GEOTHERMAL DISTRICT HEATING IN TIANJIN, CHINA: PRESENT STATUS AND SUGGESTED DEVELOPMENT USING THE RESOURCES OUTSIDE THE CITY

Sun Kaiyao[+]

UNU Geothermal Training Programme,

National Energy Authority,

Grensásvegur 9,

108 Reykjavík,

Iceland

[+]Permanent address:

Tianjin Gas Company,

The West End of Chengdu Street,

Peace Area,

Tianjin,

People's Republic of China

"A beautiful tapestry of the Great Wall of China hangs on the wall of the United Nations building in New York. It was made in Tianjin. Some of this beauty is due to its treatment in Geothermal Water."

ABSTRACT

This report first introduces aspects of the present level of geothermal utilization in Tianjin and its status in China. The author then gives information which suggests that a development of the geothermal resources around Tianjin is feasible and would provide fossil fuel energy savings and an improvement in the local environment.

A preliminary technique feasibility study of a model district heating scheme for a residential area to the north of the Sports College is then presented. This is based on the known geothermal resource in the south western suburb. Data from a well in this area, Seismic Station No. 4, is used with information from wells in the other suburban areas to establish an assumed well performance on which the study is conducted. Following a discussion of the scientific and engineering capability of the Tianjin area it is concluded that to support a large development of district heating in the area, manufacturing facilities of some of the specialized equipment will have to be established.

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1 INTRODUCTION

1.1 Scope of Work

The author was awarded an UNU Fellowship to attend a 6 months Geothermal Training Programme in Iceland starting from April 1981. After an introductory lecture course lasting about four weeks in which an overview of geothermal exploration and exploitation methods and techniques was presented, the author received specialized training in the utilization of low temperature geothermal energy. This included lectures and practical exercises in geothermal district heating design and utilization, use of thermal water and flow rate measurements.

A two week field excursion included visits to a number of district heating services, the power station at Krafla (Northern Iceland) and most of the low and high temperature resources across the country.

The author is employed by the Tianjin Gas Company and is expected, on his return to China, to take charge of a programme for geothermal district heating in Tianjin. This report has been written in five weeks and represents a preliminary study of such a scheme for the city.

1.2 General Situation of Geothermal Utilization in the World and in China

Tianjin is the largest user of low temperature geothermal energy in China (Table 1). It has been selected by the state as the model for the development and direct utilization of geothermal energy in China. This calls for a comprehensive plan for geothermal utilization of the Tianjin area which is the subject of this report.

Firstly some aspects of geothermal utilization in the world, in China and in Tianjin area are reviewed. Later chapters discuss the feasibility of expanding the usage of geothermal fluids in the city, leading to a proposal for a model district heating scheme at the North of Sports College Area. Finally a set of recommendations are made as to how the development and utilization of geothermal energy in Tianjin could proceed.

There are 44 countries in the world known to have low temperature geothermal energy (Table 2). About 8200 MW-thermal above a reference temperature of 15°C are installed in the 11 main low temperature geothermal countries (Table 3). The low temperature geothermal fluids used for other purposes than bathing amount to 2830 MW-thermal above the 15°C reference temperature. Iceland is the largest user of low temperature geothermal energy in the world. Other big users are Hungary, U.S.S.R., China, U.S.A., Japan, Italy, France, Romania, Czhechoslovakia,Austria (Table 4) (Gudmundsson and Palmason, 1981).

Today many countries have installed electrical capacity (MWe) using high temperature geothermal fluids. They are China (0.4), El Salvador (9.5), Iceland (32), Indonesia (0.25), Italy (440), Japan (168), Mexico (150), New Zealand (202), Philippines (446), Turkey (0.05), U.S.A. (923) and U.S.S.R. (5). The total installed capacity is 2462 MWe. By 1990, the Azores, Costa Rica, Chile, Ethiopia, France, India, Kenya and Nicaragua are all planning to have high temperature geothermal electricity. By that time the total installed geothermal electrical capacity is expected to be 8.355 MWe (Fridleifsson, 1980), (Fig. 1, adapted from Fanelli and Taffi, 1980):

China is comparatively rich in geothermal resources and geothermal energy has been used in the country for over 2000 years. The geothermal surface manifestations are about 2500 in number, spread over thirty provincial, urban and autonomous regions. There are over thirty geothermal fields which have been and are being explored and great potential remains for further development. At present geothermal energy is extensively utilized in the country for industrial production, for people's homes, such as space heating, air conditioning, and washing, for refrigeration, power generation, agriculture, aquaculture, medical treatment, and so on. As a result, excellent economic and environmental gains have already been obtained from these uses, such as savings of coal, reduction of transportation of coal ashes and alleviation of environmental pollution .

The higher temperature geothermal resources are mainly utilized for power generation. Several experimental geothermal power stations have been in operation since 1971 (Cai, 1981). Most of the geothermal resources in China, however, are of the low-temperature type. They are developed for direct uses. About 350 MW-thermal above 15°C reference temperature are installed in the 16 areas (Table 1).

Today a number of geothermal areas which look promising and are accessible for exploitation and utilization in the near future, such as the areas in Beijing, Tianjin, Xizang, Yunnan, Fujian and Guandong, have been declared priority areas where direct and comprehensive uses of geothermal energy have been emphasized. To ensure the maximum benefits from the exploitation and utilization of geothermal energy, the priority research work and development of the major areas has been put under a national plan.

1.3 Some Aspects of Geothermal Utilization in Tianjin

The exploration and exploitation of geothermal resources in Tianjin were initiated in 1970 under the direction of the late Dr. Li Siguang who was the Minister for Geology of China at that time. By the end of 1979, a total of 381 wells with temperature above 30°C had been drilled of which 259 wells are utilized today with a total hot water production of about 50 million tonnes per year. About 70% of this is used in local industries, 25% for public uses and 5% in agriculture. It is estimated that by 1977 about 290.000 tonnes of coal have been saved by geothermal utilization. The main aspects of this utilization are as follows (Bureau of Geology of Tianjin, 1981):

Industrial use: The geothermal water is mainly used as processing water for cotton and wool spinning, knitting and dyeing works and as supply water for boilers. Among the advantages of coal, electricity and industrial salt for water softening and enhancement of the lustre, whiteness and fastness of colour dyeing and printing of the textile products. In addition, attractive results have been achieved by the utilization of geothermal water in papermaking, wood-processing, food-processing and chemical processes.

Public use: Utilizes the geothermal water for space heating, swimming pools and tubs in hotels, clubs and office buildings resulting in large savings of coal.

Agricultural use: Satisfactory results have been obtained from use of geothermal water in simple greenhouses, for growing seedlings, vegetable cultivation, poultry hatching and so on.

For further details of utilization see Appendix A.

The above systems which use mostly geothermal water from the Tertiary system have been developed since the beginning of the seventies and have been extracting water for use on a large scale. Apart from a few boreholes, the bedrock thermal water has not been widely developed.

A serious problem in the exploitation of geothermal water in Tianjin is the drop in the level of the hot water. In order to protect the geothermal resources in Tianjin the city authorities decided in 1979 that a geothermal district heating system must be under the centralized management of the Tianjin Gas Company. The company was appointed by the city authorities to draw up a development programme for the geothermal utilization in Tianjin. In the near future the company hopes to exploit geothermal resources of higher temperature than is at present available in the city from thermal areas outside the city where the water temperature is over 80°C and supply geothermal water to new residential quarters. It has been decided by the Tianjin authorities to use geothermal water for space heating of the residential area "North of the Sports College" (NSC area).

2 FEASIBILITY OF GEOTHERMAL UTILIZATION IN TIANJIN

2.1 Necessity of Exploitation of Geothermal Energy for Heating in Tianjin

Tianjin lies near the western shore of the Pacific Ocean by the bay of Bohai Sea. Tianjin is the second biggest commercial and industrial city in China. The port of Tianjin is the largest one in the north of China and it is Beijing's gateway to the sea, the distance between the cities being 137 km. The area of Tianjin is about 11,000 km^2 with a population of more than 7 million of which 2.7 millions live within the city.

About 80% of the factories are situated in the city, and they consume a large amount of energy, derived mainly from coal. For example, the consumption of coal for heating in Tianjin is more than 3 million tonnes per year. Of this amount about 2 million tonnes per year are used for heating in factories and 1 million tonnes per year for public buildings and domestic heating. Most of the houses in Tianjin are heated by stoves burning coal with no district heating service. Only a few factories and office buildings have central heating systems. The data on the general energy consumption for heating are not very exact, especially for homes where in winter, the coal burning stoves are used both for heating and cooking.

In Tianjin there is at this time an increase in energy consumption of about 10% per year as a result of the development of urban construction and the progress of industrial and agricultural production, as well as the improvement in the living standards of the people.

Air pollution is a serious problem. The authorities have paid great attention to this problem and they have decided to exploit and develop new energy resources in the city. To cope with the problem of environmental pollution, the development of geothermal and other kinds of energy on a large scale is of great importance.

2.2 Exploration of Geothermal Resources for Utilization

The exploration of the geothermal resources of Tianjin was initiated at the beginning of the seventies. The main effort was put into the exploration and development of the shallow Tertiary void thermal water which has a temperature of 30-53°C. By the end of the seventies the exploration work for the deep bedrock water was initiated. The investigation work on the geothermal resources has involved gravitational, magnetic, and seismic methods as well as airborne infrared and other remote sensing techniques. Efforts have also been devoted to geological reconnaissance and exploration tests using hydrogeology. As a result of these studies the promising geological conditions of the Tianjin geothermal resources have been ascertained. The indications are that there is a good prospect for exploitation of the geothermal energy in Tianjin.

The main features of the three geothermal fields in Tianjin may be described as follows (Bureau of Geology of Tianjin,1981):

1) Distribution of the geothermal anomaly: The fields are located in the high temperature gradient part of Beijing-Tianjin area (Fig. 2). At a depth of 300 m the average gradient is 4 to 6°C/100 m the maximum is 6-9°C/100 m with a centre temperature gradient of 8.3°C/100 m (Table 5). This shallow thermal reservoir extends over a total area of 700 km^2 (Fig. 3).

Below those shallow reservoirs, in the bedrock a thermal reservoir extending over a total area of about 900 km^2 has been identified there. The temperature gradient averages 2°C/100 m (Table 6).

2) Type of geothermal water: The thermal water can be classified into two types, namely, the void water of Tertiary system and the fracture karst water of Ordovician system and Sinian Suberathem (Table 7).

3) Hydrochemical characteristics of thermal water: The geothermal water of the Tertiary System is characterized by high alkalinity and low-hardness and mineralization, while that of the bedrock is characterized by relatively high mineralization, alkalinity and fluorine content, and a relatively low-hardness (Table 8).

4) Water output of individual wells: This varies significantly with different thermal water layers. The output of the single well in the bedrock thermal water layer is higher than that in the Tertiary System layer (Table 9).

5) Dynamic range of discharge of geothermal water: The extraction volume of the geothermal water from the Tertiary System has been increasing year after year. Accordingly, the water level shows great changes and, in the urban areas it is gradually becoming lower. Before 1972, the void thermal water of the Tertiary System in the urban area was artesian but stopped flowing from the first half of 1972 to 1973. At present, the level of the geothermal water of the Tertiary System which is at depth of 600-900 meters in the urban area has already dropped to a depth of 40-60 m. The bedrock thermal waters are all artesian, but the fluids are not yet extracted on a large scale.

6) Field locations: The three fields are situated in areas of easy access and close enough to the city to make their exploitation attractive for geothermal district heating in Tianjin.

2.3 Favourable Conditions for the Development of Geothermal Energy

In many respects the conditions for the development of geothermal energy in Tianjin are favourable. As an example the following factors are listed:

Drilling experience and capability

(1) Tianjin City Water Engineering Company: This Company is under the management of the Tianjin Municipal Bureau. It operates two 1,500 m drill rigs, two 1,000 m drill rigs and eighteen 600 m rigs.

(2) Geothermal Exploration and Exploitation Company. The company has an exploration drilling team and can drill geothermal wells to a depth of 1200 m.

(3) Dagang Oil Field Drilling Team. This company specializes in the drilling of oil wells. They may under special contracts drill other kinds of wells, but normally they do not drill geothermal wells.

(4) Marine Oil Bureau. This company specializes in offshore oil well drilling. By special arrangement, the company could undertake geothermal drilling.

Manufacture of machinery

There are many manufacturing plants in the city which produce various kinds of machinery and equipment such as pumps, boilers, heat exchangers, compression and absorption refrigeration equipment, valves, metering devices, steel and plastic pipes as well as prospecting equipment.

Geothermal scientific team

The Tianjin Geological Bureau is equipped to carry out scientific exploration work with specialist staff in the fields of geology, geophysics and geochemistry.

A comprehensive study of geothermal energy is now being conducted in the Energy Sources Laboratory of the Tianjin University and about 60 students specializing in district heating (H.V.A.C.) are graduated every year from the Tianjin University.

Tianjin Gas Company

The company is an administration unit under the management of Tianjin Municipal Bureau for distributing the heating and gas supply to the district, and has facilities to carry out project design work. The total number of employees is about 3,400.

Operational Experience

About 300 geothermal wells have been operated since 1971 and a wealth of experience has been accumulated by the technical personnel.

2.4 Possible Obstacles to Geothermal Energy Development

The following factors may prove to be obstacles to the development programme of geothermal energy in Tianjin.

(1) There is a lack of understanding by some people about the necessity of conserving energy and environmental protection. Coal is very cheap and the cost of drilling and the equipment for the district heating system is very high.

(2) The full assortment of special equipment needed for exploiting the geothermal resources is not available. Some available equipment such as pumps which are suitable for low temperature water are not suited for pumping the higher temperature geothermal water.

(3) No geothermal district heating systems exist today in Tianjin. Every user of hot water gets the water from his own well.

2.5 General Considerations

Wang (1981) shows with a profit and loss analysis economical benefits in utilising geothermal fluids. He illustrates with examples, assuming a) a temperature drop in the radiators of 25°C, b) a drilling cost per one hole less than $490x10^3$ yuan, c) a geothermal water temperature of at least 57°C, d) a flowrate greater than 81.4 t/h, it is more economical to use geothermal water for space heating than to burn coal in the boiler room.

These conclusions are useful and will do much to impress the people as it emphasises that geothermal space heating can save money.

However, it may not be possible to carry out all the detailed cost comparison analysis needed to establish the economic feasibility of a geothermal heating scheme and some assumptions will have to be made since the necessary cost data are not available in China.

The following examples of items for which costs are needed.
a) The cost of long distance transmission pipe, b) the drilling cost for deeper boreholes through bedrock, c) space heating by burning coal in the

boiler room may be more expensive than heat from coal burning in individual stoves.

In any project design the general design standards should be specified from the start. This holds true for geothermal heating projects as well as for any other type of projects. It was only in recent years that geothermal heat was utilised for space heating in China. So far no criteria have been specified for this type of space heating in the country. In the following some proposals are made.

1. The first and greatest problem is that today's world is suffering from the shortage of energy. Even though Tianjin is relatively rich in oil and natural gas, it is to be expected that these resources will be completely exhausted in the not too distant future while in comparison the geothermal resources may be long lasting. Oil and natural gas of high thermal value should be set aside for specific and limited uses.

2. Another problem is air pollution. The price of coal is low and in addition the government has set a fixed preferential price on coal for civilian use (25 yuan per tonne of 5000 kcal/kg). No rules have been set limiting the direct burning of coal in the central area of the city. The government, if it adopts geothermal space heating, may spend more money than it spends on space heating by coal fired individual stoves, but in return the air pollution will be eliminated and the environment will be improved upon. As the living standard of the people is raised, it is considered worth while spending money on improving the environment.

3. Experience in other countries show that the cost of geothermal utilization is below that of comparable fossil fuel energy and that it will be even more competitive with future rises in fossil fuel costs.

4. The national law of environmental protection stipulates that major efforts are to be devoted to developing geothermal utilization and actively to expand district heating in the city.

It is the author's opinion that the feasibility for the development of geothermal utilization in Tianjin should be studied and established in accordance with the above arguments.

3 "THE FIRST BOREHOLE" IN TIANJIN

The "First Borehole" in Tianjin was located in a new residental area and drilled at the edge of a geothermal field. Its location is shown on Fig. 3. Of the 259 geothermal wells already drilled in Tianjin only "The First Borehole" was specially allocated for district heating and designated by the Tianjin City authorities. It has been put under the management of a municipal service, the Tianjin Gas Company.

3.1 Course of Exploitation

"The First Borehole" was designed by the Tianjin Geological Bureau and drilled by the drilling team of Dagang Oil Field. The purpose of the drilling was to obtain higher temperature water from the geothermal resources of the deep formation and for heating of the residential district north of the Sports College. The designed depth of the borehole was 2400 m.

Drilling began in May 1979. When the borehole had been drilled to a depth of 1.411 m a circulation loss was encountered and at the depth of 1543 m the drill stem got stuck, and the well was completed at this depth in April 1980. The formation producing the thermal water lies between 1195-1250 m. The well is artesian and yields 153 m^3/h of water at 58°C.

3.2 Influence of Water Quality on Use

The quality of the water from the well is given in Table 10. The chemical species and equilibrium state of the thermal water from the borehole indicates that the oxidation potential is extremely hazardous and that the borehole water is supersaturated with calcium. Also the water quality data indicated that the hardness of the thermal water is high. Data supplied by the Tianjin Geological Bureau was analysed using the National Energy Authority of Iceland computer code "WATCH 2". The input and output information is given in Appendix B. In China such hard water must go through chemical treatment before it is fed to the boilers, the cost of which would be high. Another way is to pass the fluid through a heat exchanger, however there are still two problems involved in the use of a heat exchanger. One is scaling inside the heat exchanger.

The other is the low temperature of the geothermal water, which is only 58°C at the well head and giving, say, a 5° terminal temperature difference at the clean water outlet, the temperature from the heat exchanger would be only 53°C.

Additionally, because of the high content of hydrogen sulfide and thus the unpleasant odor of the water it cannot be piped directly to the house. It could be expected that ordinary black steel pipes would be corroded by such water and the cost would be high if stainless steel pipes are used. However, corrosion tests need to be performed to establish if this is true. These are the main reasons why this borehole has not been in operation up to now.

3.3 Original Ideas of Utilization

When the First Borehole was drilled, a programme was drawn up for utilising the geothermal heat of the well in the city, based on the local climate. This programme adopted the French experience (Dam, 1978) with the heat pump and the New Zealand experience (Reynolds, 1970) with natural hot water as a source of energy for an absorption heat pump. This programme is described in Chapter 6.

It is not at all certain that this method can be used with this borehole, the measured temperature of the thermal water was only 58°C, which is too low to be used as the energy source for an absorption heat pump. Many of Li-Br absorption equipment quote a minimum usable temperature of above 115°C.

In addition, the chemical analysis of the borehole water has revealed very poor quality water which has led the author to conclude that the higher temperature geothermal water of good quality should be made use of in Tianjin even though the geothermal areas are far from the city.

4 PROPOSED PROGRAMME OF GEOTHERMAL UTILIZATION IN TIANJIN

4.1 The Location of the Geothermal Fields

According to the original ideas, the geothermal wells were to be drilled within the city area. From the experience gained by "The First Borehole", it is concluded that the wells should not be drilled within the large residential districts. The main problems are that both the temperature gradient and the temperature of the geothermal water are not high, and the water quality is not good. Moreover, the quantity of the water would be reduced and the water level would fall by the drilling and usage of many geothermal wells in the area.

Based on the experience of Iceland and other countries, it is proposed that several geothermal wells should be drilled in the vicinity of the city in areas where higher geothermal gradients exist.

The geothermal water will be delivered through a main pipeline to the city area 8-30 km away. The cost of the pipeline will be high, but this will be compensated for by the higher water temperature, reducing the number of wells required. There could be other advantages, for example convenience in drilling and in laying the pipelines in the open fields rather than drilling wells in the crowded city both in terms of techniques and time limits for the project.

4.2 Basic Data of Programme

In this chapter a proposal is presented for building a district heating scheme for Tianjin based on geothermal fluids from the three Suburban fields (Fig. 3). At present there are about 20 million square meters of building area in the city, of which approximately half are unsuitable for conversion to district heating. In the next decade the City building plan calls for 2 million square meters to be constructed per year so that by the year 1990 30 million square meters of area will need to be heated. As at the end of 1979 about 14000 tonnes/hour of geothermal water are used to heat an equivalent area of 10 million square meters (authors estimate based on data from Bureau of Geology of Tianjin (1981)). So to heat 30 million square meters to the same standard by 1990 about 42,000 tonnes/hour of hot water will be needed (Table 11).

4.3 The Wells

Technical data of some of the operational wells in the City and Suburbs, together with their chemistry is presented in Table 10. This table shows that the city wells have a relatively low temperature, 42-52°C and are all pumped to give about 50 tonnes/hour. The water hardness is low, a fact that has been exploited by the Woollen and Carpet factories, however some corrosion has been experienced in these and other plant. In addition considerable drawdown of the waterlevel has been experienced in the city requiring control of the geothermal fluid withdrawal.

The suburban wells drilled so far, indicate water temperature in the range 58-96°C with artesian flows of 60 to 153 t/h and shut in pressures of 1 to 4 bar. The quoted chemistry of these wells indicates that there is unlikely to be a corrosion problem. However, it would be necessary to conduct an experimental programme to establish this to enable satisfactory materials to be chosen for the project.

From the well data it is assumed that an average well in the city would have a temperature of 50°C and would need to be pumped to give 50 t/h and the suburban wells would support 100 t/h of artesian flow at a temperature in excess of 60°C (NB. The 60°C valve was measured in a borehole at the edge of the field).

4.4 Review of Advanced Experience in Using Geothermal Water for District Heating

Iceland is the largest user of direct geothermal utilization for district heating. In 1979 there were 24 public district heating services in Iceland (Table 12). These services provide 69% of the population with geothermal heating. Geothermal district heating systems are becoming an accepted standard feature in the country and by June 1981 it was estimated that over 75% of Icelandic population enjoyed geothermal heat in their homes and it is expected that in 3-5 years this figure will be over 81%. Icelandic authorities have set it as a goal to elimate fuel burning as a source of space heating altogether by the year 1990. (Gudmundsson and Pálmason, 1981).

The Reykjavík District Heating Service is probably the world's largest geothermal heating system. It was started in 1928. At the end of 1979 this system served 98.4% of Reykjavík, and its suburbs, or 111,905 people. The total heated space was 22,388,000 m^3 both for homes and all commercial and industrial buildings. The Heating Service produced 45,091,000 m^3 of hot water in 1979, and it is estimated that about 10% of the hot water delivered to customers is used as tap water. The Heating Service gets the hot water from three geothermal fields. Two of these are in the city and one is 15-20 km away. The temperature drop in the 20 km long pipeline is only 2-3°C.

4.5 Feasibility

In general the temperature of the hot water supply for a geothermal district heating system should be as high as possible. Icelandic systems are based usually on 80°C supply temperature, 56°C being the lowest delivery temperature used (Tab. 12). So it would appear that the 50°C available in the City wells at Tianjin could be considered marginal for the operation of a successful and economic geothermal district heating scheme. With the possibilities of hot water available in the Suburban areas at temperatures in excess of 60°C, a temperature of 80°C seems likely.

The three fields are located between 8 and 30 km from the City (Table 13). Again Icelandic experience shows that the transmission of hot water over these distances is technically possible. Table 14 details a number of long pipelines installed in Iceland feeding district heating schemes, the source temperature range is 70°C to 95°C and the temperature losses are of the order of 0.1°C/km for insulated and 1°C/km for uninsulated pipe (Lund, 1978). Experience in Turkey also indicates that a transmission distance of 12 km is satisfactory (Zoega, 1975).

It is therefore possible and desirable from a technical viewpoint to use the 80°C geothermal water in the Suburban fields and transmit it to the City.

4.6 Proposed Programme

From the facts presented, it is concluded that the hot water requirements for Tianjin city for the next decade could be met by developing the geothermal resources in the three areas to the South, South West and East of the city. It is anticipated that about 80°C geothermal water would be available in reasonable quantities and having a water chemistry which would allow it to be used directly in a heating system. The design transmission system is considered to be feasible.

It is suggested that the development should progress in stages, to enable the full extent of the resources to be assessed and allow good management principles to be applied to the areas. It is further suggested that a model district heating scheme be designed and built north of the Sports College area to give experience in design and operation and to establish the economics of a geothermal district heating scheme. Chapter 5 presents the finer details of a preliminary programme for this area.

5 DISTRICT HEATING DEVELOPMENT PROGRAMME IN THE "AREA NORTH OF THE SPORTS COLLEGE" (NSC AREA)

5.1 Basic Data of the Area

The total area of the buildings in the residential district in NSC area is 663,216 m^2 with 66,321 inhabitants (see Fig. 4a & b).

5.2 Weather Conditions

In Tianjin the mean temperature of the year is 12.3°C. In July it is 26.7°C and in January it is -4.2°C.

The design standard for heating and ventilation of China gives the outdoor design temperature in winter for Tianjin as tw =-9°C, and the inside room temperature in winter for home and public buildings as tn = 18°C.

According to the national standard the mean temperature of a day in the heating season must be lower than 5°C. The mean temperature of the heating season is -1.2°C in Tianjin, and it lasts 122 days (from November 15th to March 15th).

The heating season was determined as the period when the mean temperature of the day is lower than 5°C in order to save fuel either coal or oil. When geothermal energy is used for heating, it is proposed that the standard of space heating be reconsidered. Since space heating using geothermal energy does not consume fuel, and the cost of operation is cheap the full utilization of the geothermal water should be planned in order to provide a more comfortable living environment.

Some professors and scientists (First Medical College in Shanghai 1959) studied this question in 1959. According to their studies when the room temperature falls to about 10°C the human body becomes inefficient in performing work tasks. Space heating should therefore be considered when the room temperature goes down to this level. In light of the meteorological records the mean outside temperature of the day in Tianjin is below 10°C from 29th October to 31st March, and the heating season will last 155 days, i.e. from 25th October to 31st March. This should enable the room temperature to be held above 10°C for this period.

5.3 Thermal Load

There are many types of apartments and public buildings in the residential district. The heat consumption of each building should be calculated at this stage of the design. Table 15 shows the programme criteria of heat consumption for various buildings with different usages. It is used at this stage as a basis for estimation. This table was recommended for use by the specialists at the 1980 Tianjin Heating Conference. It is based on the weather conditions in Tianjin and engineering experience in the design of district heating schemes.

For simplicity 70 kcal/m^2 h is used initially as an average criterion for the heating and hot water consumption of all buildings.

The total heat consumption for the residential district is therefore 663,216 x 70 = 46,425,120 kcal/h.

If it is assumed that the inlet water temperature is 80°C (section 4.5) and a temperature drop of 40°C occurs then the flowrate is G = 46,425,120/40 = 1,160 m^3/h (322 l/s).

5.4 The Selection of the Pipeline

The experience of Iceland shows that it is important to exploit the higher temperature geothermal water at the right sites even if they are far from the city. Special attention should then be given to the thermal water transportation and insulation of the pipeline.

Table 16 shows the insulation materials widely used in China for hot water transmission. The insulating layers from inside to outside of the pipe are: paint, insulation tile, wire netting, jacket (asphalt or asphalt felt, glass clott, asbestos cement). The thickness of the insulation depends on the temperature of fluid in pipes and the allowable temperature drop.

During operation in China, there has not been any trouble with the insulation materials themselves, but seeping of the water through the brick or concrete channels that are used for laying the pipes has presented problems.

The level of ground water in Tianjin is at a depth of 60-70 cm. During the construction of the pipe system, therefore, problems such as water seeping through brick or concrete channels corrosion, insulation and the useful life of pipe must be carefully considered.

For the above mentioned reasons some district heating systems have been scrapped and reconstructed at considerable expense within a short period, for example Tianjin Power Station No. 1 and Tianjin Guesthouse. The selection of good economical engineering designs of pipelines are therefore important for district heating in Tianjin.

The practice overseas suggests that pipelines used for heating are of five types, as follows:

1. Above ground pipeline with a sheet metal protective cover.
2. Steel pipe in concrete duct.
3. Steel pipe with a protective polyethylene cover.
4. Asbestos cement pipe with an earth and grass over.
5. Double layer corrugated pipe with polyurethane foam and protective polyethylene cover.

The details of the above pipe systems and from this review are given in Appendix C.

It is proposed that a steel pipe with a protective polyethylene cover be used for the Tianjin installation.

5.5 District Heating System

The utilization of the S-W Suburb geothermal field in Tianjin is proposed for a district heating system for North of the Sports College Area.
It is suggested that several boreholes could be drilled around the Seismic Station in the suburb where the temperature gradient is comparatively high. According to the operational experience at the station the water

chemistry allows the use of the geothermal fluid directly for a distribution network as well as for house heating systems. On this basis a single pipe distribution system is proposed. The geothermal fluid is also used directly as hot tap water. A schematic line drawing of this arrangement is shown in Fig. 10.

The anticipated temperature of the borehole head is 84°C. The design temperature of the supply water to building is assumed to be 80°C and the leaving water temperature is 40°C. It is suggested that the main transmission pipeline and distribution pipeline be made of steel pipe with a protective polyethylene cover. After passing through the radiators the cooled thermal water is then transmitted to a swimming pool through an asbestos-cement pipeline. With the assumptions outlined above it is anticipated that 12 wells would be needed.

A layout of the distribution system network is shown in Fig. 4.

No set rules have been laid down on the diameter of the supply pipeline. This is dictated by local conditions such as the grade of the land over which the pipeline is laid, available power for pumping, etc. An approximate rule of thumb is to design the diameter of the pipe so that the pressure drop in a straight section of pipe at maximum rate of flow is on the order of 0.5~1.0 bar/km (Karlsson,1981). The nomogram of pipe diameter-flow of water and the pressure drop has been widely used for pipe design in the Tianjin Gas Company. From the required conditions which are thermal load of the building, design temperature drop (80/40°C) and pressure drop, the diameter can be deduced from the nomogram.

Using the above process the diameters of pipelines for every section can thus be worked out as shown in Table 17. The diameter of pipes are from 65 mm to 450 mm. The total length of the distribution pipeline is 23,648 m and the total of the main pipeline is 8 km with a diameter of 450 mm. The grand total of the pipeline is thus about 32 km.

5.6 Typical House Connection

In Iceland there are two basic methods by which the geothermal water supply to houses is metered. One is based on total volume of water that is measured by a regular flow meter at the intake to each user. The other method is the maximum rate of flow method, where the customer has at his disposal a predetermined maximum rate of flow that he is free to use as and when he pleases.

According to the customs and living standards of the population of Tianjin, the flow meter method is considered to be more suitable and it is suggested that each apartment be metered separately.

A possible method of a house connection is shown schematically in Figure 11. After the house line passes through the wall it is fitted with a gate valve, a strainer, a sealed regulating valve, a flow meter, and a branch for the hot tap water as well as individual thermostatic valves fitted in each radiator.

A small water tank will be arranged in the hot tap water system. Its advantages are that it utilizes the leaving water after it passes through the radiators and provides the volume flow required for the hot tap water. According to the design standard for domestic hot water supply of China, the lowest water temperature for the bathtubs and shower-baths should be 37-40°C, which is the geothermal water temperature after passing through common radiators so it may meet this requirement. During the non heating season or if some people like higher water temperature, the supply water of 80°C from the supply branch can be used for the hot tap water.

5.7 Main Equipment

Although there are many plants producing various types of equipment in Tianjin which can be used in the engineering of geothermal utilization, they are in some respects technically not up to date. Some of the advanced techniques needed for the main equipment will be described below.

5.7.1 Borehole Pumps

The type of borehole pumps where needed for geothermal operation in Tianjin has mostly been the multistage, mixed flow impeller type turbine pump, driven by an electric motor on top of the well, through a line shaft going down through the well to the submerged pump assembly. The line shaft of the pump is supported by open rubber bearings and lubricated by the hot water. It was soon apparent, however, that the rubber bearings could not stand up to the high temperature experienced in Tianjin.

In Reykjavík, Iceland, a design using teflon bearings was tested in 1966. These bearings were lubricated by filtered geothermal water pumped down the shaft-enclosing pipe. This design has since been used for all deep well pumps of this type, and bearing maintenance is no longer a problem, as evidenced by the teflon bearing life of three to four years in comparison with a bearing life of three to four months with rubber bearings.

The deep well pump, however, has its disadvantages, such as, noise from the pump motor at the surface, and difficulties may also be encountered when the well is not straight or if the pump has to be set at great depth. In order to avoid these problems the deep well pumps have also been built with a closely coupled driving motor. The motor is completely sealed and of a small diameter so that it can be submerged in the well. This type of pump is called a submersible pump. With this arrangement the long drive shaft is eliminated and the shaft friction losses and total thrust are minimized.

The maximum temperature at which deep well turbine pumps in Iceland have been used so far is about 130°C. This may not be the temperature limit for the line shaft pumps, but the present pump design does not allow for more differential expansion between the pipe column and line shaft than experienced at this temperature at a depth of 130 m. According to the manufacturer of submersible pumps, such pumps have operated successfully running continuously at 150°C.

5.7.2 Plate Heat Exchanger

If a heat exchanger is found to be necessary then the plate heat exchanger would be the most appropriate type. Its advantages are:

a. Working pressures up to 15 kg/cm^2
b. Withstands extremely high hydrodynamic shock loads
c. Virtually no risk of deforming or fracturing plates by excessive tightening of assembly bolts
d. Gasket contained - cannot blow out - standard feature of all plate heat exchangers.
e. The cost is lower than snake pipe heat exchange.

5.7.3 Storage Tank

In the early years the storage tanks in Reykjavík were made from concrete. It is well known that concrete is not well suited for high water temperature and some crevices are evident in these tanks. In recent years, the storage tanks have been made from steel plate with rock wool insulation and there is no problem maintaining the temperature of the water.

Based on the practical storage sufficient for experience of the Reykjavík district heating system, water supply of 4 hours has been chosen as the capacity of the storage tank (Zoega, 1974). The water supply quantity of the programme area is 1160 M^3/h. 1160x4 = 4640. 5000 m^3 of capacity will be chosen for NSC area.

5.7.4 Transmission Pump

Vertical multistage turbine pumps can be used for long distance supply line where relative high pressures are needed. Single stage centrifugal pumps which are widely used in Tianjin are not well suited for this purpose.

5.7.5 Valves, Water Meters and Radiators

It is recommended that the experience of the Reykjavík District Heating Service be used in the selection of these components.

The ball valve and butterfly valve seal hermetically and only occupy a small space, so they are widely used in pumping stations and in pipelines. The gate valves and shutoff valves which have been widely used in Tianjin are more expensive, and have been eliminated in recent years in Icelandic schemes. The water supply to each building is limited by sealed maximum regulators, according to the heat requirements of each consumer. In the last years, individual thermostatic valves fitted in the return of each radiator have become popular. Inferential water meters are used with magnetic coupling between water-wheel and register mechanism. So hot water meters are included in the supply of higher temperature water.

Panel radiators as used in Iceland are recommended.

5.7.6 Bellows

Bellows type expansion joints are used extensively in all types of heating pipeworks. These compensators are generally employed with large diameter pipelines and Z-shaped swing compensators. Their main advantage is their completely sealed construction, the expansion movement being absorbed by the flexing of a carefully designed convoluted section of high grade material of thinner section than that of the pipe (Fig. 12).

There is a good experience of such joints in Iceland and it is proposed here that their manufacture in Tianjin needs to be encouraged.

5.7.7 Proposal

The successful and efficient operation of a geothermal district heating scheme is dependent upon having the correct operating equipment. Experience in Iceland has shown that the items discussed above have given many years of service with relatively little maintenance. It is suggested that this type of equipment should become available in Tianjin. The manufacture of this equipment should be well within the capacity of the local industry.

6 APPLICATION OF HEAT PUMP

6.1 The Relation Between the Climate in Tianjin and Use of Heat Pump

Severe winters and hot summers are the feature of the climate in Tianjin. Tianjin, Washington and Lisbon are on the same latitude, but the air temperatures both in winter and in summer in these cities are quite different (Table 18).

Due to the relatively hot summer, it is necessary to utilize geothermal energy for air conditioning. The climate in Tianjin is very different from that in Reykjavík of Iceland. The heating season there is almost all year around. If the geothermal energy is used only for space heating in Tianjin, a large quantity of geothermal energy will be wasted during the non-heating season. It is therefore desirable to utilize geothermal energy for refrigeration in summer.

If a system of absorption heat pump is built for use both in winter and summer geothermal energy will be utilized more fully.

6.2 Original Idea for Use of a Heat Pump

When planning the exploitation of the "First Borehole" in Tianjin, the use of a heat pump was contemplated for the purpose of conserving energy and to reduce still further the temperature of the geothermal water which had already been used before it was drained or reinjected.

According to the original idea, the design water temperature was expected to be 95°C. The plan called for the adoption of the French experience with the heat pump and the New Zealand experience with natural hot water as source of energy for an absorption heat pump. Figure 13 shows a simplified schematic drawing of a possible utilization of geothermal water.

Natural thermal water of 95°C is pumped from the borehole and injected into a heat exchanger, where its heat is released and the water is returned to the underground reservoir at a temperature of 10°C.

The temperature of the circulating water in the heating system is raised to 90°C by the heat exchanger, it is then piped to buildings for heating. The temperature drop through one building is chosen as 25°C and after passing through the second building, its temperature drops down to 40°C. It then drops further to 5°C in the evaporators before it returns to the exchanger.

Apart from the heat exchanger it was also planned to use a heat pump for space heating. The temperature of hot water coming from the condensers would be about 55°C. It could be piped into buildings for heating and then returned to condenser at a temperature of about 30°C.

It is reported that the compressor of the heat pump in France is driven by electricity in Tianjin, however, the cost of electricity is too high (0.16 yuan/kWh) so that it was planned to use a Lithium Bromide absorption heat pump. This type of a heat pump has already been used in the town of Rotorua in New Zealand (Reynolds, 1970).

The program described above was for the utilization of geothermal water in winter. After making some changes to this system, the absorption heat pump could be used as a refrigerator in summer, piping cold water for air conditioning or for other uses.

6.3 Discussion of Some Technical Problems

It is of importance to evaluate the source of energy for the heat pump, as seen by the following:

6.3.1 The Compression Heat Pump

It is driven by electricity, where its actual C.O.P. is in the range of 3-7 when used for space heating with geothermal water. This means that the heat output for the best heat pump is 7 x 860 = 6020 kcal per kWh electricity. At Tianjin the present cost to the consumer for electricity is 0.16 yuan/kWh, resulting in a heat cost of $0.16 \times 10^6/6020 = 26.58$ yuan/Gcal.

On the other hand the price of steam or hot water for direct heating is only 7.56 yuan/Gcal. The expense of using the heat pump is therefore

35 times more expensive than using direct heating. At the moment therefore and even at long-term it would not appear to be economical to use electricity as a source of energy in Tianjin or in any other city of China.

The calculations above are intended to demonstrate that on a basis of running costs alone the compression heat pump would not be competitive with hot water heating.

6.3.2 Absorption Heat Pump

The following facts are known to apply to the absorption heat pump:

(1) Lu (1980) concludes that the absorption heat pump has few advantages in terms of conserving energy when the energy source is below 150°C, except for some particular circumstances.

(2) The conclusions of Breindel et al. (1978) which is concerned with refrigeration in the food processing industry states that:

i. Developing the geothermal resources for use in the production of refrigeration alone is not economically justified.

ii. The cascaded use of the geothermal discharge from the refrigeration plant for process heating improves significantly the economic feasibility in all cases, i.e., geothermal absorption refrigeration is best used as a "topping cycle".

iii. Returns on investment of more than 20% after taxes can be expected for potato processing and freeze-drying with the cascaded system but not for medium or small basic meat processing plants.

iv. Valuable heat energy would remain in the geothermal effluent from each plant at temperature waste for space heating, air conditioning or other uses.

(3) In Rotorua of New Zealand, geothermal energy is not merely used for space heating in winter. It is used in summer for cooling by using an absorption heat pump. Both the cold winter and the hot summer are suitable seasons to make full use of the geothermal energy.

However it is necessary to evaluate the lowest economical temperature of the energy used in the Bromide Lithium absorption heat pump.

An evaluation on theoretical or thermodynamic grounds must be linked with the reality of the manufacturing capability of China. If the cost of the equipment is not high, and since the geothermal water as a source of energy costs little, it could be economical to use the absorption heat pump.

7 DISCUSSION

Tianjin and its vicinity have a number of geothermal resources which could be developed. The total area identified is about 900 km^2. It also has considerable experience in utilising geothermal fluids, 259 wells have been drilled and operated in the area. There are many industrial plants which manufacture equipment which can be used for geothermal district heating engineering. Four drilling teams work from Tianjin and the Tianjin Geological Bureau and other scientists are available for scientific work. However before any development can take place, it is neceessary to demonstrate that it is both technically feasible and economic to pursue such a development.

It is believed that the technical feasibility has been demonstrated in this report, an economic study is the logical next phase, however cost data for the specialised equipment under Chinese conditions is difficult to obtain but an order of magnitude approach based on European experience suggests that for a pilot district heating scheme heating 663,216 m^2 of apartments the cost would be about US \$ 18 million which in China would be classified as a medium priced project.

In order to establish a cost structure and to obtain operating experience a pilot scheme is considered to be necessary. This suggested that a development based on the South-western suburban geothermal field be used to provide heating to the area to the north of the Sports College, a distance of 8 km from the resource. Long distance transmission of hot water over these distances should not be a problem and with the water quality temperature and flowrate anticipated from this field, the energy requirement can be met from about 12 wells using a single pipe system with the reject fluid discharged through the city sewage system.

The building construction programme for the city over the next decade will demand, if geothermal district heating becomes established as a major component of new projects, large quantities of hot water and equipment to control and deliver the heat energy. Such a development needs careful planning to ensure that the design, equipment and manpower commitments lead to a district heating system which is able to operate efficiently and economically. It will be necessary to develop and construct new industry to manufacture the specialised equipment not available locally. This will have a beneficial effect on the community at large providing employment and income for the city.

In order to fully utilise the geothermal fluid throughout the year an absorption heat pump appears to be attractive, this would enable further heat to be extracted from low grade energy and provide cooling in summer. However the low cost technology for design and manufacture in the Chinese situation needs research and it is recommended that efforts be made to start this work in the near future.

8 CONCLUSIONS

1. The Tianjin suburban geothermal fields should be developed to support a city district heating scheme.

2. New factories will be needed to manufacture some of the specialised equipment.

3. The residential area to the north of the Sports College should be developed as a pilot district heating scheme.

4. Research on the absorption heat pump should be undertaken.

ACKNOWLEDGEMENTS

The author is grateful for the opportunity for participating in the 1981 UNU Geothermal Training Programme in Iceland, and is also grateful to all the people at the National Energy Authority who contributed to the training.

Special thanks are due to the following people:
Prof. Thorbjorn Karlsson, who supervised this project and gave the author valuable advice.
Dr. Jon Steinar Gudmundsson, for his unlimited help and supervision in all aspects of the training.
Dr. Einar Gunnlaugsson and engineer María Jóna Gunnarsdóttir for a very good assistance in chemical analysis and pipeline engineering respectively.
Ms. Sólveig Jónsdóttir, Sigrídur Valdimarsdóttir and Gyða Gudmundsdóttir for expertly typing the manuscript and drawing the figures.
Prof. Derek Freeston at the Geothermal Institute, Auckland University in New Zealand, who gave lectures and valuable help and encouragement during the project work.
Lastly the author would like to extend his thanks to Dr. Ingvar B. Fridleifsson and Dr. Hjalti Franzson for excellent organization of the Geothermal Programme.

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TABLE 1

Known uses of low-temperature geothermal energy in China
(Xin Kuide, Deputy Director, Bureau of Hydrogeology and Engineering Geology, Ministry of Geology, China. 20. July 1981.)

	Thermal power (MW)		
	> 0°C	> 15°C	> 40°C
Tianjin	202.6	112.9	11.2
Huabei (except Tianjin and Beijing)	78.3	58.8	26.1
Beijing	42.0	39.5	8.8
Fuzhou	35.9	29.5	19.0
Yingcheng	32.5	25.0	12.5
Xingcheng	27.1	21.3	11.7
Jingshan	17.2	12.8	5.5
Huitang	13.1	10.2	5.4
Zhao Yuan	11.5	9.7	6.8
Lucheng	11.1	9.2	6.2
Yingshan	7.9	6.1	3.2
Weihai	5.5	4.2	2.2
Tanggamzi	3.4	2.7	1.5
Kunming	3.2	2.3	0.9
Xiongyue	2.1	1.7	1.1
Xian	0.8	0.5	0
Total	494.2	346.4	122.1

TABLE 2

Low temperature geothermal energy - an overview

(Gudmundsson and Palmason, 1981)

	Country	Low-Temperature	Utilization	Exploration	Assessment
1	Algeria	+	-	-	-
2	Argentina	+	-	+	...
3	Australia	+	-	-	-
4	Austria	+	+	+	-
5	Canada	+	-	-	-
6	China	+	+	+	...
7	Colombia	+	-	+	-
8	Costa Rica	...	...	...	...
9	Czechoslavakia	+	+	+	+
10	Denmark	-	-	-	-
11	Djibouti	...	...	...	...
12	Ecuador	+	-	...	...
13	El Salvador	...	...	...	...
14	Fiji	+	-	+	-
15	France	+	+	+	+
16	Germany, East	...	-	-	-
17	Germany, West	+	...	+	...
18	Greece	+	-	-	-
19	Guatemala	...	...	...	...
20	Haiti	...	...	...	...
21	Honduras	...	...	...	...
22	Hungary	+	+	+	+
23	Iceland	+	+	+	+
24	India	+	-	+	...
25	Indonesia	+	-	-	-
26	Israel	+	-	...	...
27	Italy	+	+	+	+
28	Jamaica	...	...	...	...
29	Japan	+	+	+	+
30	Kenya	...	...	...	...
31	Mexico	+	-	-	-
32	Netherlands	+	-	+	-
33	New Zealand	+	-	-	-
34	Nicaragua	+	-	-	...
35	Nigeria	...	...	...	...
36	Panama	...	...	...	...
37	Peru	+	-	...	...
38	Philippines	...	...	...	...
39	Poland	+	-	+	-
40	Romania	+	+	+	+
41	Sweden	+	-	-	-
42	Switzerland	+	-	+	...
43	Turkey	+	-	-	-
44	USSR	+	+	+	+
45	UK	+	-	+	-
46	USA	+	+	+	+
47	Venezuela	...	...	...	...
48	Yugoslavia	+	...	...	...
49	Bolivia	+	-	...	...
50	Brazil	+	-	...	...
51	Egypt	+	-	...	...
52	Eire	+	-	+	...
53	Korea, North	+	...	+	-
54	Korea, South	+	-	...	...
55	Solomon Islands	+	-	-	-
56	Tanzania	+	-	...	...
57	Thailand	+	-	+	...
58	Uganda	+	...	...	...
	Total	44 +	11 +	23 +	9 +

+ = Known

- = Unknown

... = No information

TABLE 3

Total installed low temperature geothermal power in countries with other utilization than just hot springs.
(Gudmundsson and Palmason, 1981). +New data, see Table 1.

Country	Thermal power (MW)		
	>0°C	>15°C	>40°C
Japan	...	4475	...
Hungary	1523	1166	690
Iceland	1361	1127	747
U.S.S.R.	669	555	364
Italy	318	∿265	∿177
China	494+	346+	122+
U.S.A.	...	∿115	...
France	74	56	25
Czechoslovakia	59	43	21
Romania	47	36	22
Austria	7	5	4
Total	...	8189	...

TABLE 4

Utilized low temperature geothermal power excluding bathing (Gudmundsson and Palmason, 1981). +New data, see Table 1.

Country	Thermal power (MW)		
	0°C	15°C	40°C
Iceland	1111	923	628
Hungary	808	619	366
U.S.S.R.	669	555	364
China	484+	330+	119+
U.S.A.	...	111	...
Japan	103	81	44
Italy	88	73	49
France	74	56	25
Romania	47	36	22
Czechoslovakia	49	35	21
Austria	3	2	1
Total	...	2830	...

TABLE 5

Distribution of the shallow thermal anomaly zone of Tertiary System (Bureau of Geology of Tianjin 1981)

Location	Area of distribution (km^2)	Geothermal gradient of the center of anomaly zone (°C/100 m)	Burial depth of the basal plate of Tertiary System (m)	Burial depth of the roof of Tertiary System (m)
Urban, South-west suburb	409	8.3	800-1400	550-600
South suburb	119	8.3	1000-1300	$600^{\pm}$
East suburb	171	8.1	1100-1300	$600^{\pm}$

TABLE 6

Distribution of the reservoir of deep-seated bedrock (Bureau of Geology of Tianjin 1981)

Location	Area of distribution (km^2)	Average geothermal gradient (°C/100 m)	Burial depth of bedrock	Lithological character of bedrock reservoir
Urban, South-west suburb	609	1-2	800-1400	Limestone of Sinian Suberethem Limestone of Ordovician System
South suburb	119	1-2	1000-1300	Limestone of Sinian Suberathem
East suburb	171	1-2	1100-1300	Limestone of Ordovician System

TABLE 7

Types of geothermal water of Tianjin Geothermal Area (Bureau of Geology of Tianjin 1981).

Type	Burial depth (m)	Water temperature (°C)	Water head (m)
Void thermal water of tertiary system	600-1000	30-53	Burial depth 30 - 60
Fracture and karst thermal water of limestone of Ordovician system and Sinian Suberatherm	Below 1000	58-96	Above surface 10-30

TABLE 8

Hydrochemistry of the underground thermal water of Tianjin Geothermal Area (Bureau of Geology of Tianjin, 1981).

Type of water		Hydrochemistry	Mineralization (g/l)	Total hardness °DIN	Alkalinity °DIN	Fluorine content (mg/l)	pH value
Tertiary system thermal water		HCO_3-Na	0.6-1.0	0.7-1.0	20-25	3-5	8-8.5
Bedrock thermal water	Ordovician system	Cl.HCO_3(SO_4)-Na	1.58-4.4	4.4 (higher in particular)	25.88	10.40	7.116
	Sinian Suberathem	Cl. HCO_3-Na	1.8-2.0	5-7	17-20	6-10	7.5-8.0

TABLE 9

Variations of water output relative to different thermal water layers (Bureau of Geology of Tianjin 1981).

Thermal Water Layer	Single Well Output (t/h)
Tertiary system	30 - 60
Ordovician system	80 - 120 (artesian)
Sinian Suberathem	60 - 100 (artesian)

TABLE 10

Main data of some existing wells

Name	Location	Distance from city km	Year drilled completed	Cost 10^6 yuan	Depth m	Temperature °C	Flow t/h	Artesian pressure kg/cm^2	Total hardness °DIN	Salinity mg/l	pH	Chemical type
1st Borehole	in city		1980	1.48	1543	58	153	1	88.2	4495	7.45	$SO_4 \cdot Cl-Na$
Seismic Station ZHEN 4	W-S Suburb	8			1406	84	83	2.8	8.52	2262	7.39	$SO_4 \cdot Cl-Na$
Wang 3	W-S Suburb	14	1980	0.55	1150	78	125	2.3	9.53	1806	7.18	
ZHENG 3	S.Suburb	30			2397	96	60	4.0	7.01	2017	7.65	$Cl \cdot HCO_3-Na$
Carpet Factory No. 1	in city		1975		804	42	50	No	1.93	1050	7.98	$HCO_3-Cl-Na$
Woolen Fabric Mill	in city		1972		820	49-51	50	No	1.18	874	8.3	$HCO_3-Cl-Na$
Tianjin Guesthouse	in city				641	42	60	No	0.7	602	8.4	
Tianjin Friendship Club	in city		1973		889	47	60	No	1.96	702		$HCO_3-Cl-Na$
Duck Farn	in city		1970		798	49-52	30-40	No	1.12	1021		$HCO_3-Cl-Na$

TABLE 11 Building development in Tianjin and its hot water requirement

Year	Construction area $\times 10^6 m^2$	Heating requirements Gcal/h	Quantity water requirements M^3/h
1980	10	700	14,000
1985	20	1,400	28,000
1990	30	2,100	42,000
1995	40	2,800	56,000
2000	50	3,500	70,000
N.S.C.	0.66	46.42	928
Reykjavík 1979	$\approx$ 7.46		$\approx$ 7740

Note: 1. The constructional area except old houses 10×10^6 m^2.

2. The thermal water design temperature is 75°C and use in 2 stages.

3. N.S.C.: North of the Sports College Area

4. Reykjavík as a reference unit for study

TABLE 12

All public geothermal district heating services in Iceland 1979. (Gudmundsson and Palmason, 1981)

Town/Region	Year	Population 1979.12.01	Temperature (°C)		Quantity Water Sold		Heated Space ($x10^{-3}$ m^3)			Revenue*
			Delivered	Returned	$x10^{-3}$ (m^3)	(l/min.)	Total	Homes	Other	$x10^{-3}$IKR
Reykjavík	1930	111,905	80	40	41,178	-	22,388	...	...	4,865,220
Seltjarnarnes	1972	2,981	80-85	40	-	2,289	520	...	...	72,915
Mosfellshreppur	1943	2,253	80	40	-	3,106	...	...	...	68,405
Sudurnes xx	1975	11,500	80-88	35-40	-	9,200	1,762	1,391	371	645,820
Thorlákshöfn	1979	500	80	40	-	350	...	...	...	1,952
Selfoss	1948	3,157	78	...	934	1,166	...	...	...	161,432
Hveragerdi xx	...	1,180	80-85	...	-	2,500	...	...	...	74,257
Laugarás	...	91	90	...	-	216	12	10	2	13,859
Flúdir	1967	162	80	40	-	1,403	60	15	45	15,974
Brautarholt	1979	50	73	...	-	300	...	...	...	1,548
Vestmannaeyjar xx	1975	1,650	75	35	273	-	211	165	46	74,372
Reykhólar	1974	90	100	...	-	173	...	...	...	977
Sudureyri	1977	512	60	...	-	658	...	...	...	48,700
Hvammstangi	1973	564	78-80	40	19	847	122	...	...	56,488
Blönduós	1978	1,012	60	30-40	-	1,435	176	108	68	93,402
Saudárkrókur	1953	2,113	66-68	30-45	-	3,520	408	259	149	99,125
Siglufjördur	1975	1,700	80	...	255	1,259	...	...	...	137,233
Ólafsfjördur	1944	1,100	57	25-30	-	2,113	158	116	42	45,031
Dalvík	1969	1,253	60	34-38	-	2,158	223	137	86	64,158
Hrísey	1973	295	56	...	-	455	...	...	...	13,700
Akureyri	1977	9,000	82-90	...	-	6,000	...	...	...	481,288
Húsavík	1970	2,587	80	40	17	3,110	...	...	...	121,312
Reykjahlíd xx	1969	284	80	40	-	-	39	29	10	7,923
Egilsstadir	1979	450	60-65	30-40	-	700	93	59	34	-
Total	.	156,389	.	.	42,676	42,858	...	...	...	7,165,091

*Average 1979 rate of exchange US$ = 353 IKR.

xx In high-temperature geothermal areas.

TABLE 13 Suggested Stages of Developmental Programme

Stage	Distance of pipeline	Geothermal field	Depth of borehole M	Expected temperature of water °C
1	8	S-W Suburb	≥ 1400	84
2	26	S-W Suburb	≥ 1400	> 84
3	32	S Suburb	≥ 1300	96
4	15	E Suburb	≥ 1300	84
5	21	E Suburb	≥ 1300	84
...				

Note: simultaneously see Fig. 3

TABLE 14 A review of some geothermal district heating systems in Iceland.

Name of System	Distance of pipeline km	Inhabitants	Temperature of water °C	Quantity of water l/min.	Notes about pipeline
Selfoss Eyra*	5.6 8.6	3,200 1,100	83	124	Steel insulated with polyurethan
Borgarfjordur	62	7,000	95	175	Asbestos pipe insulated with rockwool and scoria
Laugabakki	8	650	94	23	Asbestos pipe without insulation. Temperature drop 20°C
Blönduós	14	1,000	70	35	Asbestos pipe without insulation. Temperature drop 9°C
Akureyri	12.4	10,000	75	150	Steel insulated with rock wool. Temperature drop 1.5°C
Húsavik	18	2,600	95	71	Asbestos pipe without insulation. Temperature drop 15-18°C

* Under construction

TABLE 15 Programme criteria of heat consumption for various buildings in Tianjin.

No	Various Buildings	Heat Consumption $Kcal/m^2$ hr_p	Hot Water Tap Use $Kcal/m^2$ hr_p
1	Apartment	55-60	3
2	Office, school	65	2
3	Hotel, shop	70-75	4-10
4	Hospital, kindergarten	75-80	4
5	Theatre, cinema	100	
6	Baths, single story house	100	
7	Workshop	100	

TABLE 16 Insulation materials widely used in China

Material of insulation tile	Unit weight kg/m^3	Coefficient of conductivity $Kcal/m \cdot h \cdot {}^\circ C$
Vormiculite	350-480	0.07-0.12
Pearlite	60-120	0.032-0.041
Rock wool	130-250	0.035-0.06
Glass fibre	100-160	0.035-0.05
Diatomite	450	0.09-0.11
Asbestos	280-300	0.09-0.11
Foam concrete	500	0.109-0.12

TABLE 17 Length of pipe for development programme in North of the Sports College Area

Pipe size	Length of pipe
mm	m
65	1,774
80	4,770
100	7,305
125	2,640
150	1,730
200	2,120
250	1,190
300	1,170
350	693
400	80
450	176
Total of distribution pipeline	23,648
Total of main pipeline (D450)	8,000
Grand total	31,648

TABLE 18 Mean temperature of some cities on the same latitude

City	Mean temperature °C	
	in January	in July
Tianjin	-4.2	26.7
Bejing	-4.7	26.1
Washington	0.7	24.6
On the same latitude of the earth	5.5	24
Lisbon	10.8	21.8

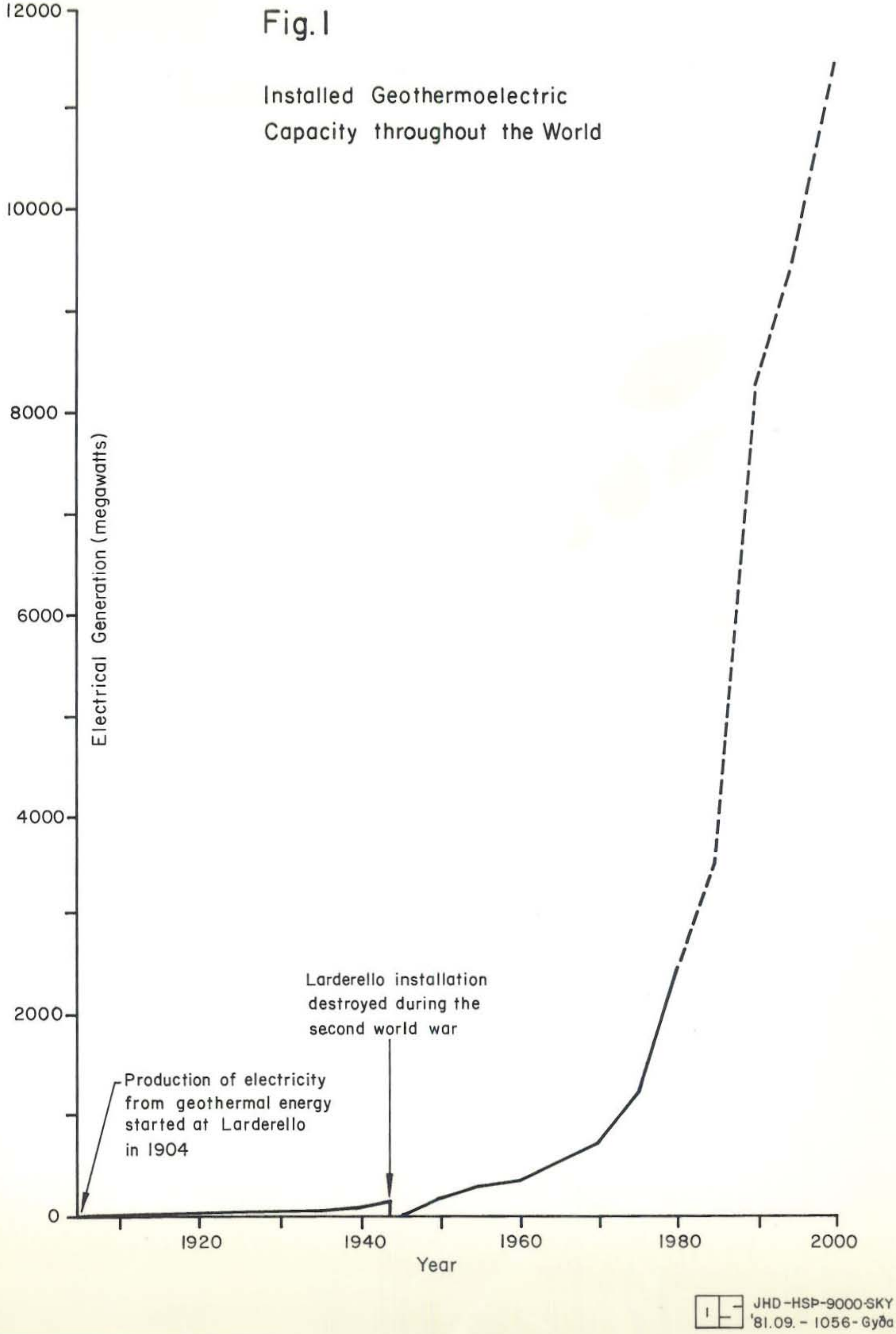


Fig. I
Installed Geothermoelectric
Capacity throughout the World
12000
10000
8000
6000
4000
2000
0
Electrical Generation (megawatts)
Larderello installation
destroyed during the
second world war
Production of electricity
from geothermal energy
started at Larderello
in 1904
1920
1940
1960
1980
2000
Year
JHD-HSP-9000-SKY
'81.09. - 1056-Gyða

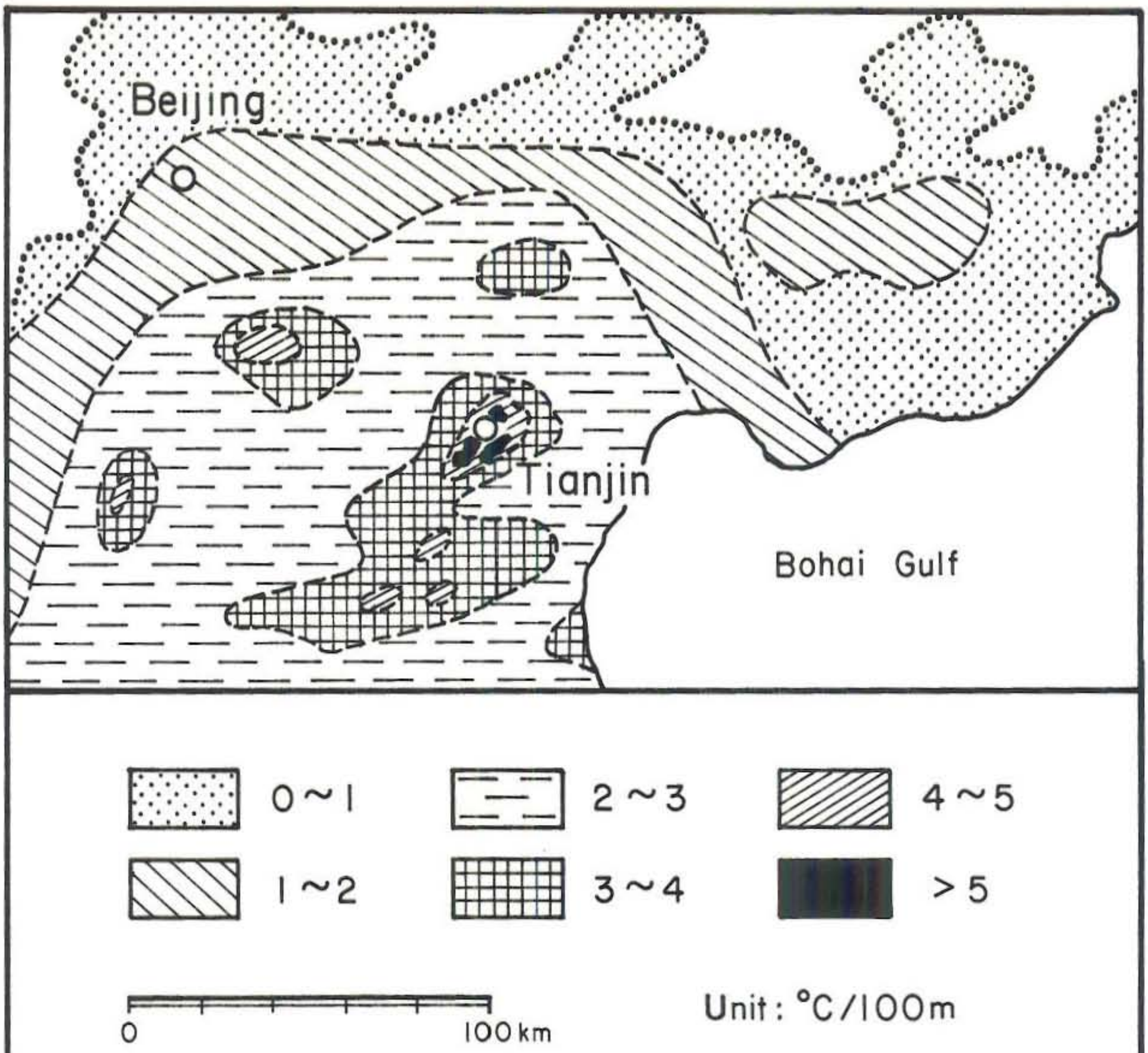
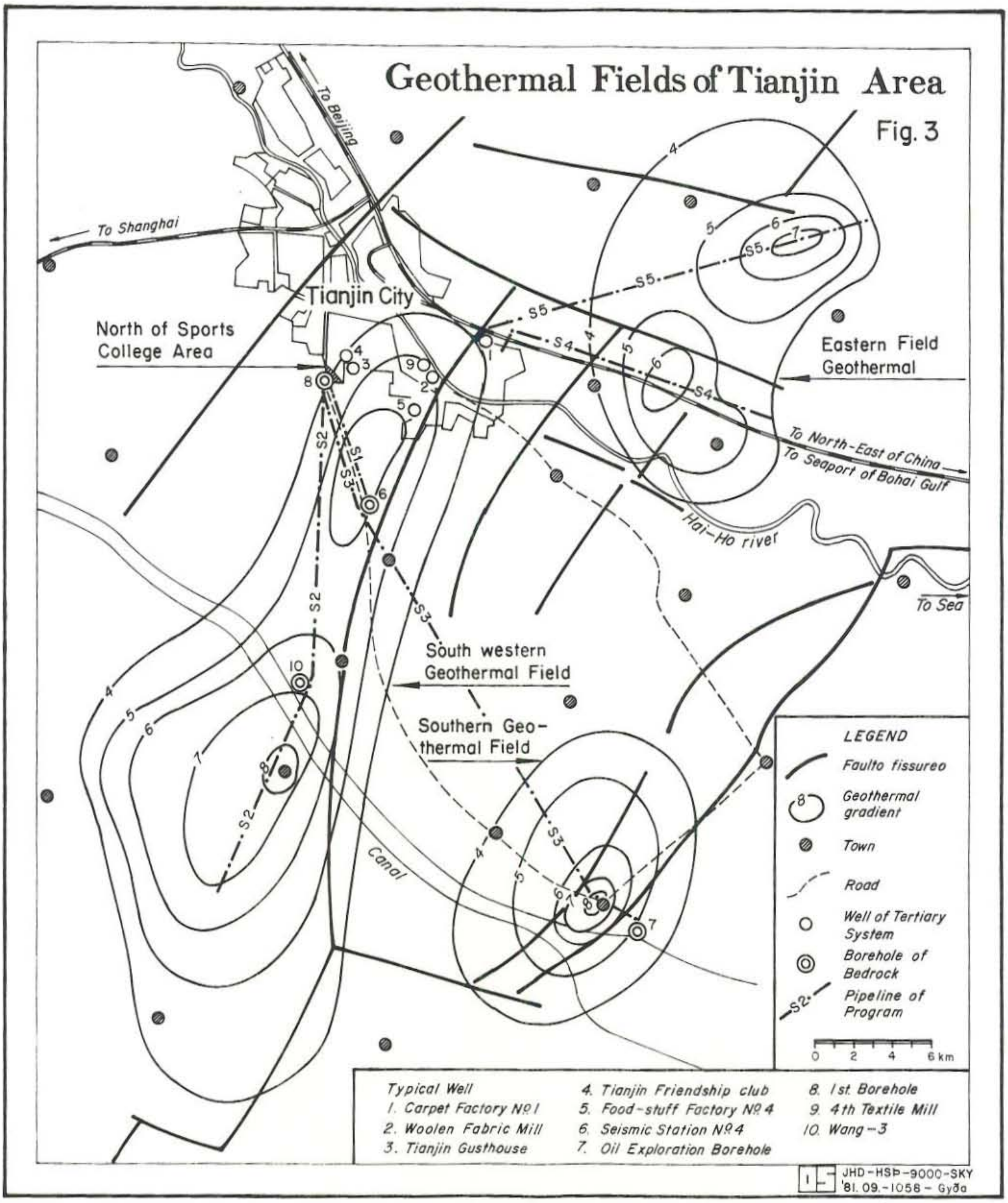


Fig. 2

Average Geothermal Gradient of 300m Depth of Beijing – Tianjin Area



Geothermal Fields of Tianjin Area
Fig. 3
To Beijing
To Shanghai
Tianjin City
North of Sports College Area
Eastern Field Geothermal
To North-East of China
To Seaport of Bohai Gulf
Hai-Ho river
To Sea
South western Geothermal Field
Southern Geo-thermal Field
Canal
LEGEND
Faulto fissureo
Geothermal gradient
Town
Road
Well of Tertiary System
Borehole of Bedrock
Pipeline of Program
0 2 4 6 km
Typical Well
1. Carpet Factory No 1
2. Woolen Fabric Mill
3. Tianjin Gusthouse
4. Tianjin Friendship club
5. Food-stuff Factory No 4
6. Seismic Station No 4
7. Oil Exploration Borehole
8. 1st Borehole
9. 4th Textile Mill
10. Wang-3
JHD-HSÞ-9000-SKY
'81.09.-1058 - Gyða

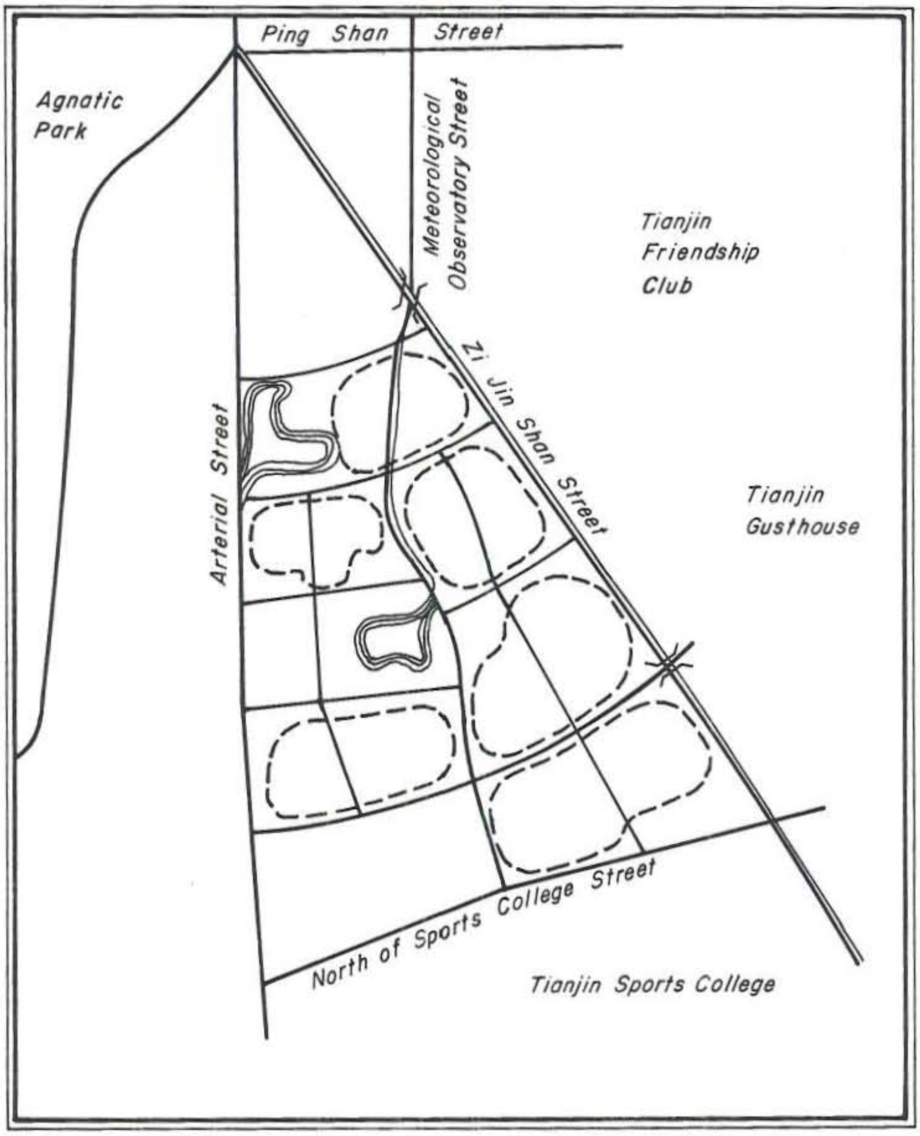


Fig. 4a

Position of North of Sports College in Tianjin

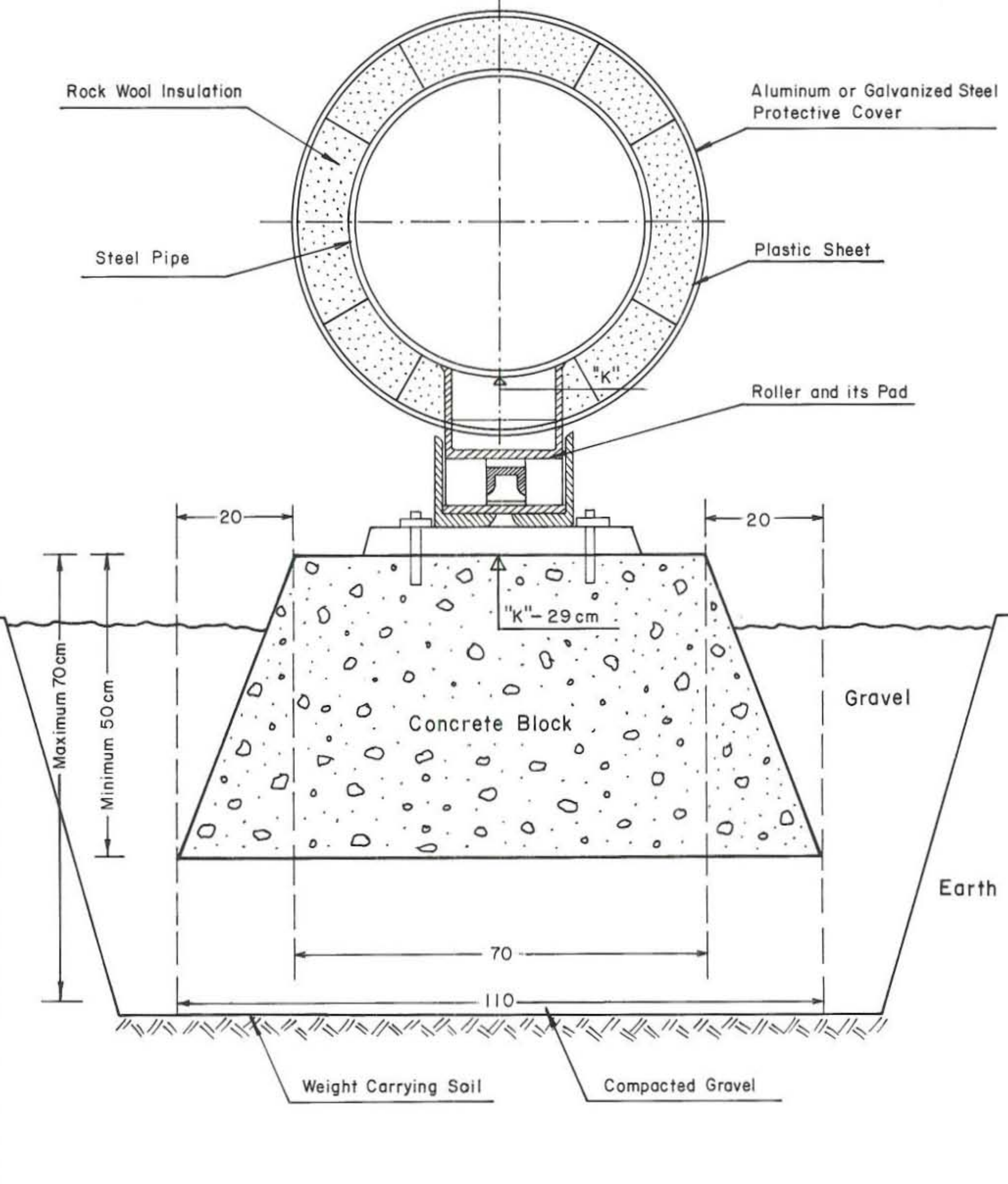


Fig. 5 Typical Above Ground Pipeline

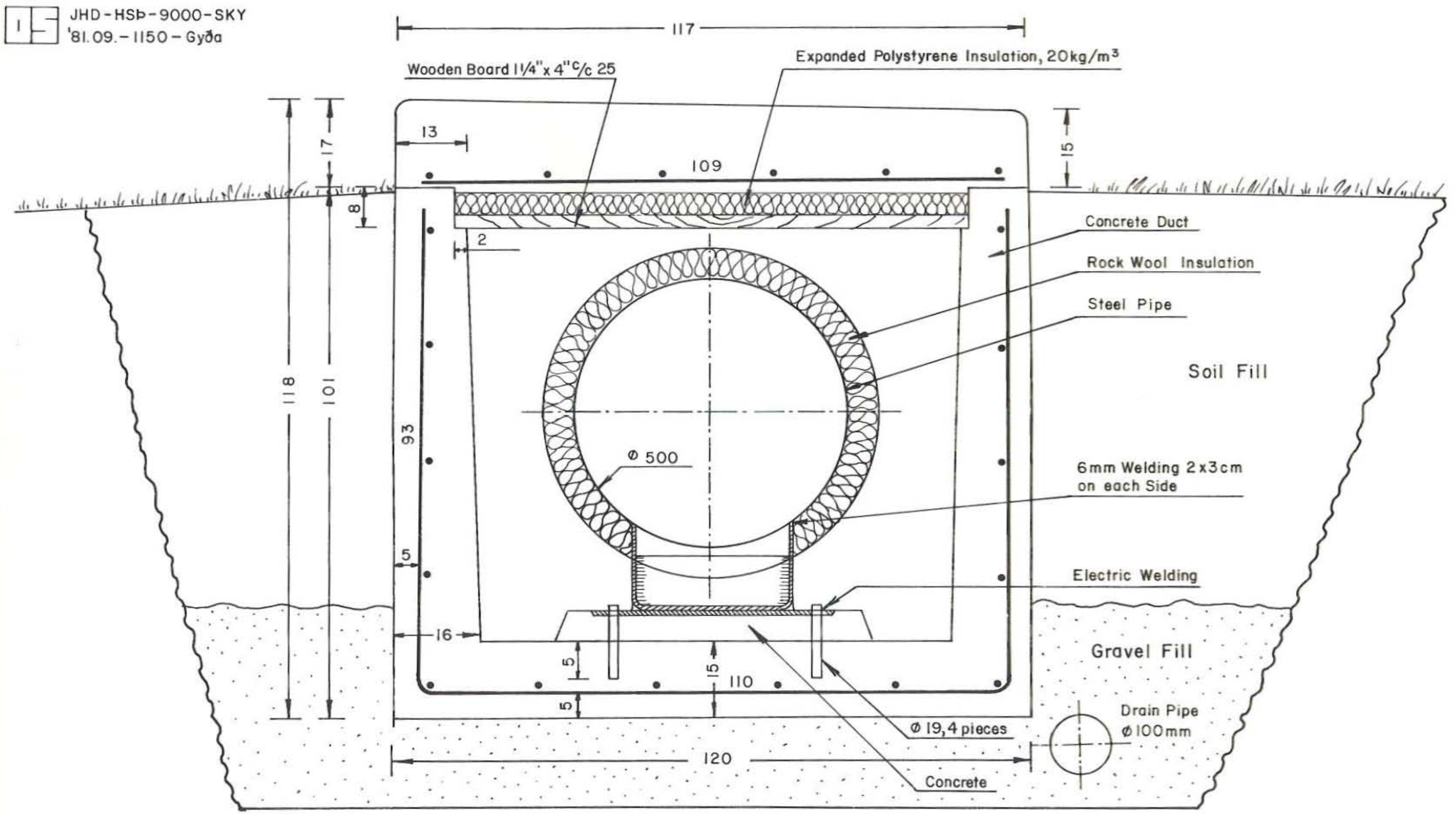


Fig. 6 Typical Steel Pipe in a Concrete Duct

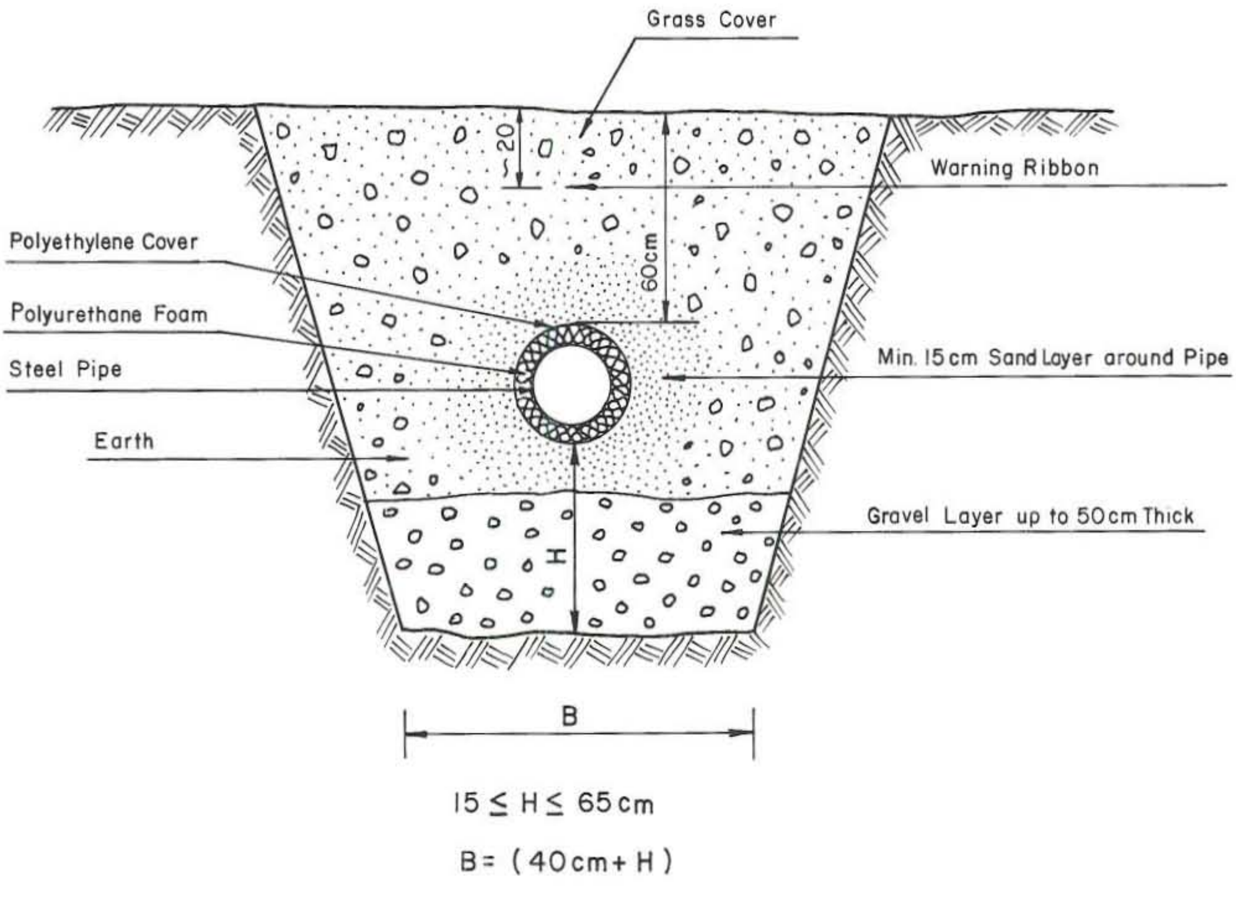
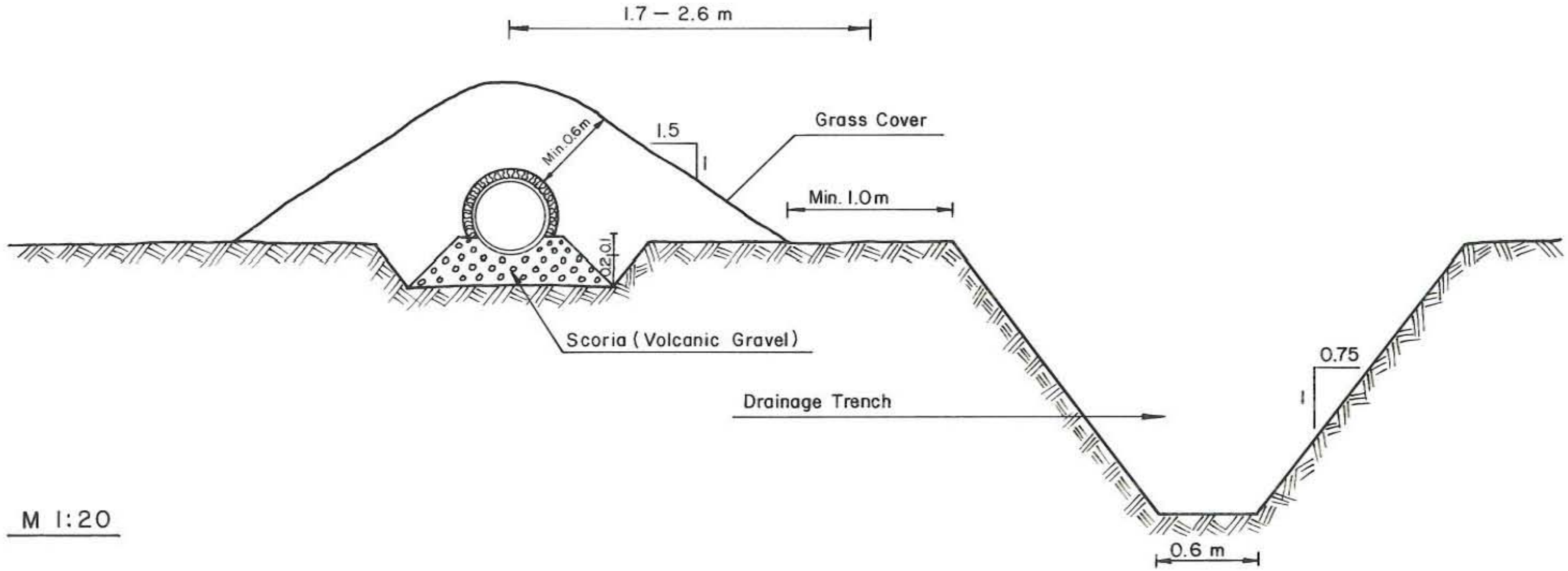


Fig. 7

Typical Steel Pipe with a Pratective Polyethylene Cover

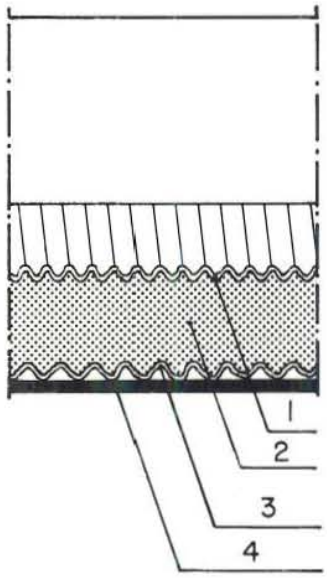
JHD-HSÞ-9000-SKY
'81. 09. - 1187-Gyða



M 1:20

Fig. 8

Typical Asbestos Cement Pipe



1. Corrugated Service Pipe

Stainless Steel or Copper
The corrugations have been designed to offer optimum flow characteristics

2. Thermal Insulation

Consisting of flexible solidified Polyurethane foam, with a thermal conductivity of 0.021 W/m x K at 20 °C.

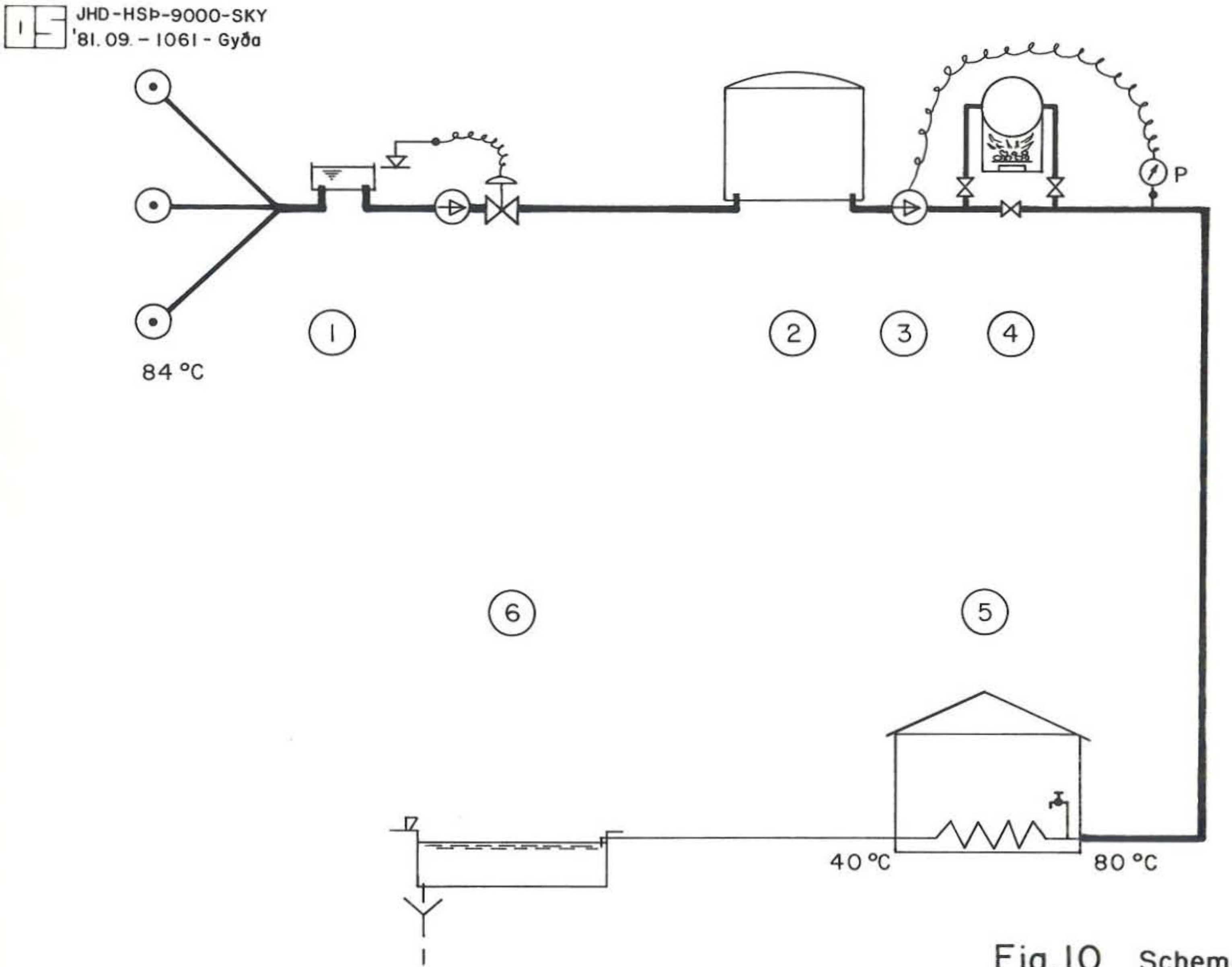
3. Corrugated steel casing

To absorb earth and traffic loads.

4. Corrosion protection

Consisting of two layers of rubber/bitumen polyment separated by a layer of Hostaphane foil with an overall Polyethylene sheath, altogether up to 5mm thick depending on pipe size providing a dielectric strength of 120 KV to 300 KV

Fig. 9 Double Layer Corrugated Pipe



1 *Geothermal Field*

2 *Storage Tanks*

3 *District Pumping Station*

4 *Peak Loading Boilers*

5 *Single Pipe Distribution System*

6 *Swimming Pool*

Fig. 10 Schematic Line Diagram of Geothermal District Heating System in Tianjin

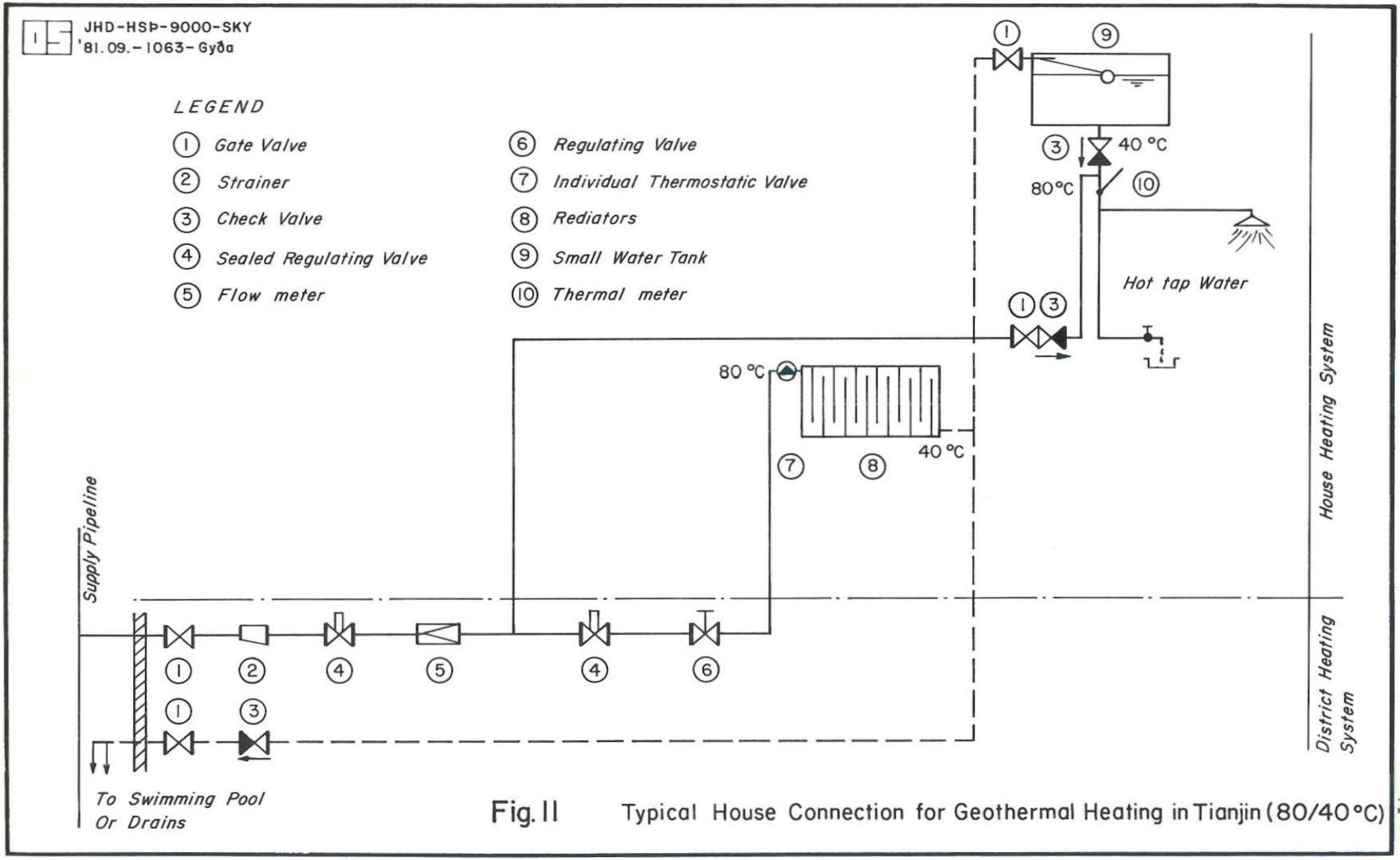
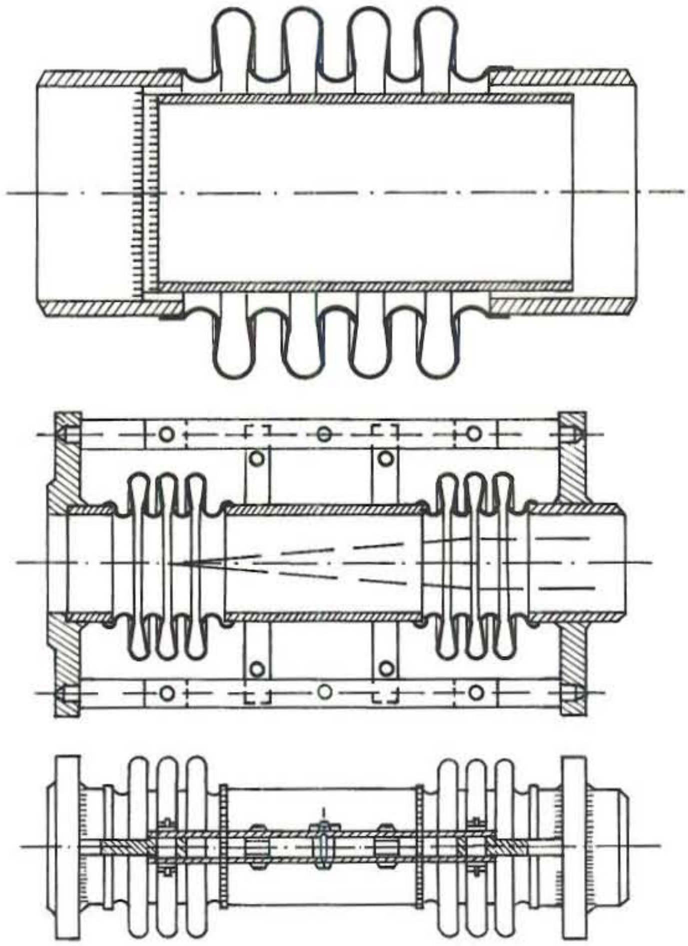


Fig. 11 Typical House Connection for Geothermal Heating in Tianjin (80/40 °C)



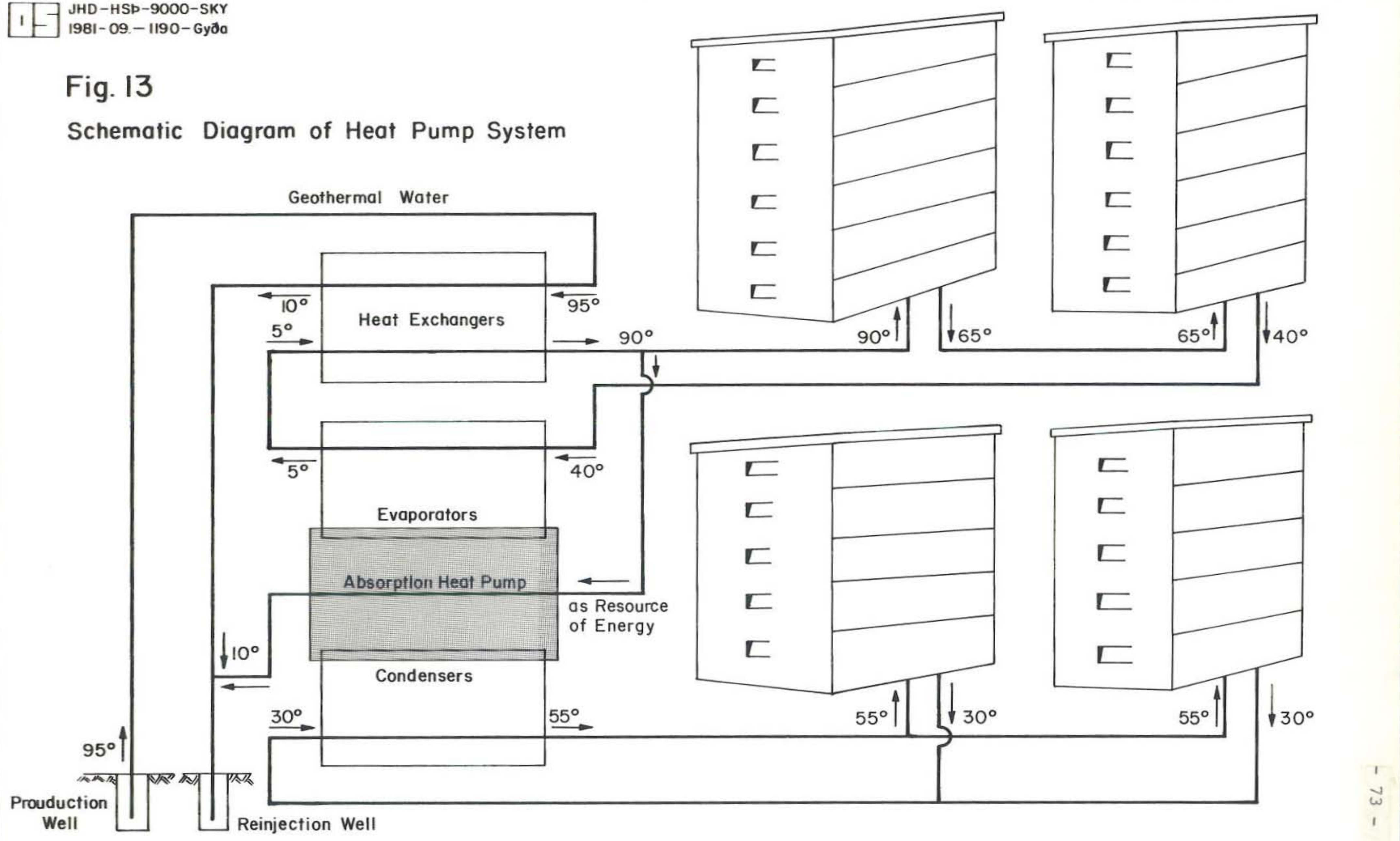
Top: Axial compensator with welding ends and internal sleeve.
Below: Swing compensator, one flanged end, the other weld end.

Fig. 12 Bellows

JHD-HSÞ-9000-SKY
1981-09.-1190-Gyða

Fig. 13

Schematic Diagram of Heat Pump System



Appendix A Typical Applications of the Geothermal Energy in Tianjin

A.1 Carpet Factory No. 1

A.1.1 Introduction

The geothermal well in this factory was drilled late in 1975. The depth of the well is 804 m, with water production formation at 780-850 m. The output of the well is 50 t/h at a temperature of 42°C.

The total hardness of the water is 1.93° DIN, ph = 7.98, chloride content 240 mg/l, salinity 1050 mg/l, fluorine 2.5 mg/l, and the alkalinity is 21.84°DIN. Chemical type HCO_3-Cl-Na.

In this well a submersible pump is used. It pumps water at 90 m below the surface. Its hydrodynamic level is at 81 m, and hydrostatic level at 57 m below the surface.

The water from the well is used for space heating, hot water and for processing in the workshop (washing of wool and carpets and dyeing of wool). The geo-heat water consumption of the factory is 400,000 t/year.

A.1.2 The benefits from utilizing geothermal water in this factory

1. The saving of 900 tonnes of coal every year.
2. The water for the boiler does not need to be softened, so 50 t/year of salt is saved.
3. By using geothermal water, the alkali for washing wool is reduced, saving 10 t/year.
4. The quality of the products is improved. The dirt in the carpets after washing by geothermal water is reduced from 2% to 15%, the bleach is higher, and the carpets look brighter and more beautiful.
5. It is a therapeutic water for bathing and good for chronic diseases (such as rheumatism).

A.1.3 Problems encountered

1. Cracks have been found at the joints of the 14"-16" supply pipes, and sand is found in the water.
2. During repairs of the well, corrosion was found in the pipe from the pump.

A.2 Woollen Fabric Mill

A.2.1 Introduction

The well in the mill was drilled in February of 1972 and completed in August the same year. The depth of the well is 820 m and the water producing formation is at 785 m. The temperature of the well is 49-51°C and the output of the well is 50 t/h. The quality of the water: The total hardness is 1.18°DIN, salinity 874 mg/l, ph=8.3. Chemical Type $HCO_3 \cdot Cl\text{-}Na$.

The hydrostatic level at the beginning was 7 m, but now it is down to 49 m below the surface. At present the output of the well using a submersible pump is 50 t/h.

A.2.2 Applications and benefits of using the water

1. For space heating (10,000 m^2), bathing and technological processing. Supplies water for 2 boilers with a capacity of 10 t/h, the water consumption is 800 t/h.
3. The saving of 8 tonnes of coal a day and 2,400 tonnes a year.
4. The water supplied to the boilers does not need to be softened, so 450 tonnes of salt is saved every year.
5. The saving of electricity is 15,000 kWh per year.
6. The geothermal water is directly used to wash the raw materials and the products. In dyeing, because the high alkalinity of geothermal water, the time for neutralization is shorter, recuding it from 2.5 hours to 1.8 hours. With the geothermal water the colour of the product is more durable and pleasant, and both the brightness and the bleach are much higher than before.

Note: 700.000 blankets and 600.000 meters of fabric are produced annually.

A.3 Tianjin Guesthouse

A.3.1 Introduction

Tianjin Guesthouse is the biggest hotel in Tianjin and specially built for important meetings and guests. Combined with the peak loading boiler the geothermal water here is used for space heating of a total of 80.000 m^2 and the hot water supply to bathrooms.

The depth of the well is 641 m, water producing formation at 586-605 m, water temperature 42°C, and the output of the well is 60 t/h. The quality of the water: The total hardness is 0.7°DIN,the salinity 602 mg/l, and the ph = 8.4.

A.3.2 Application and savings

1. The 1000 rooms and their bathrooms in the hotel are supplied and heated with geothermal water.
2. Saves 3.000 tons of coal every year.

A.3.3 Problems in using the geothermal energy in the hotel

In order to prevent the submersible pump used in the well from damage, the rated power of the motor (72 kW) is much higher than it should be (28 kW). The readings on the meters show the voltage to be 380 V and the current 130 A. This is not reasonable, however the motor of the submersible pump is not designed for the high ambient temperature.

A.4 Tianjin Friendship Club

A.4.1 Introduction

The well in the club was completed in 1973. The water producing formation of the well is 808-836 m, the temperature is 47°C and the output is 60 t/h. The quality of the water: the total hardness is 1.96°DIN. Alkalinity is 25.0°DIN. The salinity is 702 mg/l and the fluorine content is 3 mg/l. Chemical type HCO_3·Cl-Na.

Here a deep well pump is used, the shaft of the pump is 40 m long. The rated power of the motor is 28 kW. The water level of the well has decreased by 3 m per year to date.

A.4.2 Application and savings

1. With heating supplied by the peak loading boiler, the total heating area is 50.000 m^2 heating 100 rooms.

2. Hot water is supplied to a swimming pool and bathrooms.
3. 1,000 tonnes of coal are saved every year.

A.5 Food-Stuff Factory No. 4 (Duck Farm)

A.5.1 Introduction

In 1970 the drilling of the well started. At the beginning it was an artesian well, but now it is pumped.

The depth of the well is 798 m and the water producing formation is at 678-703 m. The temperature of the well is 49-52.7°C and the output is 30-40 t/h.

The total hardness of the water is 1.12°DIN and the salinity is 1021 mg/l. Alkalinity is 21.78°DIN. Chemical type HCO_3·Cl-Na.

A. 5.2 The Application

Initially the well was drilled for use in predicting earthquakes and now it is used for the Duck Farm.

The water is used for the process of slaughtering and hatching of ducks, as well as for the boiler, bathrooms and space heating of 50 rooms. The use of the well saves 500 tonnes of coal every year.

Note: About 5000 "Beijing duck" and 15,000 chicken are processed per day, equivalent to 20 tonnes of meat.

A.6 Seismic Station - ZHEN No. 4 Borehole

A.6.1 Introduction

It is an artesian well. The artesian pressure is 2.8 kg/cm^2. Its depth is 1406 m, water producing formation at 1151-1406 m, temperature at the well head is 84°C, and its output is 83 t/h. Its total hardness is 8.52°DIN, salinity 2262 mg/l, and ph=7.39. Chemical types: SO_4-Cl-Na.

It is situated in West Suburb District at a distance from city of 8 km.

A.6.2 Applications

1. It is used for the long range prediction of earthquakes. The rate of flow of the water is controlled to 5 t/h.
2. For space heating of the laboratories within the station.
3. For a heating supply to a 660 m^2 greenhouse. The greenhouse is used to grow four crops of vegetables per year, with annual profits of about 25,000 yuan.

A. 6.3. Problem

Some corrosion has been found inside pipes after a long period of observation.

A.7 Oil Exploration Borehole - ZHENG No. 3

This is an oil exploration well. It has not yet been put into operation as a geothermal well.

It is situated within the Southern Suburb District. The distance from the city is 30 km.

Utilization plans: Aside from seismic observation, it is being considered to turn this area into a combined utilization base for farming services.

It is an artesian well. At a flow of 60 t/h, the pressure at the well-top is 4 kg/cm^2.

The depth of the well is 2397 m, the water formation is at 1400-1600 m and the temperature is 96°C.

The total hardness of the water is 7.01°DIN, the salinity 2017 mg/l, its pH=7.65. Chemical type $HCO_3 \cdot Cl$-Na.

Appendix B Computer Printout Showing Chemical Species and Equilibrium State of Thermal Water from "The First Borehole" in Tianjin

THERMAL WATER FROM CHINA

NORTH OF SPORTS COLLEGE AREA IN TIANJIN

PROGRAM WATCH2.

WATER SAMPLE (PPM)		STEAM SAMPLE
PH/DEG.C	7.39/25.0	GAS (VOL.%)
SIO2	27.50	CO2
NA	800.00	H2S
K	42.60	H2
CA	511.00	O2
MG	85.100	CH4
CO2	156.00	N2
SO4	1993.00	
H2S	4.44	
CL	863.40	
F	3.76	LITERS GAS PER KG
DISS.SOLIDS	4502.00	CONDENSATE/DEG.C
AL	0.0000	
B	0.0000	
FE	0.0000	CONDENSATE (PPM)
NH3	0.0000	PH/DEG.C
0		CO2
0		H2S
0		NA
		CONDENSATE WITH NAOH (PPM)
		CO2
		H2S

REFERENCE TEMP.	DEGREES C	58.0 (MEASURED)
SAMPLING PRESSURE	BARS ABS.	
DISCHARGE ENTHALPY	MJOUL/KG	
DISCHARGE	KG/SEC.	42.5
MEASURED TEMPERATURE	DEGREES C	58.0
RESISTIVITY/TEMP.	OHMM/DEG.C	0.0/ 0.0
EH/TEMP.	MV/DEG.C	0.000/ 0.0

MEASURED DOWNHOLE TEMP. DEGREES C/METERS		FLUID INFLOW DEPTH (METERS)
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0

IONIC STRENGTH = 0.08947 IONIC BALANCE : CATIONS (MOL.EQ.)0.06023627
ANIONS (MOL.EQ.)0.06093971
DIFFERENCE (%) -1.16

DEEP WATER (PPM)				DEEP STEAM (PPM)		GAS PRESSURES (BARS ABS.)	
SIO2	27.50	CO2	156.00	CO2	0.00	CO2	0.152E-01
NA	800.00	H2S	4.44	H2S	0.00	H2S	0.523E-03
K	42.60	H2	0.00	H2	0.00	H2	0.000E+00
CA	511.00	O2	0.00	O2	0.00	O2	0.000E+00
MG	85.093	CH4	0.00	CH4	0.00	CH4	0.000E+00
SO4	1992.96	N2	0.00	N2	0.00	N2	0.000E+00
CL	863.33	NH3	0.00	NH3	0.00	NH3	0.000E+00
F	3.76					H2O	0.181E+00
DISS.S.	4502.00					TOTAL	0.197E+00
AL	0.0000						
B	0.0000			H2O (%)	0.00		
FE	0.0000			BOILING PORTION	0.00		

ACTIVITY COEFFICIENTS IN DEEP WATER

H+	0.819	KSO4-	0.783	FE++	0.400	FECL+	0.766
OH-	0.758	F-	0.758	FE+++	0.177	AL+++	0.177
H3SIO4-	0.766	CL-	0.751	FEOH+	0.779	ALOH++	0.386
H2SIO4--	0.386	NA+	0.766	FE(OH)3-	0.779	AL(OH)2+	0.783
H2BO3-	0.743	K+	0.751	FE(OH)4--	0.377	AL(OH)4-	0.772
HCO3-	0.766	CA++	0.400	FEOH++	0.377	ALSO4+	0.772
CO3--	0.365	MG++	0.442	FE(OH)2+	0.783	AL(SO4)2-	0.772
HS-	0.758	CAHCO3+	0.790	FE(OH)4-	0.783	ALF++	0.386
S--	0.377	MGHCO3+	0.766	FESO4+	0.779	ALF2+	0.783
HSO4-	0.772	CAOH+	0.790	FECL++	0.377	ALF4-	0.772
SO4--	0.352	MGOH+	0.796	FECL2+	0.779	ALF5--	0.365
NASO4-	0.783	NH4+	0.743	FECL4-	0.766	ALF6---	0.104

CHEMICAL COMPONENTS IN DEEP WATER (PPM AND LOG MOLE)

H+ (ACT.)	0.00	-7.236	MG++	41.14	-2.771	FE(OH)3	0.00	0.000
OH-	0.03	-5.714	NACL	1.98	-4.469	FE(OH)4-	0.00	0.000
H4SIO4	43.48	-3.345	KCL	0.05	-6.180	FECL+	0.00	0.000
H3SIO4-	0.40	-5.373	NASO4-	54.80	-3.337	FECL2	0.00	0.000
H2SIO4--	0.00	-9.120	KSO4-	7.99	-4.228	FECL++	0.00	0.000
NAH3SIO4	0.13	-5.959	CASO4	438.89	-2.492	FECL2+	0.00	0.000
H3BO3	0.00	0.000	MGSO4	213.30	-2.752	FECL3	0.00	0.000
H2BO3-	0.00	0.000	CACO3	3.04	-4.517	FECL4-	0.00	0.000
H2CO3	16.69	-3.570	MGCO3	0.25	-5.531	FESO4	0.00	0.000
HCO3-	178.09	-2.535	CAHCO3+	28.68	-3.547	FESO4+	0.00	0.000
CO3--	0.44	-5.134	MGHCO3+	2.78	-4.487	AL+++	0.00	0.000
H2S	0.88	-4.589	CAOH+	0.01	-6.798	ALOH++	0.00	0.000
HS-	3.46	-3.981	MGOH+	0.01	-6.479	AL(OH)2+	0.00	0.000
S--	0.00	-13.020	NH4OH	0.00	0.000	AL(OH)3	0.00	0.000
H2SO4	0.00	-16.779	NH4+	0.00	0.000	AL(OH)4-	0.00	0.000
HSO4-	0.01	-6.980	FE++	0.00	0.000	ALSO4+	0.00	0.000
SO4--	1463.15	-1.817	FE+++	0.00	0.000	AL(SO4)2-	0.00	0.000
HF	0.00	-7.607	FEOH+	0.00	0.000	ALF++	0.00	0.000
F-	3.76	-3.704	FE(OH)2	0.00	0.000	ALF2+	0.00	0.000
CL-	862.10	-1.614	FE(OH)3-	0.00	0.000	ALF3	0.00	0.000
NA+	788.61	-1.465	FE(OH)4--	0.00	0.000	ALF4-	0.00	0.000
K+	40.26	-2.987	FE(OH)++	0.00	0.000	ALF5--	0.00	0.000
CA++	369.19	-2.036	FE(OH)2+	0.00	0.000	ALF6---	0.00	0.000

IONIC STRENGTH = 0.08388 IONIC BALANCE : CATIONS (MOL.EQ.)0.05745662
ANIONS (MOL.EQ.)0.05802397
DIFFERENCE (%) -0.98

CHEMICAL GEOTHERMOMETERS DEGREES C 1000/T DEGREES KELVIN = 3.02

QUARTZ 75.5
CHALCEDONY 45.6
NAK 135.8

OXIDATION POTENTIAL (VOLTS) : EH H2S= -0.279 EH CH4= 99.999 EH H2= 99.999 EH NH3= 99.999

LOG SOLUBILITY PRODUCTS OF MINERALS IN DEEP WATER

	TEOR.	CALC.		TEOR.	CALC.		TEOR.	CALC.
ADULARIA	-19.203	99.999	ALBITE LOW	-18.294	99.999	ANALCIME	-14.563	99.999
ANHYDRITE	-5.058	-4.704	CALCITE	-8.814	-8.005	CHALCEDONY	-3.215	-3.345
MG-CHLORITE	-82.293	99.999	FLUORITE	-10.684	-10.081	GOETHITE	-6.158	99.999
LAUMONTITE	-29.631	99.999	MICROCLINE	-20.913	99.999	MAGNETITE	-32.919	99.999
CA-MONTMOR.	-98.365	99.999	K-MONTMOR.	-48.560	99.999	MG-MONTMOR.	-99.275	99.999
NA-MONTMOR.	-48.403	99.999	MUSCOVITE	-24.269	99.999	PREHNITE	-38.753	99.999
PYRRHOTITE	-120.929	99.999	PYRITE	-179.064	99.999	QUARTZ	-3.543	-3.345
WAIRAKITE	-26.165	99.999	WOLLASTONITE	12.282	8.694	ZOISITE	-37.486	99.999
EPIDOTE	-47.049	99.999	MARCASITE	-152.690	99.999			

Appendix C Review for Main Types of Heating Pipelines

C.1 Above ground pipeline with a sheet metal protective cover.

The pipe is resting on supports every 5 to 10 meters. These supports are made of concrete blocks resting on a bed of sand as shown in Figure 5. If the ground carrying capacity underneath the supports is insufficient it may be necessary to undertake a soil change in these places. The blocks are generally lined up in such a way that the pipe will be straight over a distance of 100 m. The pipe rests on special steel supports fixed to the concrete blocks. These supports allow the pipe to move within limits in an axial direction due to thermal expansion. When the pipe has been welded together and all supports properly aligned it is insulated with rock wool and finally covered by a protective sheet metal cover, either aluminium or galvanized steel.

These pipelines are well suited for areas where the line can be placed above ground. However farm tractors need to be able to traverse the pipelines. These pipelines are not well suited in Tianjin.

C.2 Steel pipe in concrete duct, an example is shown in Figure 6. This type of pipeline is the most expensive: The larger diameter in the Carger sizes. These pipelines cost about $ 250 pr. meter. They have the longest life expectancy and lowest maintenacne cost but must be laid to a high standard on construction. Due to the high initial cost and the seeping problem in Tianjin this type could not be used unless the line is relatively short.

C.3 Steel pipe with a protective polyethylene cover. These preinsulated pipes have been available in Reykjavík in sizes 14" (ϕ350 mm) and 24" (ϕ600 mm) and have been used in some places. It is expected that these will in the future, replace the concrete conduit pipe. An example of an underground line is shown in Figure 7.

The polyethylene covered pipe is preinsulated wtih polyurethane foam. This means that the pipe is factory insulated in lengths of approximately 6-12 meters. Since the pipe sections are welded together in the field, the factory made insulation does not cover the ends, so the steel pipe is therefore somewhat longer than the protective polyethylene cover.

C.5 Double layer corrugated pipe with polyurethane foam and protective polyethylene cover.

These double layer corrugated pipes are used in West Germany and Japan and are produced by these countries. The operational conditions are:

Maximum pressure 16 kg/cm^2
Maximum temperature 130°C
Diameter from 20 to 200 m

Both the inner and outer pipe are corrugated (see Fig.9). The insulating layer between the double layer consists of polyurethane foam and a polyethylene coating on the outer pipe. It possesses many of the features that a heating supply pipe must be designed for: corrosion resistance, insulation and absorption of heat expansion.

The advantages claimed are following:

1. High mechanical strength. It can withstand the pressure of a truck on the ground. The fastening bolts and expansion joints are not used for this type of pipe.

2. It can be directly buried under ground without any channels and rolled as a cable, so it is very easy to lay. Both welding and flanges are used for jointing pipes.

3. The temperature loss is low.

4. Because of the good quality and the corrosion resistance, its useful life can be as long as 30 years.

The disadvantage is that its inner pipe is made of stainless steel or copper which is more expensive than steel and a Hydrogen Sulphide environment is bad for copper. So these are not well suited to use in a large installation for geothermal engineering.

When two pipe ends have been welded together and tested the bare pipe ends are covered by a slipover cuff. Two different liquids, component A and B, are then poured simultaneously through a hole in the slipover cuff. These two components are polyol, a polyhydroxide compound, and MDI, an isocyante compound mixed with a foaming agent such as Freon. When the two compounds are mixed together a polymerization reaction takes place, the Freon evaporates, and a polyurethane foam insulation fills the empty space. The hole is then closed with a plug and wrapped with a water proof tape and the pipe joint is insulated and waterproof.

These pipes are somewhat less expensive than the concrete conduct type, especially for small sizes in a single pipe system and easier and quicker to lay and install. They are, however, more vulnerable to external damage, and directional changes create problems. So care must be taken at the construction stage.

This kind of pipe is well suited for conditions of Tianjin that have a high level of ground water and narrow streets 42% of the streets are less than 10 metres wide, in addition there are many manufacturers of plastic pipes. These pipes can be used as main pipelines distribution network and house lines.

C.4 Asbestos cement pipe with an earth and grass cover. Asbestos cement pipe is commonly used for geothermal supply line to district heating systems in Iceland and other countries. These pipes are attractive because of low initial cost compared to steel pipe. Their disadvantage is that they have much greater heat losses than from insulated steel pipe, since the asbestos cement pipe is generally used with no insulation other than the earth and grass cover (See Fig. 8). The asbestos cement pipe is also much weaker, structurally, than the steel pipe which means that the maintenance cost is likely to be much higher. These pipes are therefore mainly used where the hot water must be transported over a long distance to a relatively small consumer market and when the production cost of the hot water is relatively low. In that case the large heat losses are not too important.

Because of its large temperature drop, it is not favoured in Tianjin as a supply pipeline. However, in some double pipe or two-stage system, these pipes could be used as return pipes to transport water of lower temperature to, say, a swimming pool.