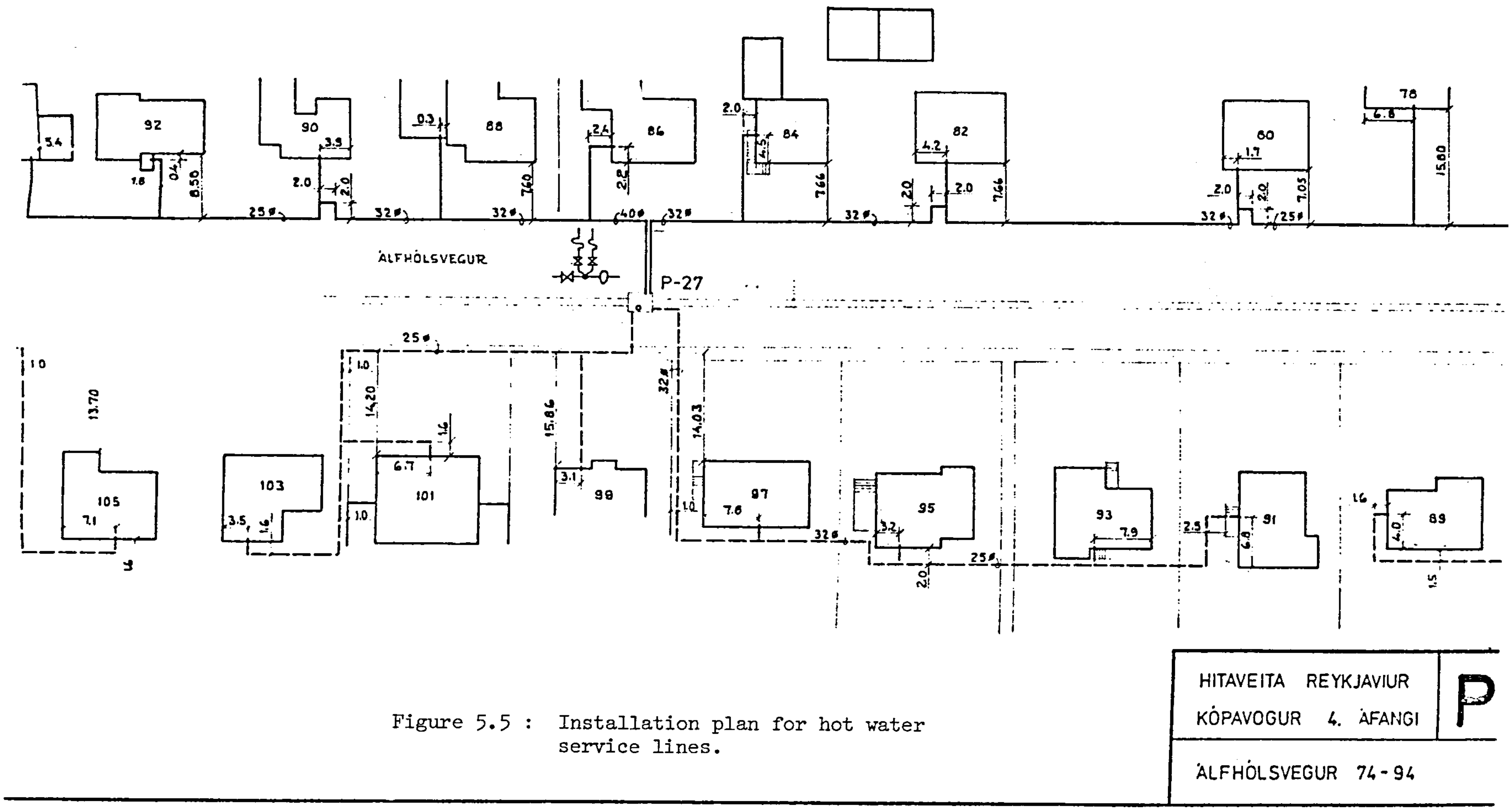


Figure 5.5 : Installation plan for hot water service lines.

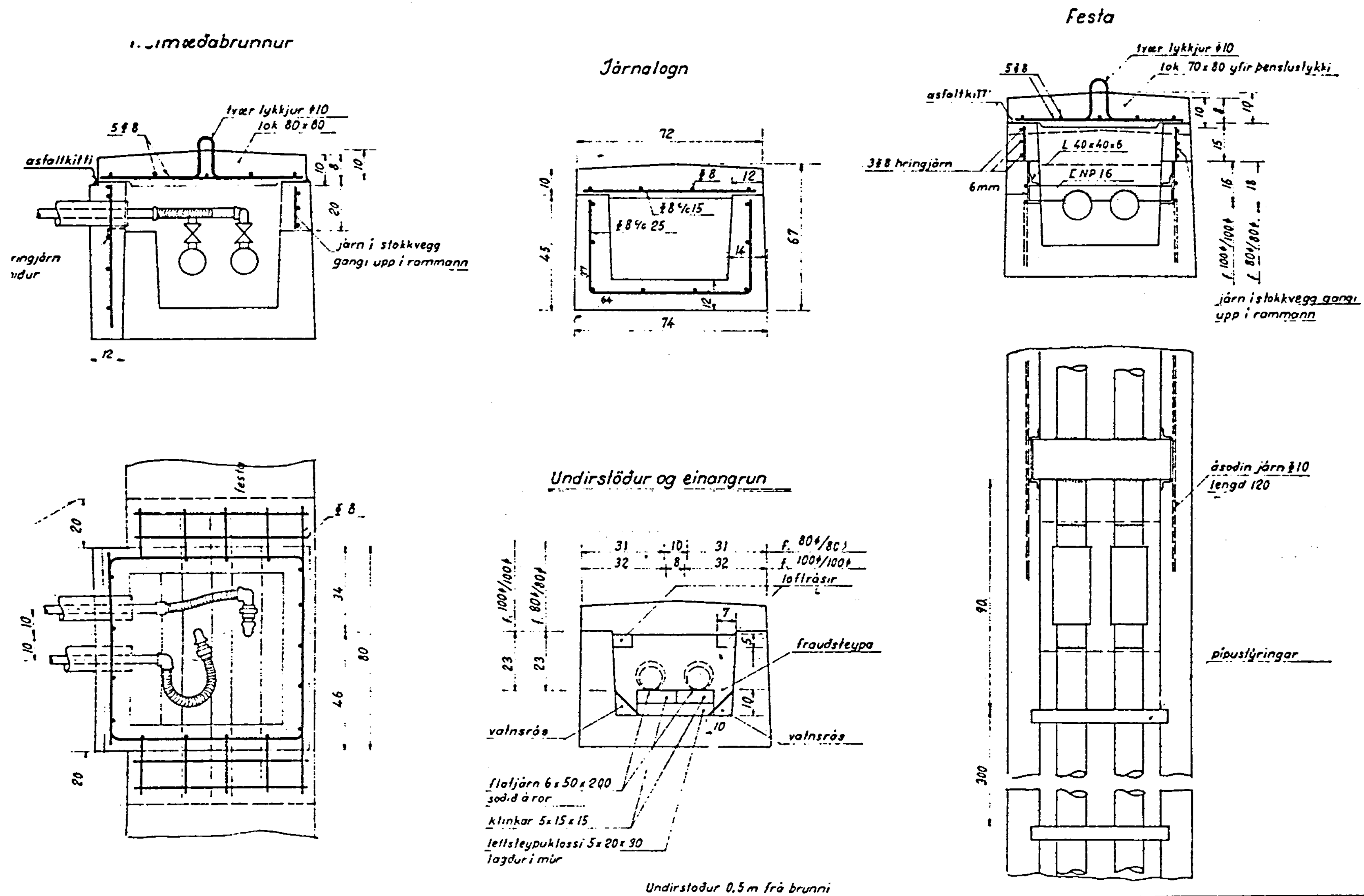


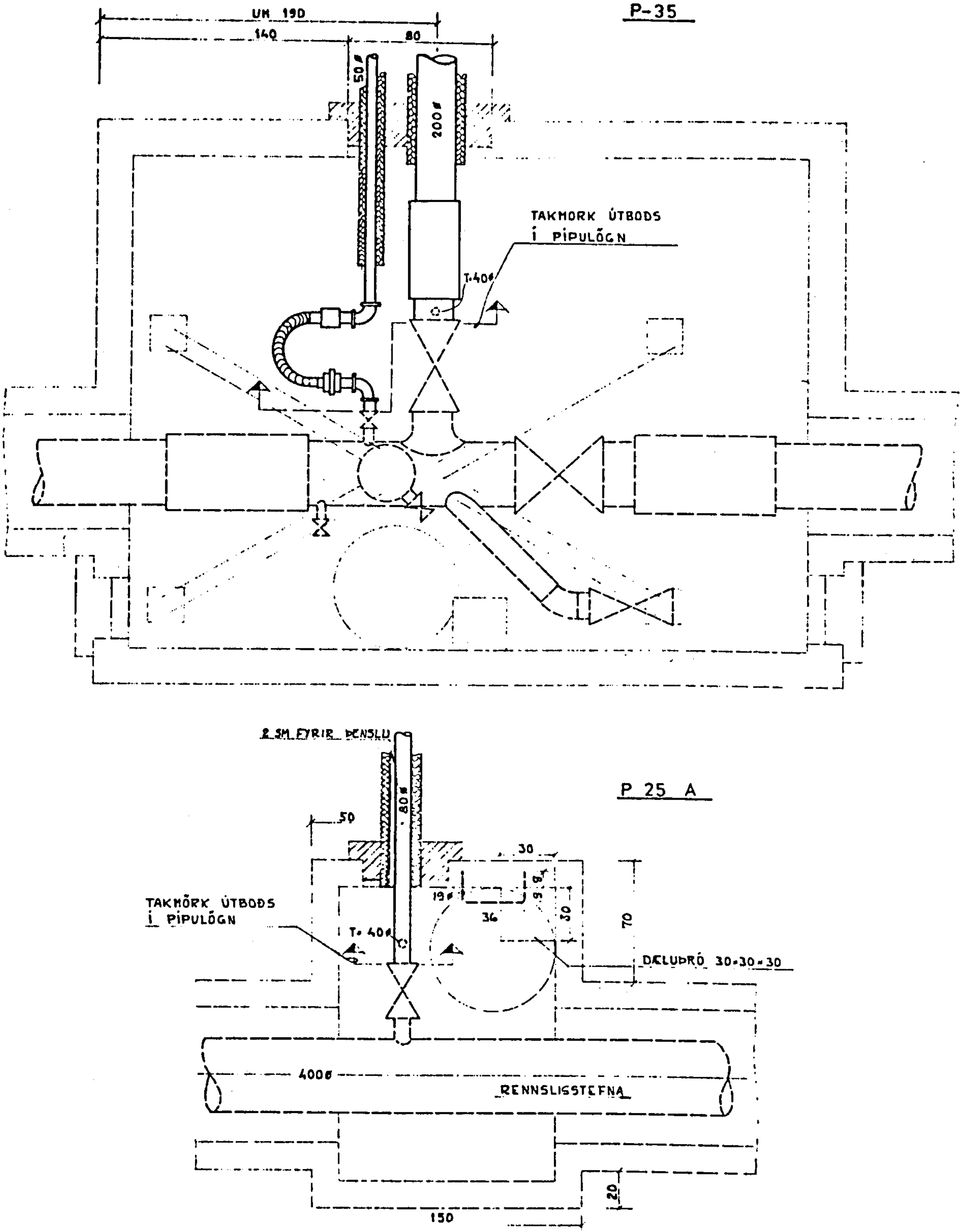
Figure 5.6 : Details of street mains and service lines installation.

Undirstoður 0,5 m frá brunni
Fjarlægð milli undirstaða 3,5m.
Öll mál eru í cm nema á járnum og pípubvermalum

HITAVEITA REYKJAVIKUR K
BREIDHOLTSHVERFI III 1.ÁF.
STOKKUR GERÐ 22

FJARHITUN
VERKFRÆÐISTOFA
ÁLFTAMÝRI 9 SÍMAR. 21040 - 2104

Reikn. | Samþ. | M 1:10
Teikn. | Dags. Feb 1967 | Nr. 35 - 05



igure 5.7 : Details of street mains and service line connections.

EITA REYKJVÍKUR

KÓPAVOGUR 4 ÁFANGI

BRUNNAR P-34, -35, -35, -25 A

P

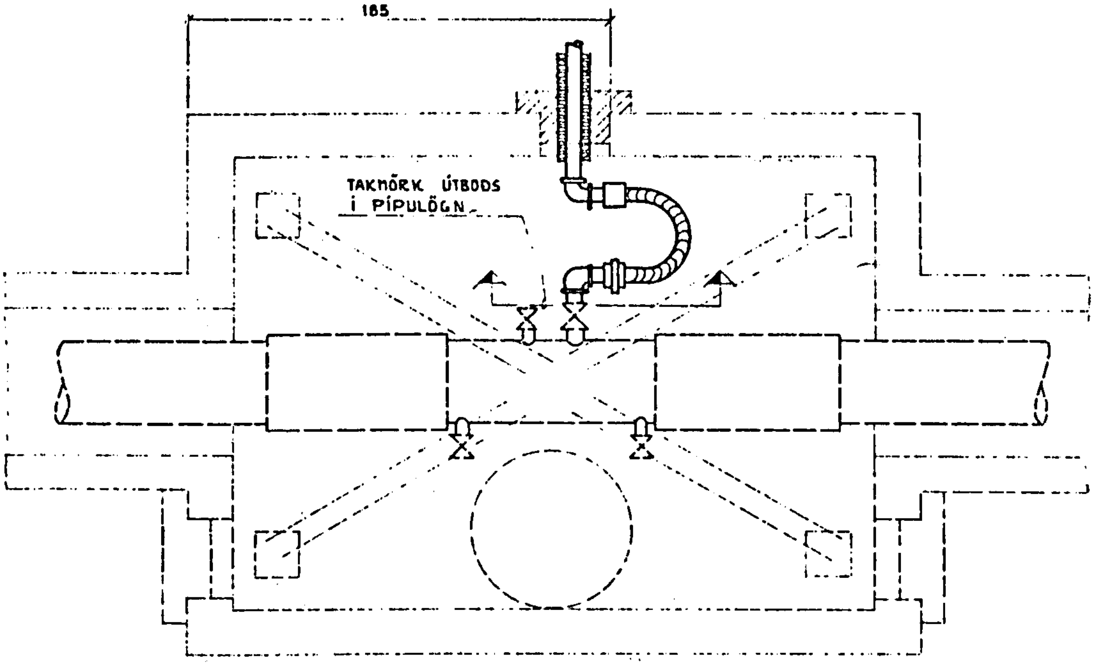
FJARHITUN HF

VERKFRÆÐISTOFA

ÁLFTAMÝRI 9 SÍMAR: 82040 - 82041

Reikn. Samþ. Mk. 1 : 20

P-34



P-36

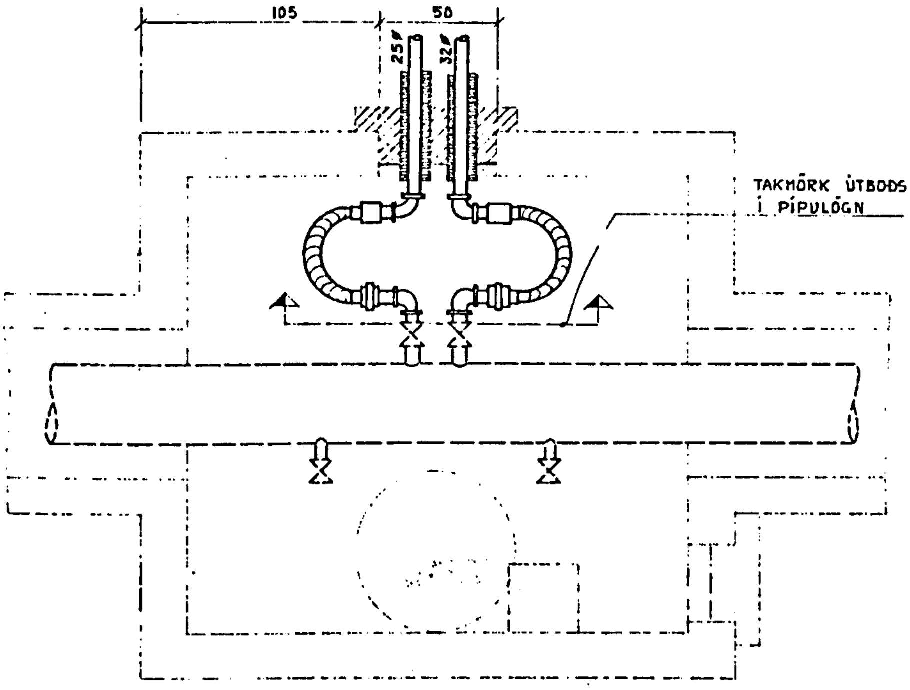
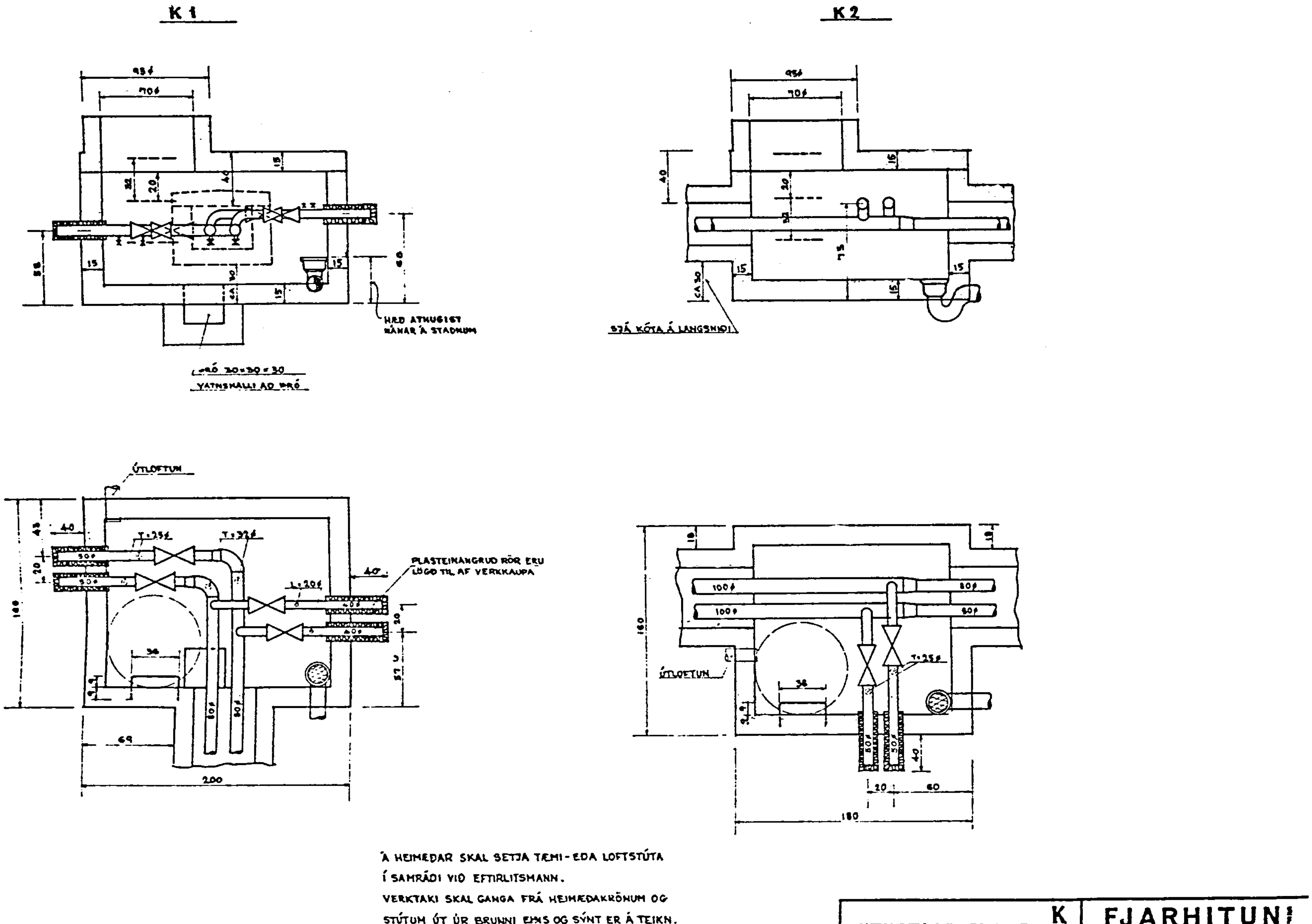


Figure 5.8 : Details of street mains and service line connections.



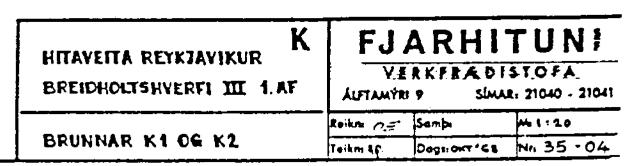


Figure 5.9 : Details of street mains and service line connections.

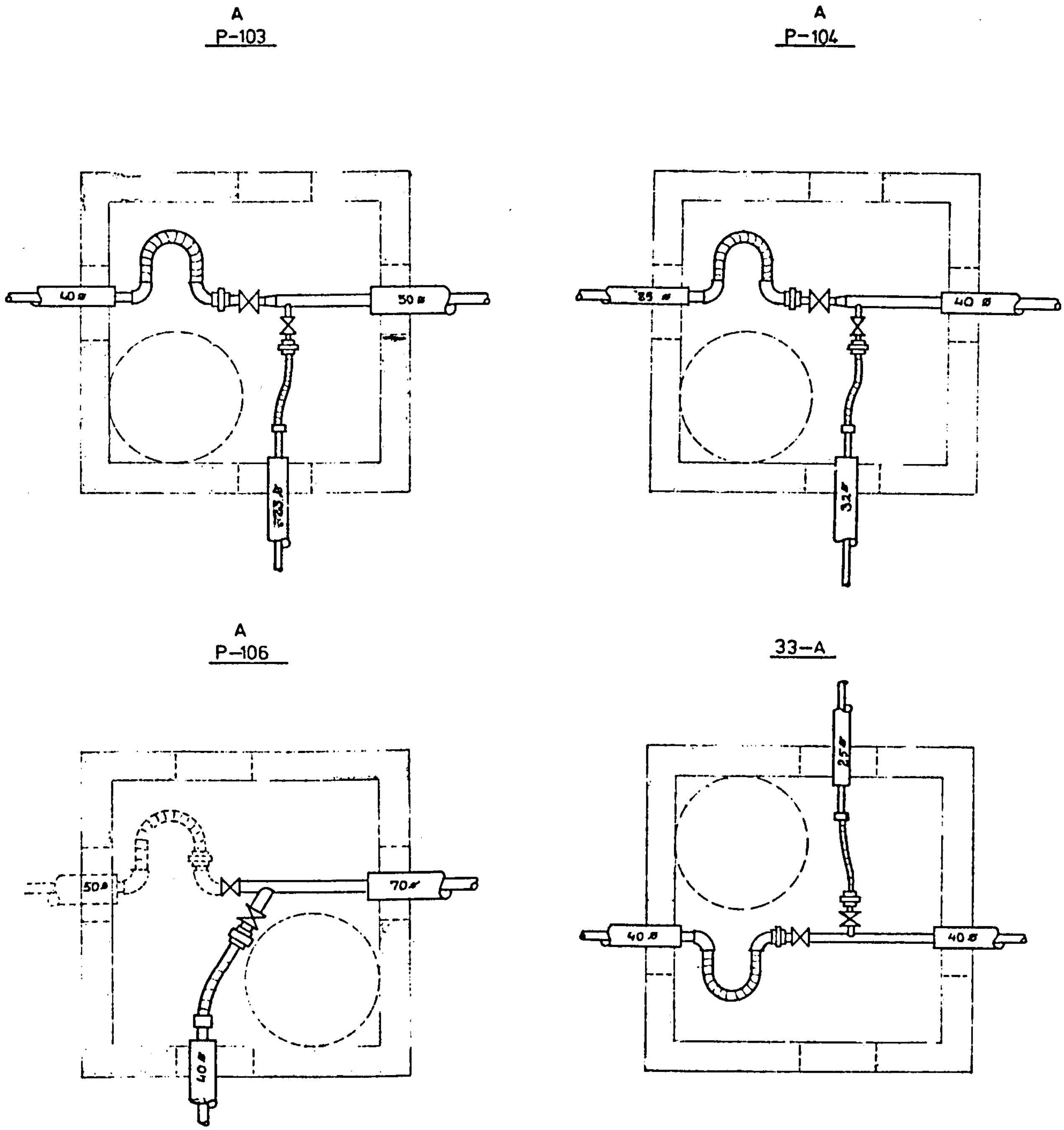


Figure 5.10: Details of service line connections.

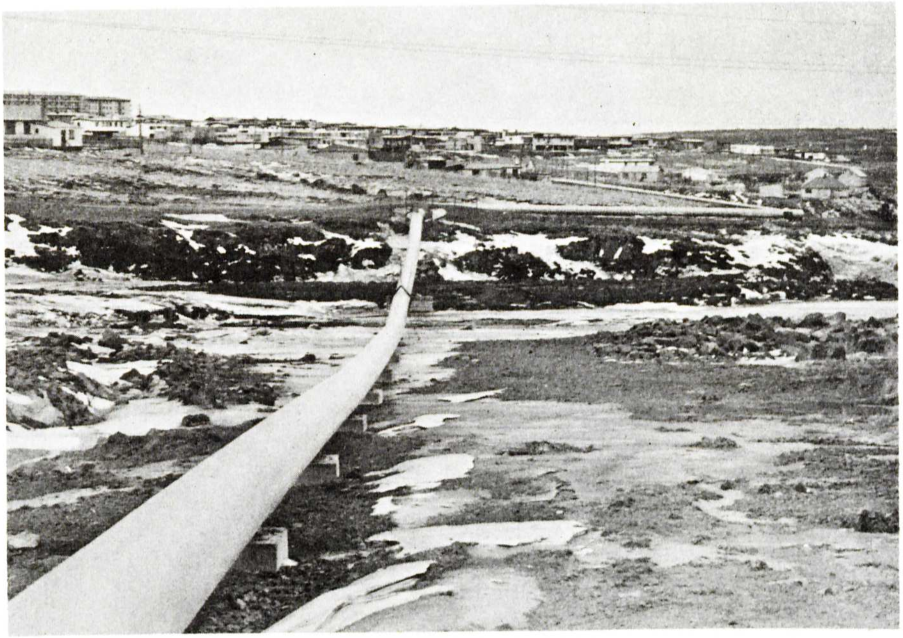


Figure 5.11: Temporary new hot water supply line

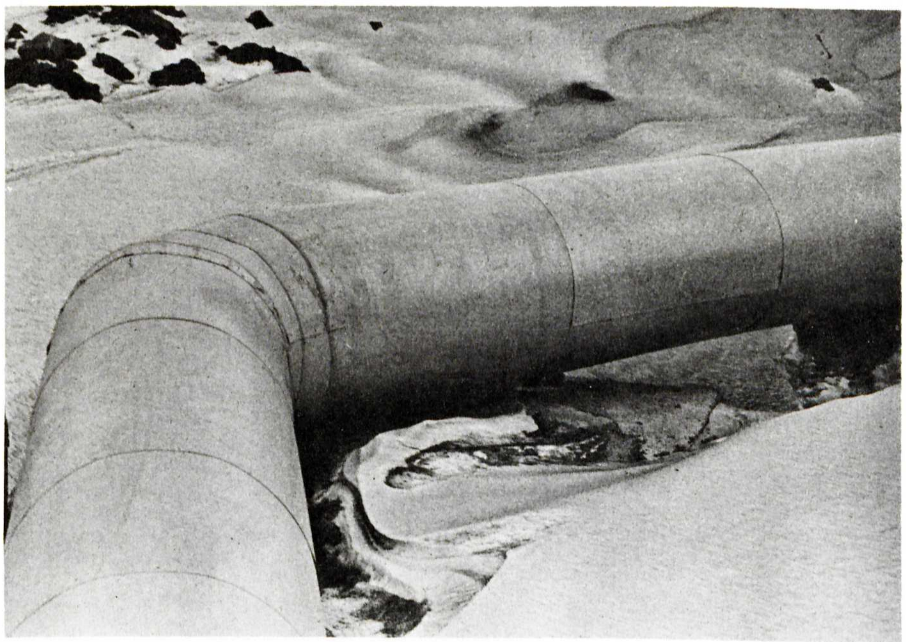


Figure 5.12: Close-up of temporary hot water line

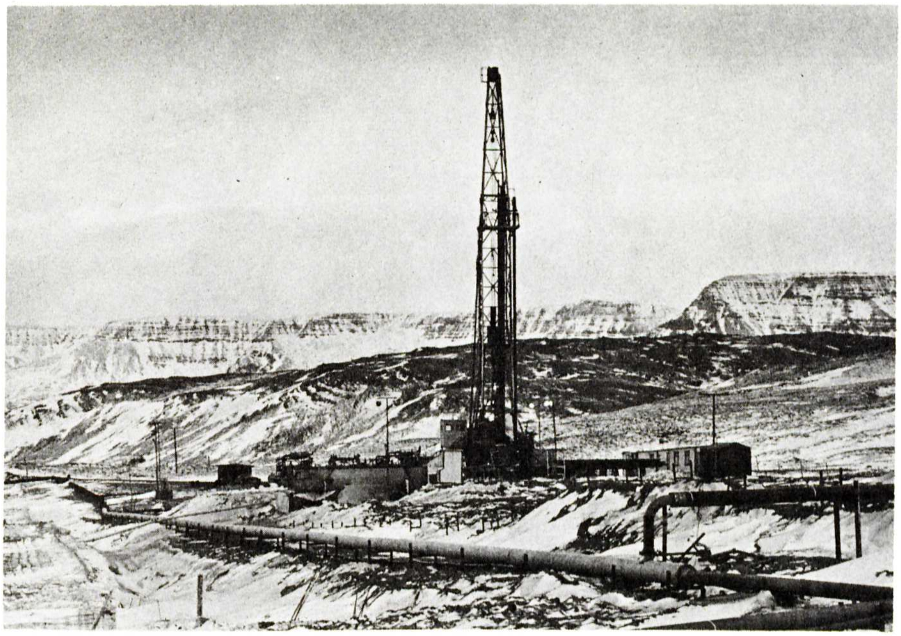


Figure 5.13: Drilling for hot water at Reykir

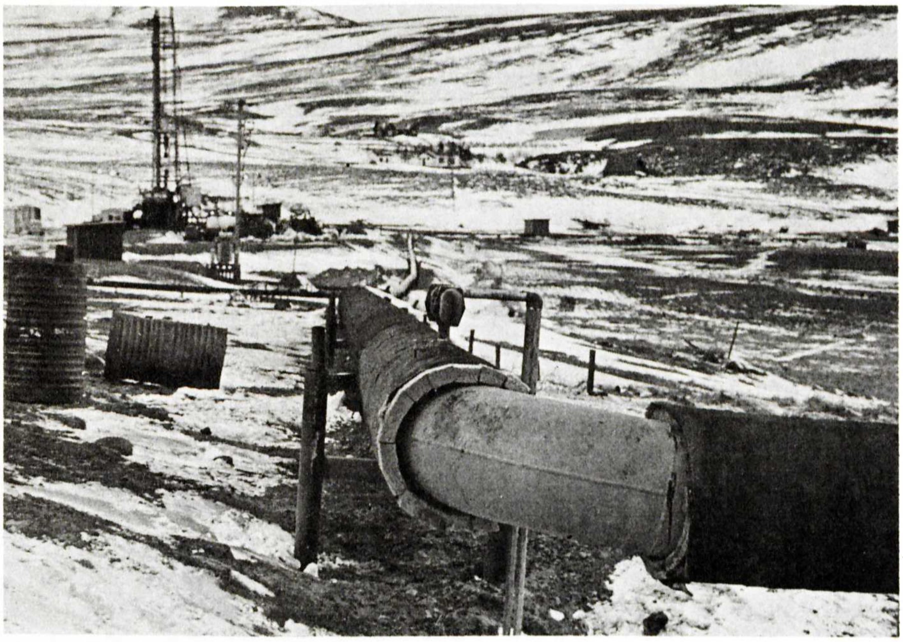


Figure 5.14: Hot water line from well to pump station

6. Geothermal Resource Development

The National Energy Authority is concerned with development of geothermal energy resources. The first application of geothermal hot water has been for space heating. Recently efforts are being directed at geothermal electric generation in connection with the discovery and development of higher temperature water and steam wells. The geothermal electricity will be complementary to hydroelectric energy because it can offset reduced hydropower in the winter and provide space heating after electric generation as in a heat and power plant. The cost of geothermal electricity is expected to be competitive with hydroelectric energy!

Geothermal areas near Reykjavik are shown in Figure 6.1. Areas 1 to 4 provide clean, potable water, originating probably from mountains to the east. Area 5 at Svartsengi provides brine which has a salinity 2/3 that of sea water.

Geothermal exploration methods are being developed through mapping of earth temperature gradients (Figure 6.2), geohydrologic surveys (Geohydrology of the Laugarnes Hydrothermal System in Reykjavik, Iceland; T. Thorsteinsson and J. Eliasson; Geothermics (1970) - Special Issue 2), and measurements of gravity, magnetic fields and resistivity (An Electrical Model for the Sub-Iceland Crust; J. F. Hermance; Geophysics, Vol. 38, No. 1.

In northern Iceland at Hveravellir, wells producing about 40 kg/s of clean water at 100°C (212°F) were developed in 1970. The water is transmitted 18 km (about 11 miles) to Husavik, population about 2000. The 10-inch pipe is uninsulated asbestos cement with rubber seal couplings, laid on the ground and covered with gravel most of the way. This inexpensive construction was chosen to achieve economic feasibility. The water arrives with a temperature of 82°C (180°F) which is just right for distribution.

Additional wells at Hveravellir, developed in 1974, are producing additional 40 kg s at 100°C. This water will be transmitted to Akureyri, population 10000, for district heating. The distance to Akureyri is 60 km (38 miles).

The geothermal field at Svartsengi is intended to serve the heating and electricity needs of Keflavik, the airport and air base, and several neighboring communities (Figure 6.3). Two 400-m wells drilled in 1971 are producing about 100 kg/s brine at 220°C (428°F). Two 1800-m wells are being drilled.

The brine will be used to produce steam and hot water from cold well water delivered from wells near Stapafell 5 km (3 miles) away. The heat exchange process is being tested in a pilot plant since January 1974. K. Ragnars reports on the project (Heat Exchangers Pilot Plant at Svartsengi, Iceland; April 1974). Figure 6.4, taken from his report, describes the process.

The only geothermal electric generating plant operating in Iceland has a capacity of 3 MW. Plans are being developed to install generating plants at sites where wells have been drilled producing hot water at 250 to 300°C (482 to 572°F). In comparison with hydroelectric plants, the geothermal generating plants will be of smaller unit sizes; their installed cost per kW may be also lower.

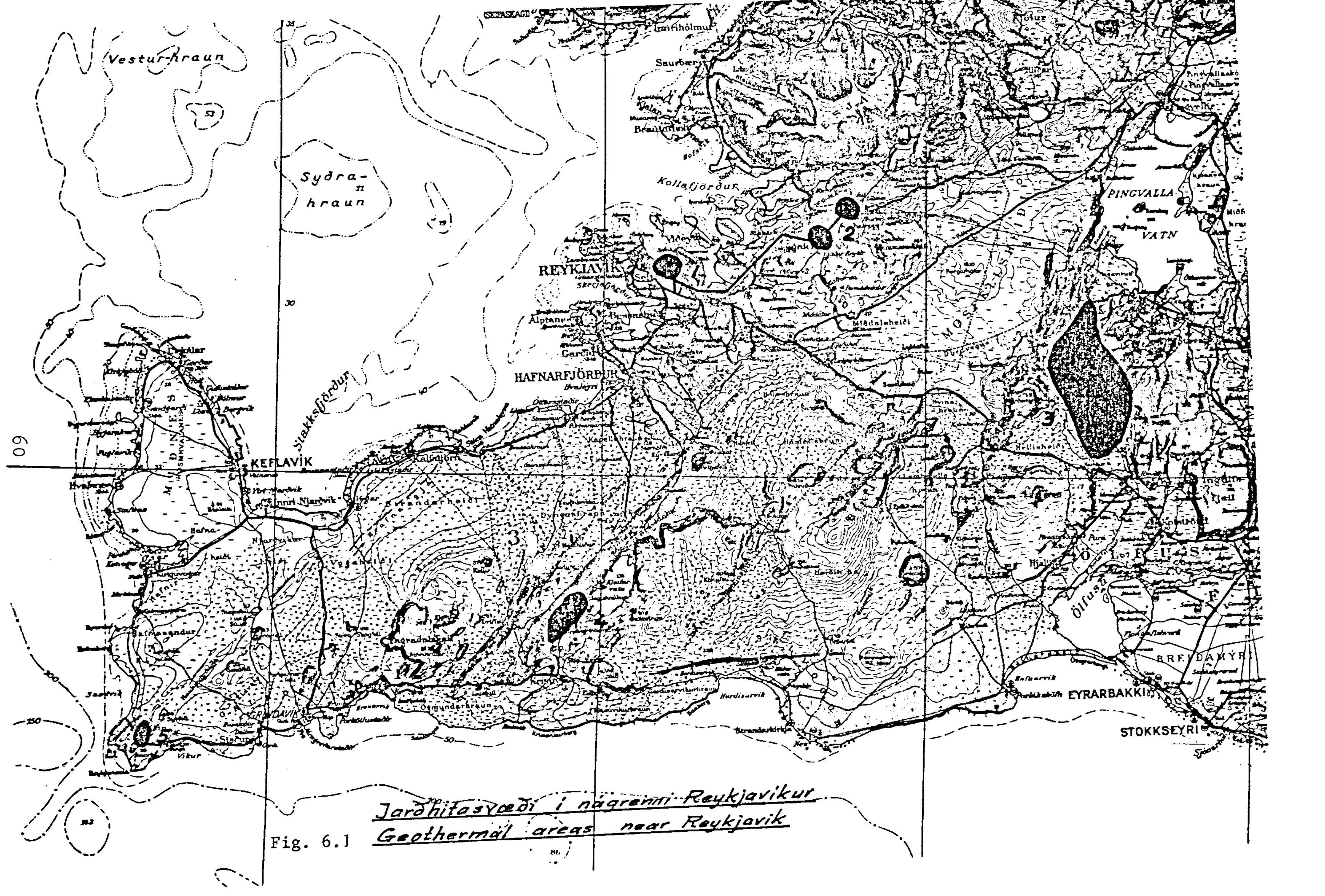
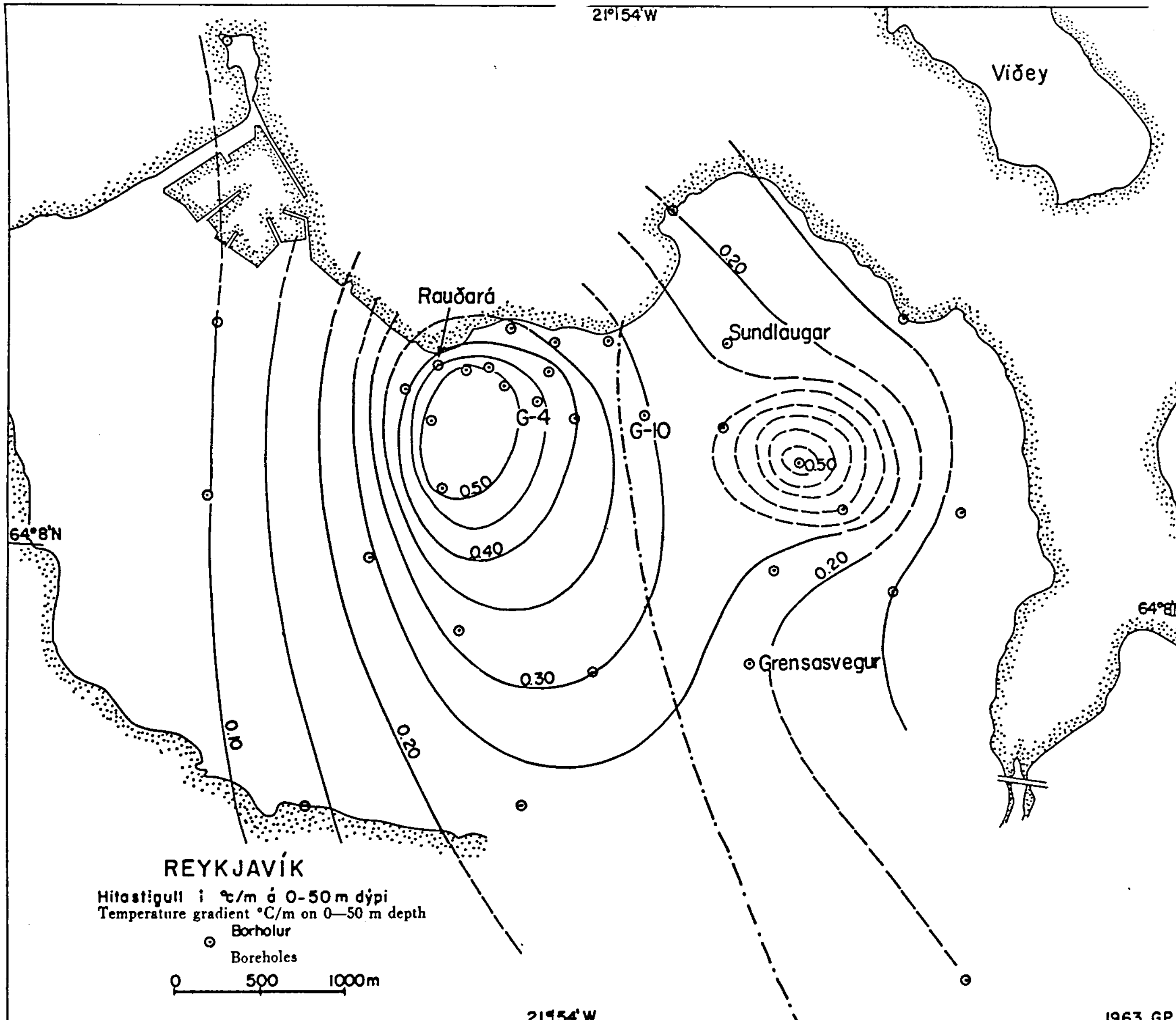


Fig. 6.1 Jarðhitasvæði í nágrenni Reykjavíkur
Geothermal areas near Reykjavik



MYND 2

Figure 6.2 : Temperature gradient map of Reykjavik.

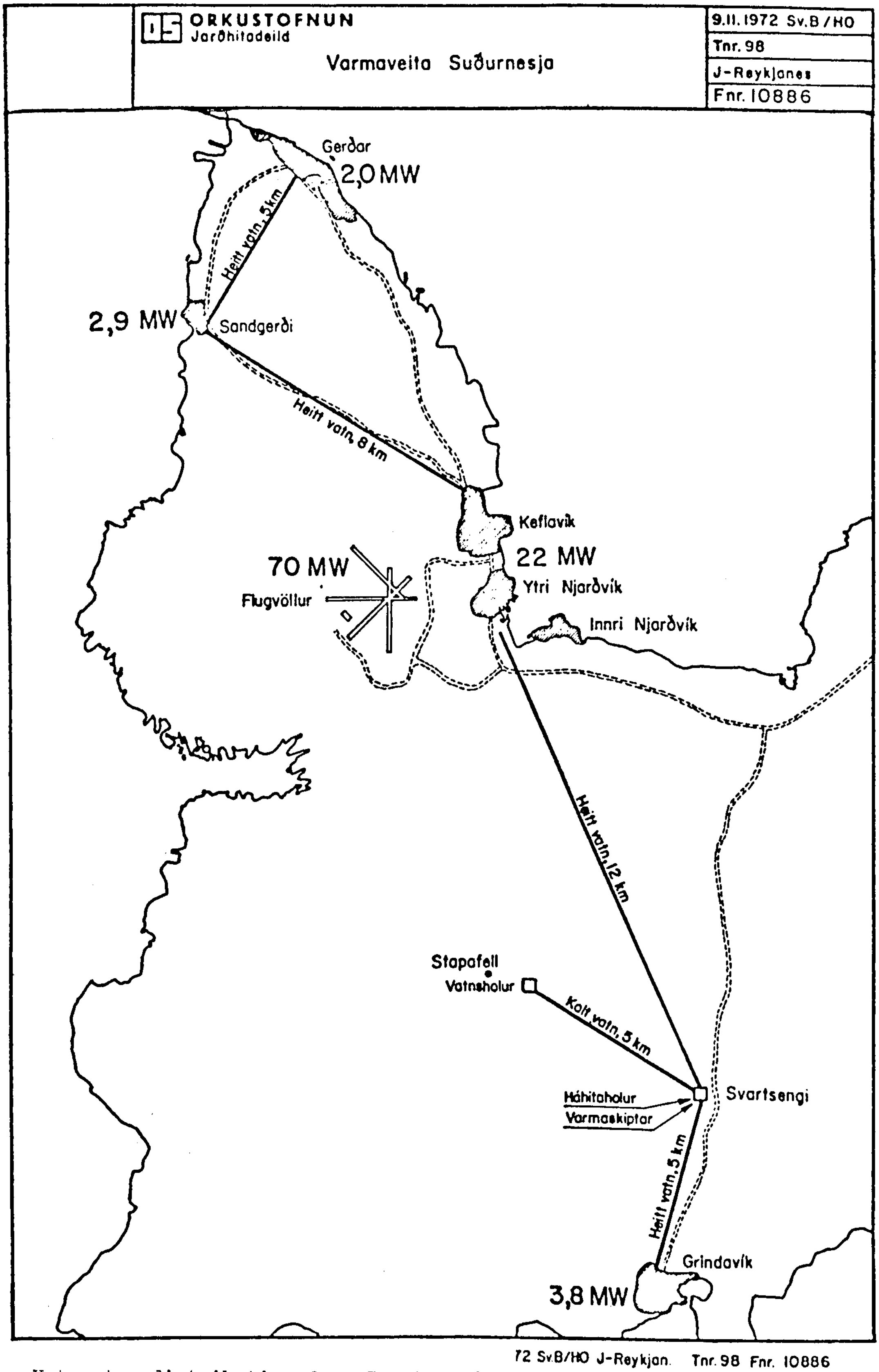


Figure 6.3 : Hot water distribution from Svartsengi.

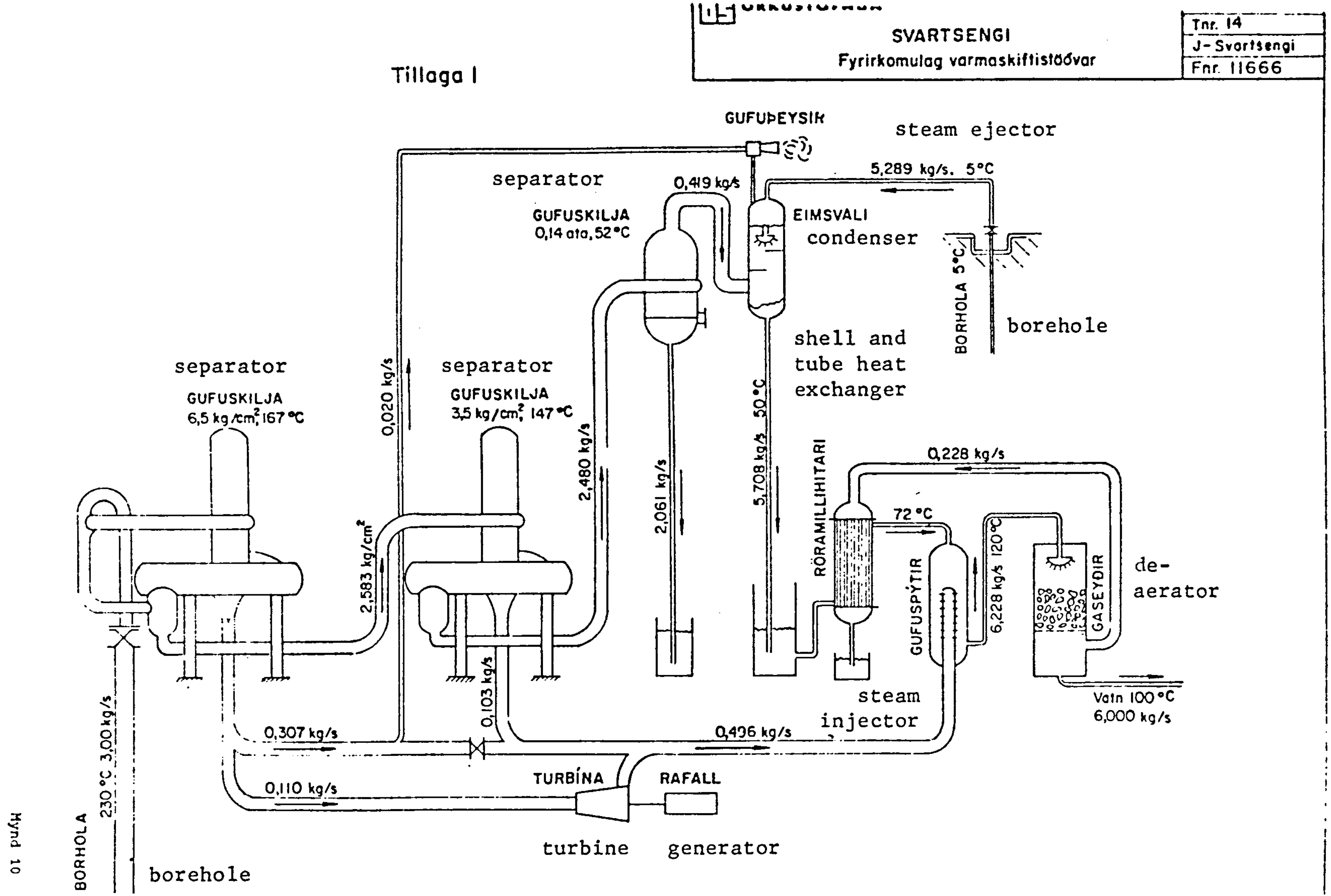


Figure 6.4 : Diagram of geothermal pilot plant at Svartsengi.