USE OF COMPUTER PROGRAMS FOR CALCULATIONS IN LOW-TEMPERATURE GEOTHERMAL UTILIZATION

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ABSTRACT

Three computer programs are presented to illustrate the use of computer calculations for solving geothermal energy utilization problems. The programs are written for the following topics: a) Deep well pump selection, b) Heat and pressure losses in geothermal water transmission pipelines, c) Evaluation of district heating system design temperatures. For each of these programs both the fundamental basis and computational methods are described. The use of the programs is illustrated by calculations for a district heating scheme that has been proposed for a part of the city of Beijing.

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1 INTRODUCTION

1.1 Scope of work

The author of this report was awarded an UNU fellowship to attend the 1981 UNU Geothermal Training Programme held at the National Energy Authority in Iceland. After about four weeks of introductory lecture course on all scientific and engineering aspects of geothermal energy, the author received specialized training in low-temperature geothermal utilization for about five weeks. During this time there were lectures dealing with various topics of low-temperature geothermal utilization given by geothermal specialists of the National Energy Authority, University of Iceland, Reykjavík Municipal Heating Service, Fjarhitun Engineering Consultants and various other institutions in Iceland associated with geothermal utilization. Some of the special lectures were given by experts from Japan, New Zealand, Scotland and France. The latter three were specially invited by the UNU Geothermal Training Programme.

The main parts in the specialized training were the exploitation of low-temperature geothermal energy, pipeline and pumping station design, district heating system design, geothermal water chemistry and computer applications.

The author visited various geothermal areas in Iceland during the two-weeks field excursions which made a good combination of the theory with the practice.

This paper was written in the final stage of the Training Programme as a final report and completed at the end of the six month training period.

1.2 Use of computer in geothermal utilization

There are extensive low-temperature geothermal energy resources in the world. In recent years low-temperature geothermal water has been widely used for various purposes to replace high-quality energy (Ref. 1). The most common uses of low-temperature geothermal energy are for district heating, greenhouse heating, fish cultivation and industry. Its application to district heating is considered to be one of the most important uses.

In the different stages of exploiting low-temperature geothermal energy a large number of complicated repetious calculations are necessary. In recent years computer programs have been used for both design and operation analysis in low-temperature utilization. Scientists at the National Energy Authority of Iceland have been using computer programs to interpret chemcial data of water samples, to obtain information about the chemical characteristics of the deep geothermal waters (Ref. 2). They also use the computer for geothermal water pipeline design (Ref. 3). It is known that engineers in France have developed a mathematical model with a computer program for optimisation of the distance between a reinjection well and the production well (Ref. 4). A mathematical model, which has been computerised for the determination of the optimum insulation thickness for prefabricated district heating pipes, is used for design purposes in Denmark (Ref. 5). It is also well known that a computer program for calculating heat and pressure losses in district heating networks has also been developed by engineers in England (Ref. 6). Another complete mathematical model with a large computer program called GEOCITY is used successfully in practice for studying the economics of district heating using geothermal energy (Ref. 7).

The author has developed three computer programs (all in FORTRAN 4) for calculation topics in low-temperature geothermal exploitation. The main purpose of writing these programs was to learn about the use of computer in solving geothermal engineering problems. The topics selected are the following:

1. Deep well pump selection.
2. Heat and pressure losses in geothermal water transmission pipelines.
3. Evaluation of district heating system design temperatures.

The topics are simple and there are available calculation formulae which have been established and used for a long time. In other words, there are mathematical descriptions for these problems and the main task left for the author is to create an algorithm for the computation and to express it in a computer program using a Fortran computer language.

The three programs are written separately. The author was interested in creating a complete computer program for geothermal water distribution system calculations. However, this was not realized because of the limited time available. The programs developed and their use for nominated tasks are described briefly in the following chapters.

2 SELECTING A DEEP WELL PUMP: PROGRAM DWPS

2.1 Principles and Criteria for Deep Well Pump Selection

2.1.1 Introduction

In a low-temperature geothermal field, the correct selection and use of deep well pumps is important because it affects the operation, economy and safety of the utilization system. The main task for the deep well pump calculation is to decide upon the pump size, number of stages and column length to obtain the required water flowrate and well head pressure and to ensure a safe level of production. In addition a deep well pump calculation can be used to check the output of the pumps and any inefficiencies in their operation. Different types of pumps require different calculation procedures and data although the goal and nature of the tasks are the same.

2.1.2 Pump size

The pump size is first chosen according to the flowrate ordered or required. The reasonable flowrates for PLWAY Vertical Pumps are given in Tab. 2.1.

Table 2.1

Recommended flow ranges of FLOWAY vertical pumps

Pump size	Column sizes	Flow range recommended
6 inch and 8 inch	6 inch column pipe 2 inch enclosure tube 1 3/16 inch shaft	14-40 l/s
10 inch	8 inch col. pipe 2 1/2 inch encl. tube 1 11/16 inch shaft	50-75 l/s
12 inch	10 inch col. pipe 2 1/2 inch encl. tube 1 11/16 inch shaft	85-110 l/s

2.1.3 Number of stages

When the pump size has been selected it is necessary to calculate the number of stages required. The pressure head which is needed for raising the hot water in the well to the surface and keeping the pressure at the well head high enough for the transmission system can be expressed as:

$$P = P_h + K_v + K_n + P_d + P_f \qquad (2\text{-}1)$$

where P = total pressure head needed (m)

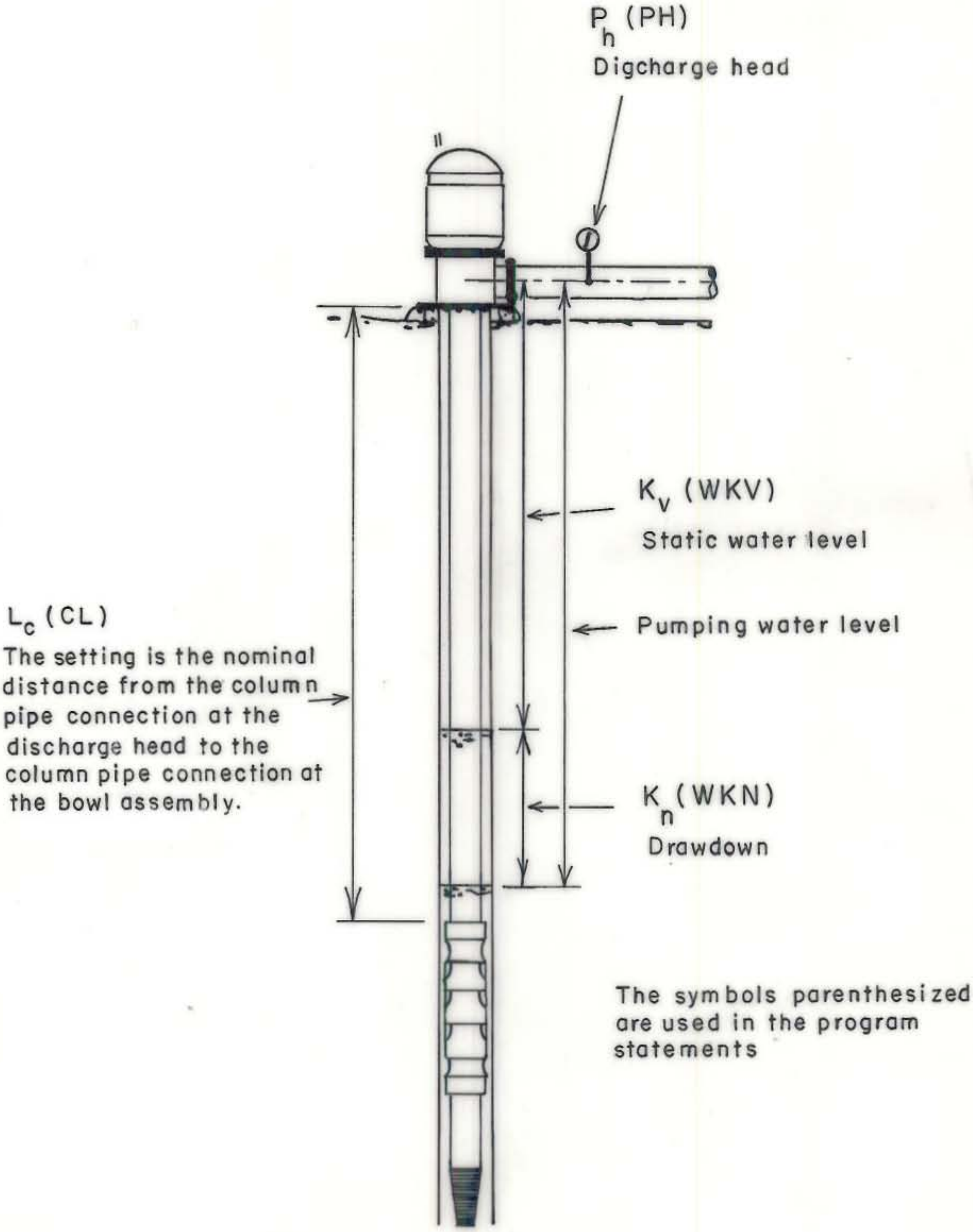
P_h = discharge head at the well head (m)

K_v = static water level (m)

K_n = draw-down (m)

P_d = velocity head (m)

Fig. 2.1 shows the main definitions used in the calculation.



The setting is the nominal distance from the column pipe connection at the discharge head to the column pipe connection at the bowl assembly.

The symbols parenthesized are used in the program statements

Fig. 2-1 Definitions used in calculations for deep well pumps

Draw-down is the difference between the static water level and the pumping water level. Customarily it is measured after several hours of continuing operation. Draw-down can usually be calculated with the formula:

$$K_n = a \cdot Q + b \cdot Q^2$$

where a and b are the flow coefficients of the well determined by a pumping test.

Column friction loss P_f is a funtion of flowrate Q and column length L_c and is found in the pump specifications (Ref. 8).

It is well known that the pressure head of deep well pumps is a funtion of flowrate. Two straight **lines** can be used to approach the pump characteristic curve by regression analysis. The pressure head of the pump can then be presented as

$$P_p = (c_1 + c_2 \cdot Q) \cdot Z$$

where Z is the number of stages of the pump as illustrated on Fig. 2.2. When the flowrate Q is less than Q_m (the flowrate corresponds to the cross point of the two lines) the constants c_1 and c_2 will have the values c_{11} and c_{21} respectively and when Q is larger than Q_m , $c_1 = c_{12}$ and $c_2 = c_{22}$.

The following equation must now be satisfied:

$$P_h + K_v + K_n + P_d + P_f = (c_1 + c_2 \cdot Q) \cdot Z \qquad (2\text{-}3)$$

There are three unknown variables in this equation: Number of stages Z, flowrate Q and column length L_c.

2.1.4 Column length

The column length L_c required is expressed by:

$$L_c = K_v + K_n + h_{min} + h_{saf}$$

In this expression, h_{saf} is the water level fluctuation and the lowering of the water level during the years of operation. It must be based upon the water level data of the field in the past. h_{min} is the minimum water column above the suction of the pump and is

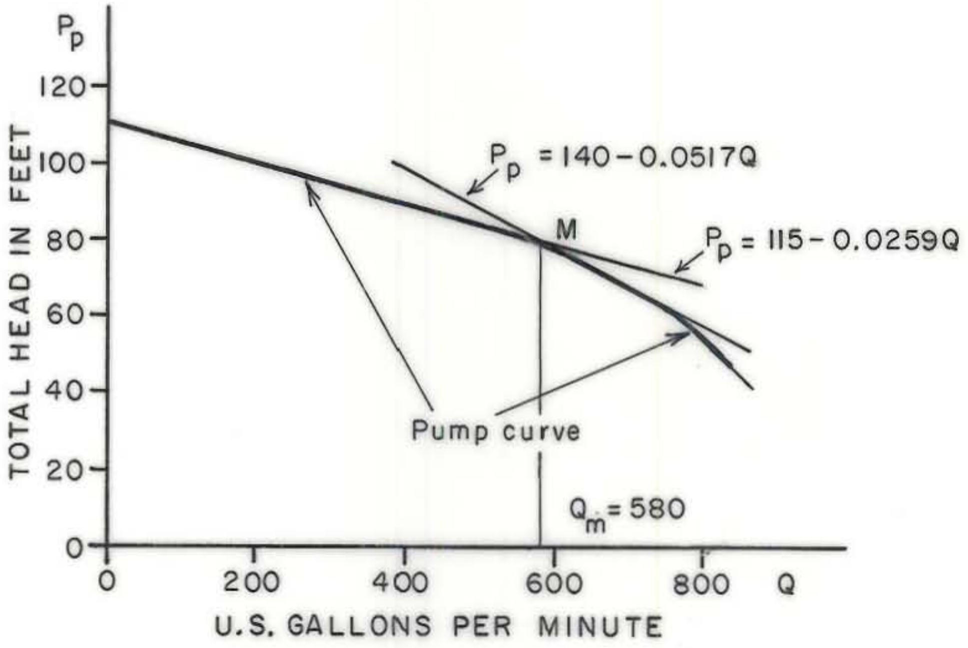


Fig. 2-2 Two straight lines are used to approximate the characteristic curve of a 8JKH Floway Vertical Pump (Ref. 8)

expressed as:

$$h_{min} = (P_o - P_a) / d \cdot g + NPSHR \qquad (2\text{-}5)$$

Here, P_o is the saturation pressure corresponding to the temperature of the water in the well, P_a is the atmosphere pressure and NPSHR is the "net positive suction need" required. It is one of the characteristic parameters of the pump and can be found from the performance sheet of the pump as a funtion of flowrate. When a linear funtion is used to approximate the NPSHR curve it can be calculated as:

$$NPSHR = c + d \cdot Q \qquad (2\text{-}6)$$

From expressions (2-4), (2-5) and (2-6) it is clear that the column length L_c is a funtion of flowrate Q. Thus, both the column length L_c and flowrate Q can be calculated from the equation system (2-3) and (2-4) combined, provided that the number of stages Z has been decided first.

2.1.5 Shaft thrust

The total shaft thrust TT is calculated and the elongation of the shaft E_a needs to be checked. The formula for calculating TT and E_a can be found from the specification sheet of the pump (Ref. 8). The elongation of the shaft calculated must not be larger than the clearance of the pump assembly.

2.1.6 Motor power capacity

In the calculation the power capacity of the pump must be estimated to check if the shaft horsepower is within the allowed range for the shaft and to select the correct motor capacity. In these calculations the values of efficiency for both pump and motor are taken from the specification sheets.

2.2 Computation method

2.2.1 The use of the loop technique

The flowchart of the computation is shown in Fig. (2-3). To solve the above mentioned equation system (2-3) and (2-4), a loop technique

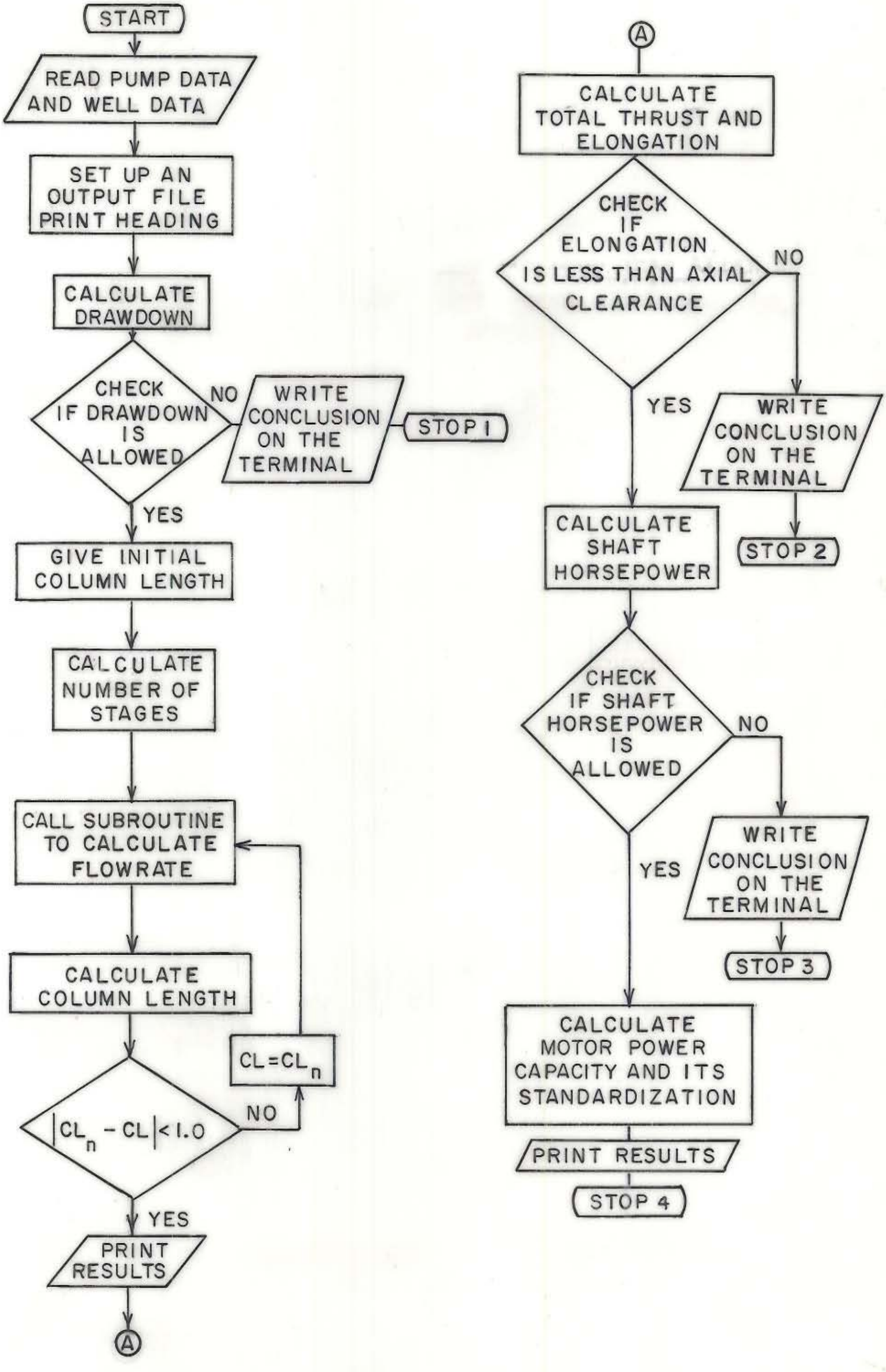


Fig. 2-3 The flowchart for program DWPS

has been used. After the number of stages Z has been decided the calculation goes into an iteration loop in which the Newton-Raphson Method (Ref. 9) is used to calculate a satisfactory flowrate Q. An outer iteration loop is used to decide the correct column length based on the flowrate calculated.

2.2.2 Use of subroutine

The above said iteration loop would be used many times in each run of the program. Obviously to arrange this loop as a subroutine is convenient. This subroutine is called "SUBFLO" (Appendix A).

2.2.3 Creating an input data file

It has been arranged that all the given values are put into two separate input data files. One is a pump data file and the other is a well data file. As an example, there are two pump data files and two well data files in Appendix E. In the input files, after each figure there is an explanation on the same line , which will enable the user to change the files correctly.

2.2.4 Pump characteristics

Usually pump manufacturers present pump characteristics with groups of curves, while some are given in tables. A regression analysis should be made to obtain the formulae presenting the pump characteristics and the corresponding constants. The available regression programs can be found in IMSL (International Mathematics Software Library). In addition, it is important to point out that care is needed in translation of the units when editing, since the units used by different manufactures are not always the same.

2.2.5 Arrangement of the checking procedure

In this program all the formulae and constants are chosen automatically by the computer, several checking procedures are executed automatically and if some criteria are not satisfied the relevant statements will interrupt the calculation process and instruct

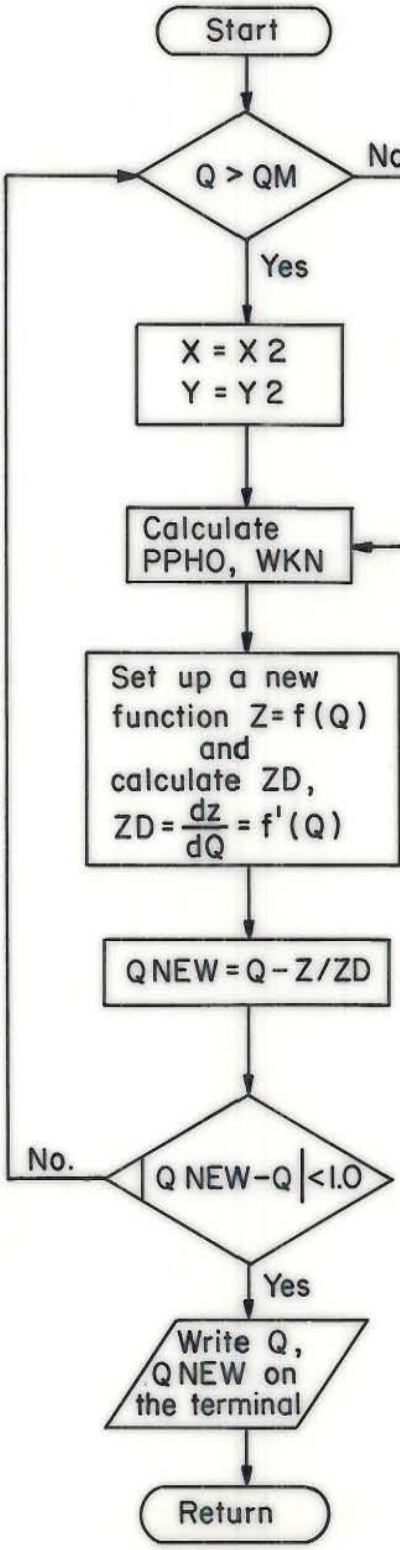


Fig. 2-4 FLOWCHART FOR SUBROUTINE PROGRAM SUBFLO

the computer to give the information on the terminal. This information advices the operator to change some of the initial values, then the calculation procedure will be repeated (see statements 32, 202 and 312 in the main program).

2.2.6 Output file

The calculation results together with some of the given values have been written in an output file named "DWPS.OUT" when the computation process is finished. As an example a printout of an output file is shown in Appendix E.

3. HEAT AND PRESSURE LOSSES IN GEOTHERMAL WATER TRANSMISSION PIPELINES: PROGRAM PIPES

3.1 Calculation principle and formulae used

Geothermal water transmission systems (transmission pipeline, distribution network and user connecting pipelines) have a wide range of design features. There are many different construction configurations, different dimensions and materials, whilst the medium (hot water) properties are also variable.

The calculation formulae for heat and pressure losses can be found in engineering handbooks and various other publications. The following is a brief description of the formulae used in this program.

3.1.1 Thermal resistance

The resistance to heat flow from hot water flowing inside a pipe to the ambient air can be divided into four parts:

1. Thermal resistance of the boundary layer of the water flowing in the pipe (R_{in}).
2. Thermal resistance of the pipe wall (R_{pipe}).
3. Thermal reisstance of the insulation layers and the protecting layer (R_{in} , R_p).
4. Thermal resistance of the air boundary layer at the outer surface of the pipeline if the pipe runs in the open, or thermal resistance

of the soil layer if buried (R_{out} or R_{sl}).

That is, the total thermal resistance can be expressed as:

$$R_{tot} = R_{in} + R_{pipe} + R_{ins} + R_{p} + (R_{out} \text{ or } R_{sl})$$

In practice there are always some items that can be neglected because they are relatively small. For open run insulated steel pipes, the thermal resistance of the pipe wall is much smaller than that of the insulation layer and therefore it can usually be neglected. The same could be true for the thermal resistance of the internal and external surfaces of the pipelines. Therefore in this case we only need to calculate the thermal resistance of the insulations, which is given by:

$$R_{ins} = \ln(D_3/D_2) / \; 2\P K_{ins}$$

Here, D_2 and D_3 are the inner and outer diameters of the insulation layer respectively and K_{ins} is the thermal coductivity of the insulation material.

For asbestos-cement pipes which are usually not insulated the thermal resistance of the pipe wall is:

$$R_{pipe} = \ln\ (D_2/D_1)/2\P K_{abs}$$

Here, D_1 and D_2 are the inner and outer diameters of the pipe and K_{abs} is the thermal conductivity of asbestos-cement.

For buried pipes, it is necessary to calculate the thermal resistance of the covering layers. The most common way is to bury the pipes in soil. In some cases the pipes are covered with sand before the pipe ditch is filled with soil and in some other cases the covering layers have different thermal conductivities due to their differing components and/or dampness (see Fig. 3-1). The thermal resistance of the covering layers can be calculated from the formula (Ref. 10):

$$R_{s1} = \frac{\ln(2(h_1+r_p)/r_p)}{2\ K_1\ \P} + \frac{1}{4(h_1+r_p)}\ (h_2/K_2 + h_3/K_3) \qquad (3\text{-}1)$$

where, R_{s1} is the thermal resistance of the covering layers

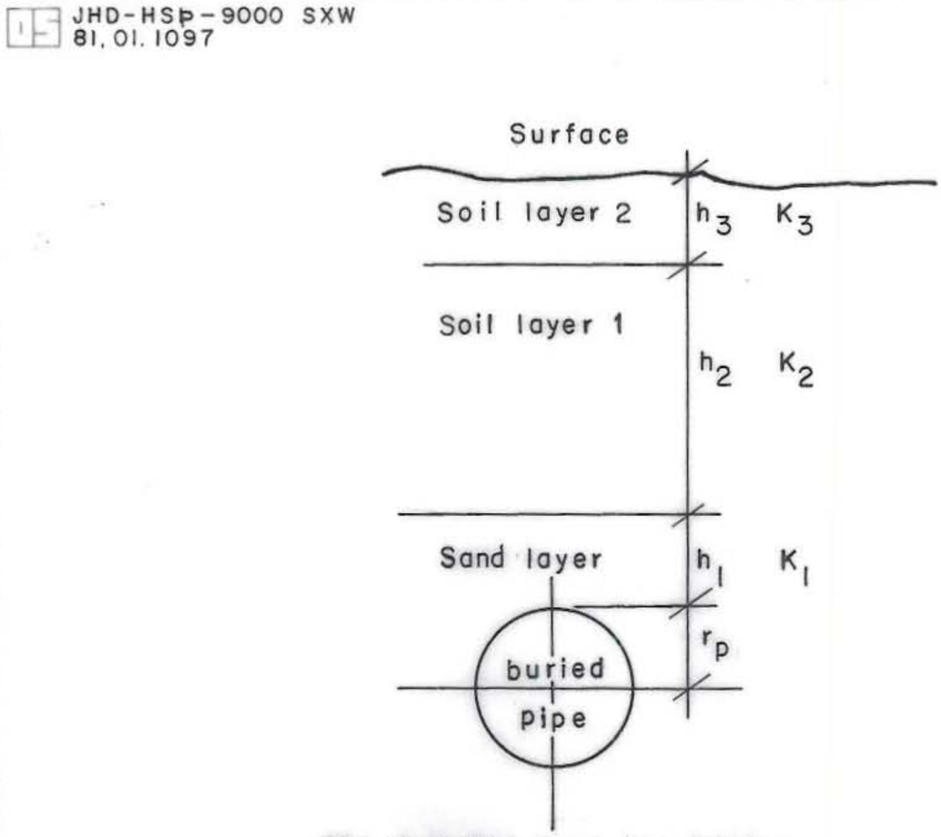


Fig. 3-1 The covering layers of a buried pipe

(m°C/W) h_1, h_2 and h_3 are the thickness' of each layer (cm),

K_1, K_2 and K_3 are the corresponding thermal conductivities (W/m°C) and

r_p is the outer radius of the pipe (cm).

When $(h_1+h_2+h_3)$ is less than $2r_p$, the following formula must used instead of formula (3-1);

$$R_{s1} = \ln((8(H/D)^2 -1) + 4\ (H/D)\ (4(H/D)^2 -1)^{0.5})/4\ K_{s1}$$

where H is the depth of the buried pipe center and K_{s1} is its thermal conductivity, while D is the outer diameter of the pipe.

3.1.2 Temperature drop and heat loss of the water in the pipes

The heat loss from one meter of pipe is given by:

$$Q = DT_m / R_{tot}$$

where R_{tot} is the total thermal resistance of the pipeline and DT_m is the logarithmic mean temperature difference;

$$DT_m = \frac{T_1 - T_2}{\ln((T_1-T_a)/(T_2-T_a))}$$

Here, T_1 and T_2 are the temperatures of the water at the inlet and the outlet respectively, while T_a is the ambient air temperature.

From another viewpoint, the total heat loss of the water is:

$$Q_{tot} = c \cdot m\ (T_1 - T_2)$$

Thus,

$$Q = Q_{tot} / L_p = c \cdot m\ (T_1 - T_2)/L_p = DT_m/R_{tot}$$

where c is the mean specific heat capacity of the water, m is the mass flowrate and $(T_1-T_2) = DT$ is the temperature drop of the water. Since, $T_2 = T_1 - DT$, we have;

$$\frac{DT}{\ln((T_1-T_a)/(T_1-DT-T_a))} = R_{tot} \cdot c \cdot m \cdot DT/L_p$$

and that is;

$$1/\ln((T_1-T_a)/(T_1-DT-T_a)) = R_{tot} \cdot c \cdot m / L_p \qquad (3\text{-}2)$$

The temperature drop can be found from the equation (3-2). The heat loss on the pipe is;

$$H_{ls} = \Omega \cdot L_p \text{ (W)}$$

3.1.3 Pressure loss of the water in the pipes

To calculate pressure loss for water flowing in a pipe an estimation of friction coefficient is necessary.

For both mild steel and asbestos-cement pipes, the Colebrooks formula is used to calculate the friction coefficients for both types (Ref. 3):

$$f^{-1/2} = -2\log\ (2.5 \cdot R_e^{-1} \cdot f^{1/2} + k/3.71\ D,) \qquad (3\text{-}3)$$

In this formula, R_e is the Reynolds number and k is the absolute roughness of the pipes and for steel pipes k = 0.025mm but k = 0.05mm for asbestos-cement pipes (Ref. 3).

For either copper or plastic pipes the Von Karman equation for smooth pipes can be applied (Ref. 6):

$$f - 1/2 = 4.0\ \log\ (R_e \cdot f^{1/2}) - 0.4 \qquad (3\text{-}4)$$

The pressure loss in the pipe will be

$$P_{ls} = 0.5\ f \cdot \rho \cdot V^2 L_{adj}/D_1 \qquad (3\text{-}5)$$

Here, ρ is the density of the water and L_{adj} is the adjusted length of the pipe, which is used to account for such items as bends, expansion joints, valves etc. For example, the bend coefficient is c_b, the pressure loss on the bend is;

$$P_b = \frac{1}{2} C_b \cdot \rho \cdot V^2,$$

the equivalent pipe length L_e is given by:

$$\frac{1}{2} C_b \cdot \rho \cdot V^2 = \frac{1}{2} f \cdot \rho \cdot V^2 \cdot Le/D_1$$

that is;

$L_e = C_b \cdot D_1/f$, the adjusted pipe length L_{adj} then is given by;

$$L_{adj} = L_p + L_e$$

In this program, the density and viscosity of the water at a certain temperature are calculated from the following formulae (Ref. 3):

$$\text{vis} = 1.951 \cdot 10^{-5} / T^{0.909} \quad (m^2/s)$$

$$\text{dens} = 1237.16/T^{0.05537} \quad (kg/m^3).$$

3.2. Computation method

The flowcharts for the programs are shown in Fig. 3-2, Fig. 3-3 and Fig. 3-4.

3.2.1 Iteration method

An iteration loop using the Secant method (Ref. 11) is adopted in this program to solve equation (3-2) for finding the temperature drop DT. It has been proved that the iteration process converges rapidly.

Another iteration loop using the Newton-Raphson method is provided to solve the friction equations, (3-3, 3-4 and 3-5) which give the friction coefficient values for different pipes.

Each of these two loops has been arranged into a subroutine. These two subroutines are called "HLOSS" and "PLOSS", (Appendix B).

3.2.2 Index P

The choice of the correct formulae for thermal resistance and friction coefficient for different pipes are selected according to the material of the pipe, the construction of the pipe line and its insulation type. The input Index P instructs the computer to select the correct formulae.

3.2.3 Output file

All the calculation results and some of the given values are stored in the output file called "PIPES.OUT" and printout from the file can be obtained (Appendix D).

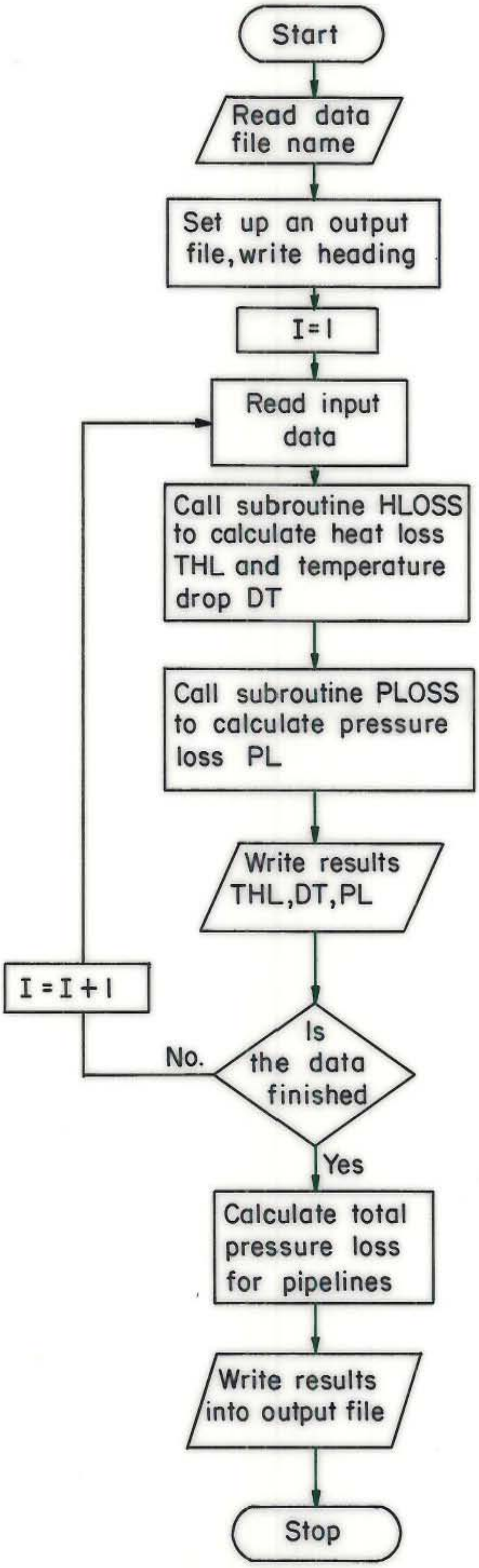


Fig. 3-2 FLOWCHART FOR PROGRAM PIPES

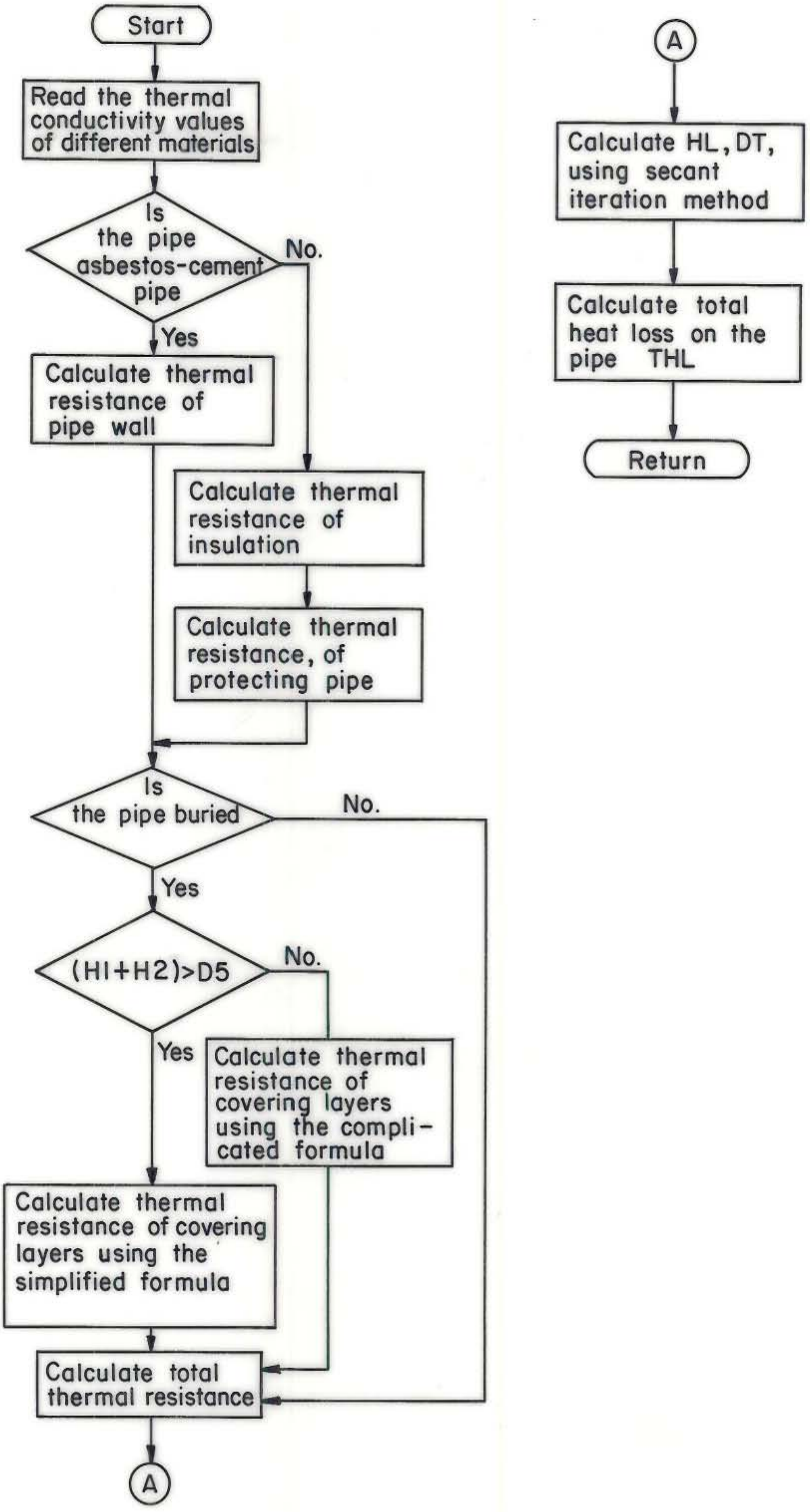


Fig. 3-3 FLOWCHART FOR SUBROTINE PROGRAM HLOSS

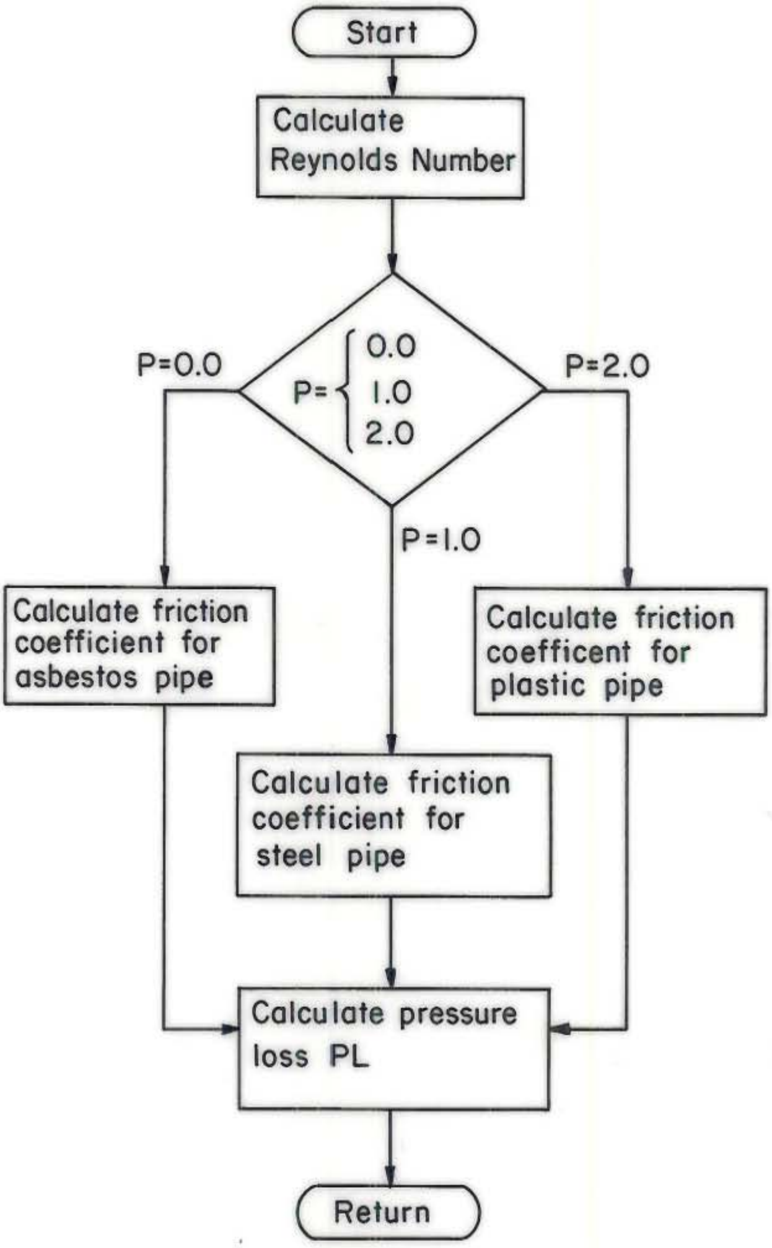


Fig. 3-4 FLOWCHART FOR SUBROUTINE PROGRAM PLOSS

3.2.4 Limitation

The pressure losses calculated in this program are those due to friction only and the pressure losses due to the differences in altitudes are not taken into account. In cases when the latter must be considered it should be calculated outside the subroutine, but in the main program.

When the network to be computed is a closed loop, or in other words, the return water goes back to the same place as the water comes from (e.g. coupled wells at the same altitude), the elevation will then be cancelled.

4 DISTRICT HEATING SYSTEM DESIGN TEMPERTURE: PROGRAM SDT

4.1 Theoretical basis

The concept of system design temperature is of major importance in the design of a new district heating system (Ref. 12). The basic theory of system design temperature is discussed here briefly.

It is well known that the energy consumption for heating is approximately proportional to the annual degree days for a given reference temperature. However, the important factor which affects the maximum thermal energy requirements a district heating system has to meet is a consideration of the "cold wave". The cold wave is the time period when the out-door temperature goes down considerably below the system design temperature and it would bring the room temperature down below the design value.

Heating systems are usually not designed to maintain the design room temperature during the worst possible "cold wave" because it means that the capacity of the system will be excessive. Instead the common practice is to use a system design temperature rather than a minimum outside temperature. The system's capacity is designed for the system design temperature being somewhat higher than the lowest temperature expected for the area where the system is to be located. Thus, when the outside temperature falls below the system design temperature, the room temperature may fall below the design room temperature for a short time. The system design temperature must be low enough in order to keep the room temperature above a predetermined value, during the most severe "cold wave".

For the determination of the system design temperature it is necessary to study the available climatic data of the area and estimate the effects of the worst "cold wave" on the room temperature. In order to evaluate the extent of cooling of buildings much research work has been done (Ref. 12) and here the author uses some of these results to develop a computer program.

4.2 Calculation formula used

For rectangular "cold wave" of the form shown in Fig. 4-1, the minimum inside temperature is reached at the end of the "cold wave":

$$T_{min} = bT_d(1-\exp(-at_0)). \qquad (4-1)$$

In this expression T_{min} is the minimum room remperature during the "cold wave"(°C) and T_d is the depth of the "cold wave" as assumed from the system design temperature (°C), t_0 is the length of the "cold wave", that is the time, for which the "cold wave" lasts,(day), while a and b are constants, the meaning of them will be discussed later.

In fact, there is unlikely to be any natural "cold wave" that appears exactly like a rectangle. However, if there is a"cold wave" temperature record available based on observations made at intervals throughout the day, the solution for a rectangular "cold wave" can be used. Assuming that the outdoor temperatures between each two observations are constant we get series of short-period rectangular "cold waves" Fig. 4-2. For each period the following formula can be used:

$$T = T_1\exp(-at) + bT_2(1-\exp(-at)).$$

This formula gives the room temperature at any time in the period where T_1 is the room temperature (°C) at the beginning of the period T_2 is the outside temperature (°C) at the beginning of the period and t is the length of the period, its unit is (day) and for data taken at M-times per-day, $t = 1/M$.

The two constants a and b in both formulae (4-1) and (4-2), are characteristic values for the houses and are defined as:

$$b = DT_m/(DT_m - T_g+T_{in}) \qquad (-)$$

$$a = h_{c3} \cdot k_1 \qquad (\text{day}^{-1})$$

$$k_1 = h_{c1}+h_{c2}/(T_{in} - T_g)$$

Here, T_g is the design room temperature, T_{in} is the design room temperature and h_{c1}, h_{c2} and h_{c3} are constants for a given type of houses, its typical values can be found from available reference

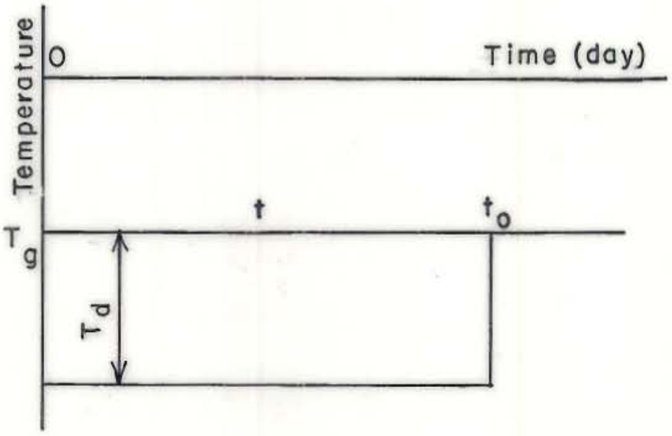


Fig.4-1 A Rectangular "cold wave"

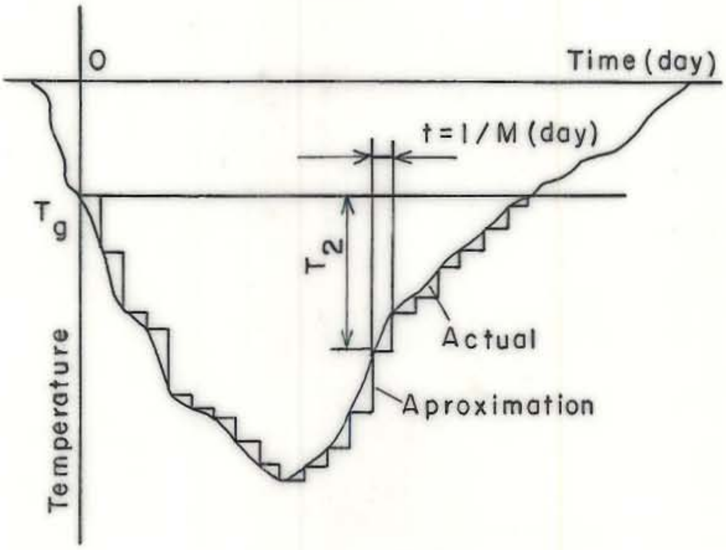


Fig. 4-2 An actual "cold wave"

books (Ref. 12).

$$DT_m = DT_{mo} \; ((T_{in} - T_g)/(T_{in} - T_{go})) \; 0.75$$

$$DT_{mo} = (T_{fo}-T_{bo})/\log((T_{fo}-T_{in})/(T_{bo}-T_{in}))$$

Here, T_{go} is the radiator system design temperature, (°C), $T_{fo}$is supply water temperature (°C), T_{bo} is return water temperature (°C), DT_{mo} is the standard logarithmic mean temperature difference and DT_m is the L.M.T.D. at the system design temperature T_g.

From what is described above it is clear that the room temperature T is a function of system design temperature T_g, when the other values are given.

After the minimum temperature for each period has been found, a comparison of all the minimum temperatures gives the minimum temperature for whole of the cold wave T_{min}. For different T_g the process of finding T_{min} is executed repeatedly, as a result a numerical funtion relationship between T_g and T_{min} is obtained and based on this result the optimum T_g can be decided.

4.3 Computation method

4.3.1 Arrangement of input data

The cold wave data (the severe cold wave temperatures recorded) of the considered area is fed into a special data file, thus this program will be able to deal with any existing recorded cold wave data for different towns, provided the data is edited according to the format specified in the program. The data file is called "CWAVE.DAT" (Appendix F).

The house characteristic values and the system parameters are fed directly into the terminal as the program is run.

4.3.2 Calculation procedures

The flowchart for this program is shown in Fig. 4-3.

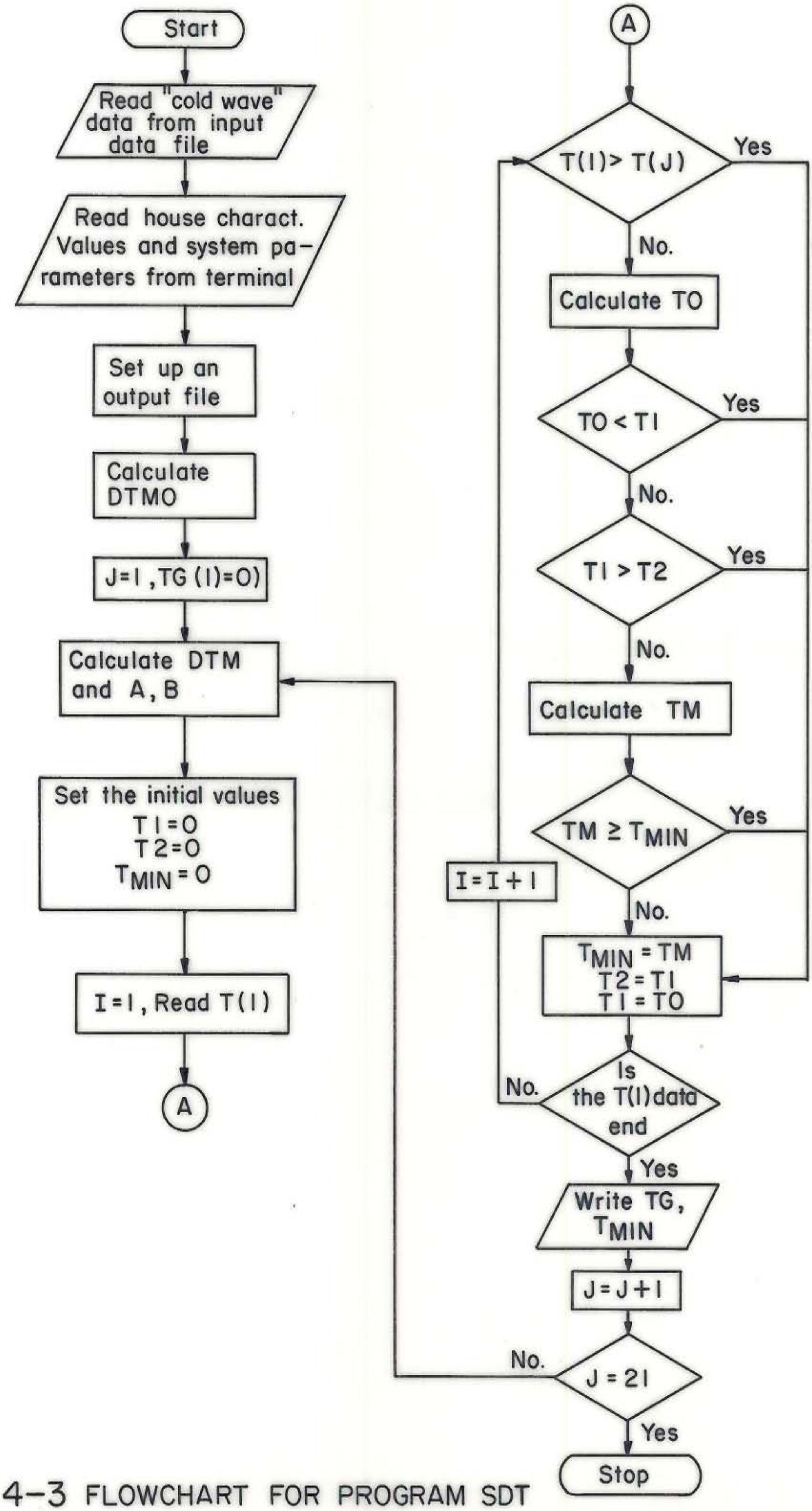


Fig. 4-3 FLOWCHART FOR PROGRAM SDT

In this program, all the main calculation procedures are arranged in an outer DO loop, in which the supposed system design temperatures (T_g) from 0 to -20°C is taken into consideration in sequence. For each T_g, the room temperature at the end of each supposed short-period cold wave (i.e. for each recorded cold wave temperature) is calculated and compared with the former one to find the minimum room temperature for the whole cold wave. The calculation and comparison process are arranged into an inner DO loop, which is included in the outer DO loop mentioned above.

4.3.3 Determination of system design temperature

All the given values and the calculation results are stored in the output file called "SDT.OUT". In the printout of the output file, following each supposed T_g is the corresponding minimum room temperature. The latter is given with the cooled down temperature (the difference between the design room cooled temperature and the minimum room temperature, and is a negative value).

As has been stated in 4.1, the system design temperature must be low enough so that the room temperature can be kept above a predetermined value and it is usually agreed that the predetermined temperature should not be more than 2 to 3 degrees lower than the design room temperature. Based on this criteria the optimum T_g can be decided by scanning results.

5 EXAMPLES OF USING THE PROGRAMS

The computer programs have been described in the preceding chapter. In this chapter, two simplified design tasks have been chosen to demonstrate what kind of problems can be solved by using these programs and how to use them for actual tasks.

5.1 Calculation for Unity Lake District heating system in Beijing

5.1.1 Brief description of the task

For further development of geothermal energy utilization in Beijing it is planned to construct an experimental geothermal district heating system in the Unity Lake (Tangjiehu) area which is in an eastern suburb of the city.

Two production wells are now being drilled and are planned to be finished at the end of this year (1981). The water temperature in these wells is expected to be about 55°C. In this area a well will be drilled for a reinjection test and an observation well is to be drilled for research purposes. The production wells are sited in the residential area while the reinjection well is about 1.2 kilometers away from the production wells. In this area 100.000 m^2 of buildings are to be heated using the hot water from the two production wells (Fig. 5-1). In the present task the purpose is to use two of the programs (DWPS and PIPES) for conditions similar to those expected in Beijing. However, only limited information is available such that several assumptions have to be made. These assumptions are selected so as to be typical for geothermal energy in Beijing. An important consideration is the flow diagram of the utlization system. For illustration purposes a suggested scheme is selected to show how the calculations can be done by using the programs.

5.1.2 Suggested scheme and preliminary calculations

The flow scheme of the supposed system is shown in Fig. 5-2. It is based on the available data on the output and chemistry of the geo-

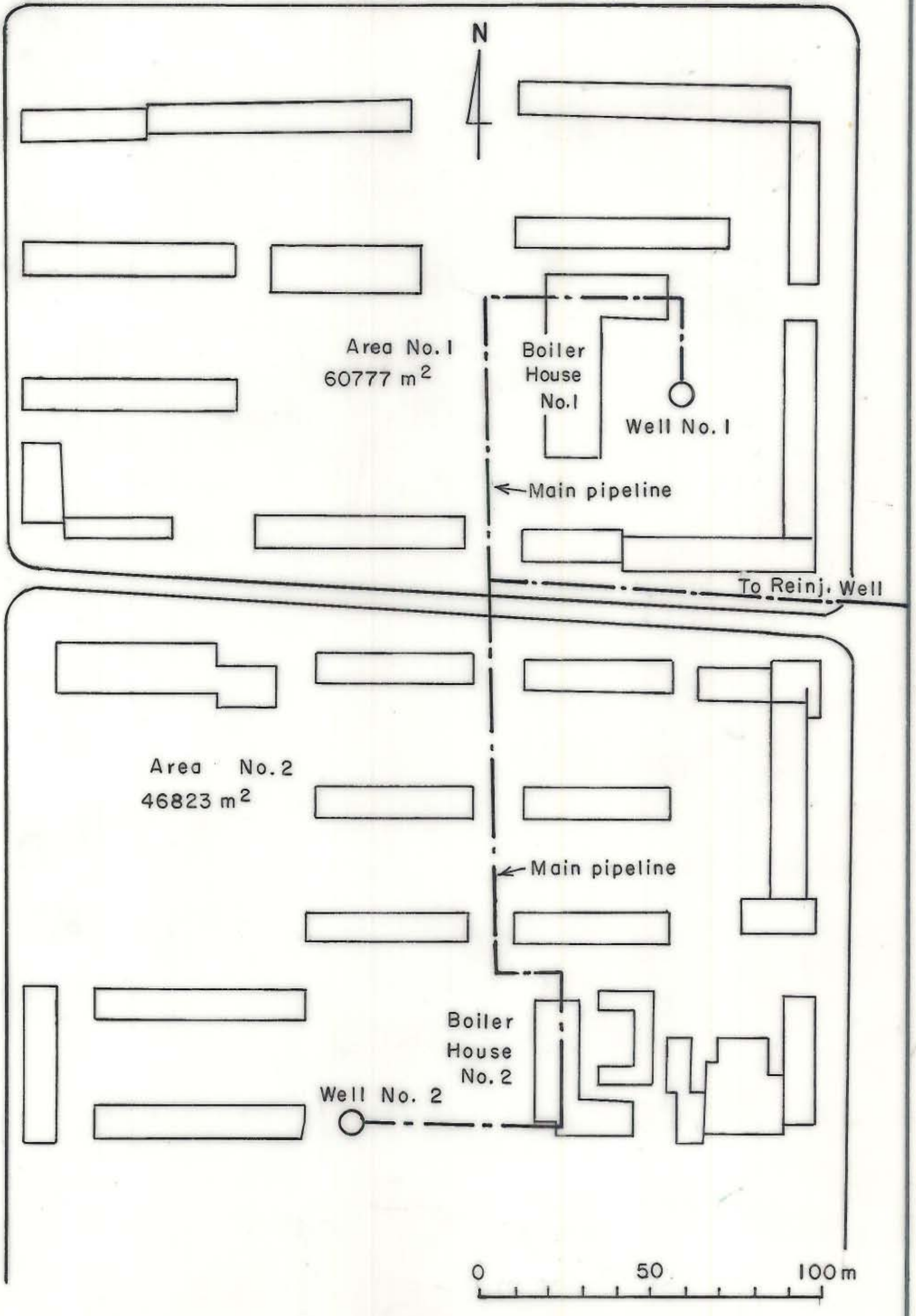


Fig. 5-1 Unity Lake (Tangjie Lake) District. A pilot geothermal district heating system in Beijing

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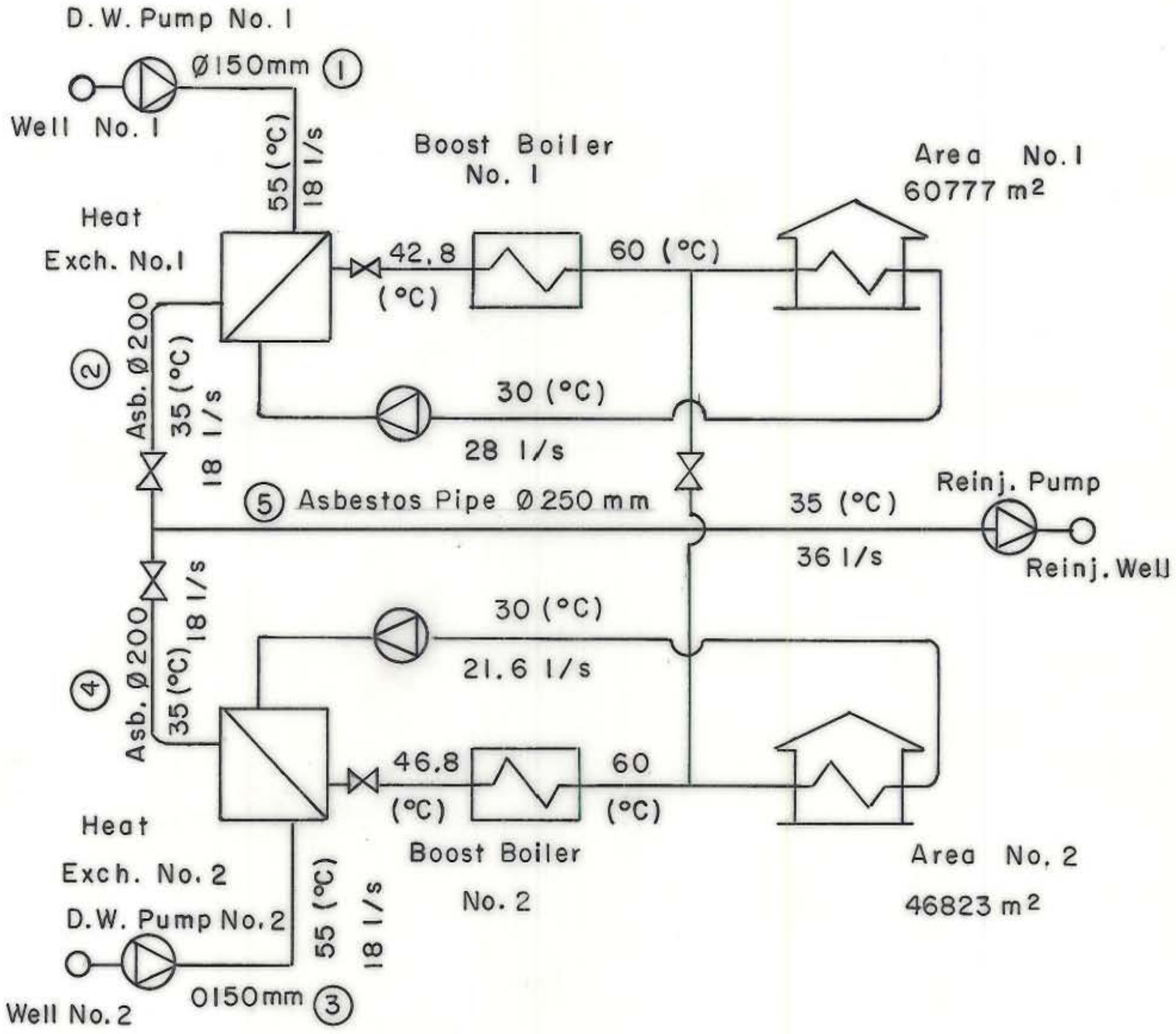

Fig. 5-2 Suggested schematic diagram of the Unity Lake District Heating System

thermal wells in Beijing (Ref. 1). The maximum discharge of the production wells are assumed to be about 18 l/s. Heat exchangers can be used in the utilization system because of the chemistry of the geothermal water. Because a high water temperature at the outlet of the heat exchangers can not be expected, boost boilers are needed in the secondary water system to raise the water temperature to at least 60°C before the water goes into the distribution system. The building area is divided into two sections with a production well in each one. The secondary water from the heat exchanger are cross-connected so that in summer time when the heat load is relatively low, one of the geothermal water systems including well, pipeline, heat exchanger and boiler can be shut down to allow a maintainance. A preliminary calculation has been made for the secondary water systems. The main parameters assumed and calculated are listed in Table 5-1.

Table 5-1 Main parameters of the secondary water system

Item	Unit	District No.1	District No.2
Heating Requirement	(W/m^2)	58*	58*
Building Area	(m^2)	60,777	46,823
Total Heat Demand	(MW)	35,25	27,15
Temp. of Supply Water	(°C)	60	60
Temp. of Return Water	(°C)	30	30
Water Flowrate in Secondary Water System	(l/s)	28,0	21,6
Temp. of Geoth. Water before Heat Exch.	(°C)	55	55
Temp. of Geoth. Water after Heat Exch.	(°C)	35	35
Temp. Diff. of Secondary Water in Heat Exchanger	(°C)	12,8	16,8
Temp. of Secondary Water from Heat Exchanger	(°C)	42,8	46,8
Temp. Diff. of Secondary Water in Boiler	(°C)	17,2	13,2
The Load of Heat Exch.	(MW)	15,05	15,05
The Load of Boiler	(MW)	20,2	12,1

*Based on the design rule for the city

The pipes for geothermal water from the wells to the heat exchangers are designed to be prefabricated polyurethane insulated steel pipes. The pipes for the reinjection water from the heat exchangers to the reinjection pump are asbestos-cement pipes. All the pipes are buried in the ground at 80 cm below surface and with 20 cm sand layer around the pipes.

5.1.3 Calculation for the geothermal water pipelines

The main calculation procedure using the program PIPES is to edit the input data file. The first line of the input data file includes the three values:

1. The ambient air temperature, TAIR: - 12,0 (°C)
2. The thickness of the sand layer, H1: 20,0 (cm)
3. The thickness of the soil layer, H2: 60,0 (cm)

From the second line downwards are the parameters for the pipes. The table 5-2 is the data for the pipes and the corresponding number for each pipe should be referenced to Fig. 5-2.

Table 5-2 The parameters of the pipes

Item	Symbol	Unit	Pipe No.1	No.2	No.3	No.4	No.5
Inner dia. of pipe	D1	(cm)	15.0	20.0	15.0	20.0	25.0
Outer dia. of pipe	D2	(cm)	15.9	24.0	15.9	24.0	29.0
Outer dia. of the 1st insulation	D3	(cm)	15.9	24.0	15.9	24.0	29.0
Outer dia. of the 2nd insulation	D4	(cm)	21.9	24.0	21.9	24.0	29.0
Outer dia. of the protecting pipe	D5	(cm)	22.9	24.0	22.9	24.0	29.0
Length of the pipe	PL	(m)	50.0	110.0	85.0	150.0	1200.0
Adjusted length of the pipe	PLA	(m)	65.0	130.0	100.0	170.0	1225.0
Water temp. at the inlet of the pipe	TST	(°C)	55.0	35.0	55.0	35.0	35.0
Flowrate	Q	(l/s)	18.0	18.0	18.0	18.0	36.0
Index	P	(-)	0.0	1.0	0.0	1.0	1.0

In editing this data table, some assumptions are made for simplification, they are:

1. There is only one elbow in each pipe, the equivalent pipe length length of which is about 10D1. This value has been added to the pipe length to get the adjusted pipe length.
2. The temperature drop in the pipes is relatively small, so for the calculations of the three asbestos pipes, the inlet water temperature is 35°C.

The well head pressures (that is the inlet water pressures of pipes No. 1 and No. 2) are calculated as:

$$PH_1 = P_r + DP_h + DP_1 + DP_2 + DP_5$$

$$PH_2 = P_r + DP_h + DP_2 + DP_4 + DP_5$$

Here, PH_1 and PH_2 are the well head pressures of the two production wells respectively, P_r is the water pressure at the inlet of the reinjection pump and is designed to be about 0.2 bar, DP_h is the pressure drop of the geothermal water in the heat exchanger and is assumed to be about 1 bar and DP_1 to DP_5 is the pressure drop for each pipe respectively.

The input data file for this task is shown in Appendix D.

After having edited the input file, the program resultant PIPES with subroutines HLOSS and PLOSS is run and the resultant printout is shown in Appendix D. In the printout, besides the given values, there are the calculation results for heat loss (THL), temperature drop (DT) and pressure drop (DP) for each pipe. Furthermore, the well head pressures needed have also been given by the calculation result.

5.1.4 Calculation for deep well pump selection

The pump data files which are edited for FLOWAY 6 and 8 inches vertical pumps and are named DATAP6.DAT and DATAP8.DAT are shown in Appendix E. The data files edited for Well No. 1 and Well No. 2 are also shown in Appendix E,which are called DATAW1 and DATAW2 respectively.

In the well data files the values for the flow coefficients of the wells are assumed values. The well head pressure values are taken from the result of the pipeline calculation.

After the input data files having been edited the program DWPS is run and the result is printed out as shown in Appendix E.

5.2 System design temperature for a town

5.2.1 Brief description of the task

The parameters of the district heating system of some town in north China are assumed as:

Supply hot water temperature: 60°C.
Return water temperature: 30°C.
Design room temperature: 18°C.
Design outdoor temperature for radiator system: - 12°C.

The house characteristic values are assumed as:

HC1 = 2.4, HC2 = 3.0, HC3 = 0.22

The worst severe "cold wave" data recorded in the history is assumed to be:

Number of observations per day, M = 8
Number of temperatures recorded, N = 40

The temperatures recorded in sequence are:

-1.1	-2.9	-3.9	-4.8	-4.6	-6.5	-7.3	-8.7
-12.5	-14.6	-16.0	-17.0	-18.3	-19.2	-18.9	-16.9
-18.3	-18.3	-18.0	-19.4	-19.8	-20.0	-17.4	-14.9
-16.3	-15.2	-16.4	-16.5	-15.6	-14.0	-13.9	-10.3
-9.8	-7.9	-6.2	-5.3	-4.6	-3.4	-2.1	-0.8

The task is to evaluate the cooling down temperatures and decide the system design temperature for the town.

5.2.2 Calculations

The data listed in 5.2.1 have been edited into the input data file named CWAVE.DAT, which is shown in Appendix F. The program SDT is run, the result is given by the printout of the output file Appendix F.

5.2.3 Interpretation of the calculation results

The system design temperature must be selected low enough so that the maximum cooling of the building during the cold wave will not lower the inside temperature more than 2-3°C below the design value. From the tabulation of the calculation result it can be concluded that -11°C should be the reasonable value to be adopted as the system design temperature for the town if the cooling down of inside temperature selected is -3°C and a lower temperature, -13°C should be used as the system design temperature if -2°C is allowed. It is also obvious that -12°C could also be used as the system design temperature for the town since the corresponding cooling calculated is -2.6°C.

6 DISCUSSION AND CONCLUSION

The computer programs described in this paper can be used for solving some of the calculation topics in low-temperature geothermal exploitation. All the calculation formulae used in the programs are based upon theoretical or empirical studies.The precision of the calculation results are high enough for engineering purposes, though simplifacation has been made in creating these programs. The calculation examples demonstrate that they are effectual.

Being a preliminary study of the use of computer program in geothermal engineering, there must be shortcomings in the programs which need to be improved. In addition, these programs should be considerd as a framework which can be extended to more complex problems. Further developments should include cost studies so that an overall optimisation program could be available to aid the efficient economic design of a geothermal utilization system.

In China the use of the computer as a design aid for the utilization of geothermal energy should be developed. This report focusses on one aspect i.e. low-termperature utilization and demonstrates the good applicability of computer work in such development. To use these or other computer programs in actual tasks in China, a collection of up-to-date data relating to pumps, pipes, fittings and other equipment throughout China needs to be done. It may be meaningful to use program SDT to estimate the system design temperatures for different towns in northern China and compare the results with the currently used values.

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APPENDIX A: Program DWPS and Subroutine Program SUBFLOW

```
FORTRAN IV-PLUS V3.0-3          16:17:54    24-Sep-81           Page 1
DWPS.FTN;55             /TR:BLOCKS/WR

C  PROGRAM DWPS.FTN
C  PROGRAM FOR DEEP WELL PUMP SELECTING CALCULATION.IT CAN BE USED FOR
C  FLOWAY VERTICAL PUMP (SIZES: 6-12 INCHES ). THE PARAMETERS OF THE
C  PUMPS HAVE BEEN STORED IN INPUT DATA FILE (DATAP.DAT) AND THE WELL
C  DATA NEED TO BE EDITED INTO ANOTHER INPUT FILE (DATAW.DAT).
C
           COMMON /BLOCK/ SIZE,Q,QM,X,Y,X1,Y1,X2,Y2,FLC1,FLC2,
           1      PH,WKN,WKV,DENS,A,B,CL,CONST,PDHO,NZ
           BYTE FILNAM (32)
C  INPUT THE NAME OF THE PUMP DATA FILE
           TYPE 10
10         FORMAT (' PUMP DATA FILE:',$)
           ACCEPT 12,IQ,FILNAM
12         FORMAT (Q,32A1)
           WRITE (5,2) FILNAM
2          FORMAT (' ',32A1)
           FILNAM(IQ+1)=0
           OPEN (UNIT=1,NAME=FILNAM,TYPE='OLD',READONLY)
C  INPUT THE NAME OF THE WELL DATA FILE
           TYPE 20
20         FORMAT (' WELL DATA FILE:',$)
           ACCEPT 12,IQ,FILNAM
           WRITE (5,4) FILNAM
4          FORMAT (' ',32A1)
           FILNAM(IQ+1)=0
           OPEN (UNIT=2,NAME=FILNAM,TYPE='OLD',READONLY)
C  READ DATA FROM PUMP DATA FILE
           READ (1,1000) SIZE,DCI,DEO,DSHAF,AC,QM,X1,X2,Y1,Y2,
           1          A,B,C,D,XX,YY,WSHAF,WIMP,ASHAF,UL,RPM,EKMOT,TK,HPR
1000       FORMAT (F10.5)
C  READ DATA FROM WELL DATA FILE
           READ (2,2000) WNAME,PA,TEMP,PS,DENS,WKV,FLC1,FLC2,WKNM,HSAFE,PH,QO
2000       FORMAT (F10.5)
C  CREATE AN OUTPUT FILE
           CALL ASSIGN (3,'DWPS.OUT')
C  WRITE HEADING LINES
           WRITE (3,100)
100        FORMAT (' ',30X,'THE RESULTS OF CALCULATION'/
           1          30X,'FOR SELECTING DEEP WELL PUMP'//)
C  WRITE GIVEN VALUES
           WRITE (3,102) WNAME,PA,WKV,TEMP,DENS,PS,QO
102        FORMAT (20X,'GIVEN VALUES:'/
           1       30X,'THE NAME OF THE WELL:',F6.2/
           2       30X,'ATMOSPHRIC PRESSURE:',F6.2,'BAR'/
           3       30X,'WATER LEVEL BELOW SURFACE:',F6.2,'M'/
           4       30X,'TEMP. OF WATER:',F6.2,'C'/
           5       30X,'DENSITY OF WATER:',F6.2,'KG/CUB.M'/
           6       30X,'SATURATED PRESSURE:',F6.2,'BAR'/
           7       30X,'FLOWRATE ORDERED:',F6.2,'L/S'/)
           WRITE (3,104) FLC1,FLC2,PH
104        FORMAT (30X,'FLOW COEFF. OF THE WELL:',F6.2,'M/(L/S)'/
           1       54X,F6.4,'M/SQ.(L/S)'/
           2       30X,'PRESSURE AT WELL HEAD:',F6.2,'BAR'//)
C  CHECK THE MAX. DROW DOWN
           WKN=FLC1*QO+FLC2*QO**2
           IF (WKN .GT. WKNM) GO TO 30
```

```
FORTRAN IV-PLUS V3.0-3          16:17:54    24-Sep-81           Page 2
DWPS.FTN;55             /TR:BLOCKS/WR

0031            GO TO 40
0032     30     TYPE 32
0033     32     FORMAT (' ','THE DROW DOWN IS TOO MUCH TO BE ALLOWED,/
                1        YOU SHOULD DECREASE THE ORDERED FLOWRATE!')
0034            STOP
         C  ITERATION CALCULATION FOR DESIGN THE COLUMN LENGTH AND NUMBER OF STAGES,
         C  GIVING THE INITIAL VALUES OF COLUMN LENGTH AND FLOWRATE
0035     40     Q=Q0
         C  CHOOSE THE CORRECT CONSTANTS FOR PUMP CHARACTERISTICS
0036            IF (Q-QM) 50,50,60
0037     50     X=X1
0038            Y=Y1
0039            GO TO 65
0040     60     X=X2
0041            Y=Y2
0042     65     CL=WKN+WKV+HSAFE+20.
         C  DECIDE NUMBER OF STAGES OF THE PUMP
0043            CONST=(DCI*.01)**2-(DEO*.01)**2
0044     70     PV=.0826E-6*(DENS/CONST)*Q**2
0045            PF=(A*Q**B)*CL*.01
0046            TDH=10.20*PH+(WKN+WKV)*DENS/1000.+PV+PF
0047            PDHO=X-Y*Q
0048            NZ=TDH/PDHO+1.
         C  USE SUBROUTINE TO CALCULATE FLOWRATE
0049     80     CALL SUBFLO
0050            NPSHR=C+D*Q
0051            HMIN=10000.*(PS-PA)/DENS+NPSHR*NZ
0052            WKN=FLC1*Q+FLC2*Q**2
0053            CLNEW=WKN+WKV+HMIN+HSAFE
         C  CHECK FOR COMPLETION
0054            IF (ABS(CLNEW-CL) .LE. 1.) GO TO 150
0055            CL=CLNEW
0056            GO TO 80
0057     150    PV=.0826E-6*(DENS/CONST)*Q**2
0058            PF=(A*Q**B)*CL*.01
0059            TDH=10.2*PH+(WKN+WKV)*DENS/1000.+PV+PF
         C  WRITE RESULTS
0060            WRITE (3,160) SIZE,NZ,Q,TDH,DCI,CL,DSHAF,DEO
0061     160    FORMAT (20X,'PARAMETERS OF THE PUMP CALCULATED'/
                1        30X,'TYPE OF THE PUMP:',F6.2/
                2        30X,'NUMBER OF STAGES:',I4/
                3        30X,'FLOWRATE CALCULATED:',F6.2,'L/S'/
                4        30X,'TOTAL DYNAMIC HEAD:',F6.2,'M'/
                5        30X,'COLUMN DIAMETER:',F6.2,'CM'/
                6        30X,'LENGTH OF COLUMN:',F6.2,'M'/
                7        30X,'DIAMETER OF SHAFT:',F6.2,'CM'/
                8        30X,'DIAMETER OF ENCLOSING TUBE:'F6.2,'CM'//)
         C  CALCULATION TOTAL THRUST
0062            TA=TDH*TK/.3048
0063            WS=(CL/.3048)*WSHAF+NZ*WIMP
0064            TT=(TA+WS)*4.448
         C      CALCULATING ENLONGATION
0065            EA=(TA*CL)/(ASHAF*.27E7)
         C  CHECK IF THE ENLONGATION IS ALLOWED
0066            IF (EA .GE. AC) GO TO 200
0067            GO TO 300
```

```
FORTRAN IV-PLUS V3.0-3          16:17:54    24-Sep-81           Page 3
DWPS.FTN;55              /TR:BLOCKS/WR

0068    200     TYPE 202
0069    202     FORMAT (' ','THE ENLONGATION IS GREATER THAN ALLOWED VALUE,CHANGE THE
                1 SHAFT SIZE!')
0070            STOP
          C  CALCULATE MOTOR CAPACITY NEEDED
          C  CHOOSE THE CORRECT CONSTANTS
0071    300     EKP=XX+YY*Q
0072            PHY=Q*TDH*DENS/(.75E5*EKP)
0073            PLOSS=CL*UL/30.48
0074            BLOSS=TT*RPM*1.69E-8
0075            PSHAFT=(PHY+PLOSS+BLOSS)*.745
          C  CHECK THE SHAFT HORSEPOWER RATING
0076            IF (PSHAFT .GT. HPR) GO TO 310
0077            GO TO 400
0078    310     TYPE 312
0079    312     FORMAT (' ','SHAFT HORSEPOWER IS GREATER THAN ALLOWED VALUE,/
                1       CHANGE THE SHAFT DIAMETER!')
0080    400     PMOTOR=PSHAFT/EKMOT
          C  STANDARDIZATION OF THE MOTOR CAPACITY
0081            IF (PMOTOR .LT. 4.8) PMS=4.8
0082            IF (PMOTOR .GT. 4.8 .AND. PMOTOR .LE. 10.) PMS=10.
0083            IF (PMOTOR .GT. 10. .AND. PMOTOR .LE. 20.) PMS=20.
0084            IF (PMOTOR .GT. 20. .AND. PMOTOR .LE. 30.) PMS=30.
0085            IF (PMOTOR .GT. 30. .AND. PMOTOR .LE. 40.) PMS=40.
0086            IF (PMOTOR .GT. 40. .AND. PMOTOR .LE. 50.) PMS=50.
          C  WRITE RESULTS INTO THE OUTPUT FILE
0087            WRITE (3,500) EA,AC,TT,PSHAFT,PMOTOR,PMS
0088    500     FORMAT (30X,'ENLONGATION OF THE SHAFT:',F6.2,'INCH'/
                1         30X,'AXIAL CLEARENCE:',F6.2,'INCH'/
                2         30X,'TOTAL THRUST:',F8.2,'N'/
                3         30X,'SHAFT HORSE POWER:',F6.2,'KW'/
                4         30X,'CALCULATED MOTOR CAPACITY:',F6.2,'KW'/
                5         30X,'STANDARD MOTOR CAPACITY:',F6.2,'KW'/)
0089            STOP
0090            END
```

```
FORTRAN IV-PLUS V3.0-3          16:19:11    24-Sep-81          Page 1
SUBFLO.FTN;30           /TR:BLOCKS/WR

             SUBROUTINE SUBFLO
             COMMON/BLOCK/SIZE,Q,QM,X,Y,X1,Y1,X2,Y2,FLC1,FLC2,
             1            PH,WKN,WKV,DENS,A,B,CL,CONST,PDHO,NZ
      C  CHOOSE CORRECT CONSTANTS
      10     IF (Q-QM) 12,12,14
      12     X=X1
             Y=Y1
             GO TO 30
      14     X=X2
             Y=Y2
             GO TO 30
      C  ITERATION FOR FLOWRATE
      30     PDHO=X-Y*Q
             WKN=FLC1*Q+FLC2*Q**2
             Z=PH*10.2+(WKN+WKV)*DENS*.001+(A*Q**B)*CL/100.+.0826E-6*(DENS/CONST)
             1 *Q**2-PDHO*NZ
             ZD=FLC2*DENS*.2*Q+.1652E-4*(DENS/CONST)*Q+CL*B*Q**(B-1.)
             1  +FLC1*DENS*.1
             QNEW=Q-Z/ZD
      C  CHECK FOR COMPLETION
             IF (ABS(QNEW-Q) .LT. 1.) GO TO 40
      C  OTHERWISE CONTINUE THE ITERATION
             Q=QNEW
             GO TO 10
      40     WRITE (5,50)Q,QNEW
      50     FORMAT (' ',2F15.6)
             Q=QNEW
             RETURN
             END
```

APPENDIX B: Program PIPES and Subroutine Programs HLOSS and PLOSS

```
FORTRAN IV-PLUS V3.0-3         16:15:33    24-Sep-81          Page 1
PIPES.FTN;45             /TR:BLOCKS/WR

                PROGRAM PIPES
                COMMON/BLOCK1/D2,D3,D4,D5,H1,H2,TAIR,CP,DENS,PL,THL,HL
                COMMON/BLOCK2/D1,TSTART,DT,P,Q
                COMMON/BLOCK3/PLA,PLS
                BYTE FNAME(32)
                TYPE 10
        10      FORMAT(' ','INPUT FILE:',$)

                ACCEPT 12,IQ,FNAME
        12      FORMAT(Q,32A1)
                FNAME(IQ+1)=0
                OPEN(UNIT=1,NAME=FNAME,TYPE='OLD',READONLY)
                CALL ASSIGN(2,'PIPES.OUT')
                READ(1,20)TAIR,H1,H2
        20      FORMAT(12F8.3)
                WRITE(2,30)TAIR,H1,H2
        30      FORMAT(' ',20X,'THE CALCULATION RESULTS OF HEAT AND PRESSURE LOSS'//
                1       ' ',20X,'AIR TEMPERATURE:',F8.3/
                2       ' ',20X,'THICKNESS OF THE SAND LAYER:',F8.3/
                3       ' ',20X,'THICKNESS OF THE SOIL LAYER:',F8.3/
                4       4X,'D1',6X,'D2',6X,'D3',6X,'D4',6X,'D5',6X,'PL',6X,'PLA',6X,
                5'Q',6X,'P',6X,'TST',6X,'DT',6X,'DP',6X,'HLS'/)
                PR=0.2
                PDH=1.0
                PH1=0.0
                PH2=0.0
                DO 100 I=1,100
                READ (1,20,END=200)D1,D2,D3,D4,D5,PL,PLA,Q,P,TSTART
                CALL HLOSS
                WRITE(5,52)DT,THL,HL
        52      FORMAT(20X,'DT=',F15.6,'THL=',F15.6,'HL=',F15.6)
                CALL PLOSS
                WRITE(5,54)PLS
        54      FORMAT(20X,'PLS=',F15.6)
                WRITE(2,58)D1,D2,D3,D4,D5,PL,PLA,Q,P,TSTART,DT,PLS,THL
        58      FORMAT(5F8.3,3F8.2,3F8.3,2F10.3/)
                IF (I .EQ. 1 .OR. I .EQ. 2 ) GO TO 71
                IF (I .EQ. 3 .OR. I .EQ. 4 ) GO TO 72
                IF (I .EQ. 5) GO TO 80
        71      PH1=PH1+PLS/1.E5
                GO TO 100
        72      PH2=PH2+PLS/1.E5
                GO TO 100
        80      PH1=PH1+PLS/1.E5
                PH2=PH2+PLS/1.E5
        100     CONTINUE
        200     PH1=PH1+PR+PDH
                PH2=PH2+PR+PDH
                WRITE(5,210)PH1,PH2
        210     FORMAT(5X,'PH1=',F15.6,5X,'PH2=',F15.6)
                WRITE(2,220)PH1,PH2
        220     FORMAT(21X,'WELL HEAD PRESSURE FOR WELL NO.1,PH1=',F8.4,2X,'BAR'/
                1       21X,'WELL HEAD PRESSURE FOR WELL NO.2,PH2=',F8.4,2X,'BAR')
                STOP
                END
```

```
ORTRAN IV-PLUS V3.0-3          16:16:30    24-Sep-81          Page 1
HLOSS.FTN;30           /TR:BLOCKS/WR

              SUBROUTINE HLOSS
        C  SUBROUTINE TO CALCULATE HEAT LOSSES FROM SURFACE OF PIPES AND TEMPERATURE
        C  DROP OF WATER IN HOT WATER PIPELINES
              COMMON /BLOCK1/D2,D3,D4,D5,H1,H2,TAIR,CP,DENS,PL,THL,HL
              COMMON /BLOCK2/D1,TSTART,DT,P,Q
        C  GIVES THE VALUES OF THERMAL CONDUCTIVITIES FOR DIFFERENT MATERIALS
              TCPC=.465
              TCINS1=.040
              TCINS2=.035
              TCPT=.40
              TCSL1=.31
              TCSL2=1.45
              CP=4188.
        C  IF THE PIPE IS ASBESTOS-CEMENT PIPE,THE THERMAL RISISTANCE OF THE PIPE WALL
        C  NEEDS TO BE CALCULATED
              IF (P .EQ. 1.0) GO TO 5
              IF (P .NE. 1.0) RP=0.0
              GO TO 10
        C  CALCULATE THE THERMAL RISISTANCE OF ASBABTOS-CEMENT PIPE WALL
        5     RP=ALOG(D2/D1)/(6.2832*TCPC)
              RINS=0.0
              GO TO 20
        C  CALCULATE THE THERMAL RISISTANCE OF INSULATION LAYERS
        10    RINS=ALOG(D3/D2)/(6.2832*TCINS1)+ALOG(D4/D3)/(6.2832*TCINS2)
        C  CALCULATE THE THERMAL RISISTANCE OF PROTECTING COVER
              RPT=ALOG(D5/D4)/(6.2832*TCPT)
        C  CHECK THE PIPE IS IN OPEN AIR
        20    IF (H1 .NE. 0.0) GO TO 25
              IF (H1 .EQ. 0.0) RSL=0.0
              GO TO 100
        C  CHECK THE DEPTH OF BURYING TO CHOOSE THE CORRECT FORMULA
        25    IF ((H1+H2) .LE. D5) GO TO 30
              IF ((H1+H2) .GT. D5) GO TO 40
        30    RATIO=(H1+H2+.5*D5)/D5
              RSL=ALOG((8.*RATIO**2-1.)+4.*RATIO*SQRT(4.*RATIO**2-1.))/12.5664*TCSL2
              GO TO 100
        40    U=ALOG((4.*H1+2.*D5)/D5)/(6.2832*TCSL1)
              V=H2/(12.5664*(H1+.5*D5)*TCSL2)
              RSL=U+V
              GO TO 100
        C  CALCULATE THE TOTAL THERMAL RISISTANCE
        100   RTOT=RP+RINS+RPT+RSL
        C  ITERATION CALCULATION (SECANT METHOD) TO FIND OUT THE TEMPERATURE DROP,
        C  TOTAL HEAT LOSSES AND AVERAGE HEAT LOSS PER ONE METER OF PIPE
              DT0=10.0
              DT1=0.05
              DENS=1.237/TSTART**.055367
        200   Y0=DT0*CP*Q*DENS-DT0/ALOG((TSTART-TAIR)/(TSTART-TAIR-DT0))*PL/RTOT
              Y1=DT1*CP*Q*DENS-DT1/ALOG((TSTART-TAIR)/(TSTART-TAIR-DT1))*PL/RTOT
              DT2=(Y1*DT0-Y0*DT1)/(Y1-Y0)
              Y2=DT2*CP*Q*DENS-DT2/ALOG((TSTART-TAIR)/(TSTART-TAIR-DT2))*PL/RTOT
              IF (ABS(DT1-DT2) .LT. .01) GO TO 300
              DT0=DT1
              DT1=DT2
              GO TO 200
        300   DT=DT2
```

```
FORTRAN IV-PLUS V3.0-3          16:16:30    24-Sep-81         Page 2
HLOSS.FTN;30              /TR:BLOCKS/WR

0044            THL=DT*CP*G*DENS
0045            HL=THL/PL
0046            RETURN
0047            END
```

```
FORTRAN IV-PLUS V3.0-3          16:17:14    24-Sep-81           Page 1
PLOSS.FTN;6             /TR:BLOCKS/WR

              SUBROUTINE PLOSS
      C  SUBROUTINE TO CALCULATE PRESSURE  LOSSES OF WATER IN PIPELINES.
      C  THE VISCOSITY AND DENSITY ARE CALCULATED AS FUNCTIONS OF AVERAGE
      C  TEMPERATURE OF THE WATER. FRICTION COEFFICIENT (F) FOR BOTH COPPER
      C  AND PLASTIC PIPES IS CALCULATED FROM MODIFIED VON KARMAN EQUATION
      C  WHILE THAT FOR ASBESTOS-CEMENT PIPES AND STEEL PIPES IS CALCULATED
      C  FROM COLEBROOKS FORMULA,SETTING .05 MM AS THE ROUGHNESS OF THE
      C  ASBESTOS-CEMENT PIPES AND .025 FOR STEEL PIPES.
      C
              COMMON /BLOCK2/D1,TSTART,DT,P,Q
              COMMON /BLOCK3/PLA,PLS
      C  CALCULATE REYNOLDS NUMBER
              VEL=12.73*Q/D1**2
              TAV=TSTART-.5*DT
              VIS=1.9518E-5/(TAV**.909054)
              RE=VEL*D1/(VIS*100.)
      C  CHOOSE THE CORRECT FORMULA FOR PIPES MADE OF DIFFERENT MATERIALS
              IF (P .EQ. 1.) GO TO 10
              IF (P .EQ. 2.) GO TO 20
              IF (P .EQ. 0.) GO TO 30
      C  CALCULATE FRICTION COEFFICIENT F BY USING NEWTON-RAPHSON METHOD
      C  FOR ASBESTOS-CEMENT PIPES
      10      F=.001
      11      Y=1./F**.5+2.*ALOG10(2.51/(RE*F**.5)+.00135/D1)
              YD=.5/F**1.5*(1.+2.1802/(RE*(.00135/D1+2.51/(RE*F**.5))))
              FNEW=F+Y/YD
              IF (ABS(FNEW-F) .LT. .1E-5) GO TO 100
              F=FNEW
              GO TO 11
      C  FOR BOTH COPPER AND PLASTIC PIPES
      20      F=.001
      21      Y=4.*ALOG10(RE*F**.5)-F**(-.5)-.4
              YD=.8686/F+.5/F**1.5
              FNEW=F-Y/YD
              IF (ABS(FNEW-F) .LT. .1E-5) GO TO 100
              F=FNEW
              GO TO 21
      C  FOR STEEL PIPES
      30      F=.001
      31      Y=1./F**.5+2.*ALOG10(2.51/(RE*F**.5)+.000674/D1)
              YD=.5/F**1.5*(1.+2.1802/(RE*(.000674/D1+2.51/(RE*F**.5))))
              FNEW=F+Y/YD
              IF (ABS(FNEW-F) .LT. .1E-5) GO TO 100
              F=FNEW
              GO TO 31
      C  CALCULATE PRESSURE  LOSSES
      100     ADENS=1237.16/TAV**.055367
              PLS=50.*F*ADENS*VEL**2*PLA/D1
              RETURN
              END
```

APPENDIX C: Program SDT

```
FORTRAN IV-PLUS V3.0-3        16:20:36    24-Sep-81          Page 1
SDT.FTN;21               /TR:BLOCKS/WR

      C       PROGRAM SDT
      C  PROGRAM TO ESTIMATE THE EFFECT OF A COLD WAVE ON THE INDOOR TEMPERATURE
      C  OF BUILDINGS. FROM THE RESULTS COMPUTED  THE OPTIMUM SYSTEM DESIGN TEMPERATURE
      C  CAN BE DECIDED. THE FORMULA USED FOR CALCULATING THE COOLING
      C  OF HOUSES IS SUITABLE FOR A RECTANGULAR COLD WAVE. BUT THIS PROGRAM CAN BE
      C  USED FOR ANY TYPE OF COLD WAVES:RECTANGULAR,TRIANGULAR AND IRREGULAR TYPES.
      C  THE COLD WAVE TEMPERATURE DATA ARE BASED ON M-TIMES-PER-DAY(24/M-HOURLY)
      C  OBSERVATION. IT IS ASUMED THAT THE TEMPERATURES BETWEEN EVERY TWO
      C  OBSERVATIONS ARE CONSTANTS.FOR EACH SYSTEM DESIGN TEMPERATURE CALCULATES
      C  CORRESPONDING MINIMUM INDOOR TEMPERATURE IN THE  PERIOD OF THE COLD WAVE.
      C  THE COLD WAVE TEMPERATURE DATA HAD BEEN EDITED IN TO THE INPUT FILE
      C  BEFORE RUN THE PROGRAM.
      C
              DIMENSION T(56),TG(25)
              BYTE FILNAM (32)
      C  INPUT COLD WAVE DATA FILE
              TYPE 10
      10      FORMAT (' ','COLD WAVE DATA FILE:',$)
              ACCEPT 11,IQ,FILNAM
      11      FORMAT (Q,32A1)
              FILNAM(IQ+1)=0
              OPEN (UNIT=2,NAME=FILNAM,TYPE='OLD',READONLY)
      C  READ COLD WAVE TEMPERATURE DATA FROM INPUT DATA FILE
              READ (2,12) N,M
      12      FORMAT (I5)
              DO 14 I=1,N
              READ (2,13) T(I)
      13      FORMAT (F10.2)
      14      CONTINUE
      C  INPUT HOUSE CHARACTERISTIC VALUES ON TERMINAL
              TYPE 20
      20      FORMAT (' ','INPUT HC1,HC2,HC3:',$)
              ACCEPT 22,HC1,HC2,HC3
      22      FORMAT (3F10.6)
      C  INPUT DESIGN CONDITIONS ON TERMINAL
              TYPE 30
      30      FORMAT (' ','INPUT TFO,TBO,TINO,TGO:',$)
              ACCEPT 32,TFO,TBO,TINO,TGO
      32      FORMAT (4F6.2)
      C  SET UP AN OUTPUT FILE
              CALL ASSIGN (1,'SDT.OUT')
      C  WRITE COLUMN HEADING
              WRITE (1,500)
      500     FORMAT (' ',35X,'THE COOLDOWN TEMPERATURE TMIN '/30X,'AS A FUNCTION OF
              1 SYSTEM DESIGN TEMPERATURE TG'/)
      C  WRITE THE GIVEN VALUES
              WRITE (1,600) M,N
      600     FORMAT (' ',28X,'THE COLD WAVE DATA:'/
              1 30X,'NUMBER OF OBSERVATIONS PER DAY M=',I5/
              2 30X,'NUMBER OF TEMPERATURES N=',I5/
              3 30X,'THE TEMPERATURE DATA RECORDED ARE:'/)
              WRITE (1,700) (T(I),I=1,N)
      700     FORMAT (24X,5F10.2)
              WRITE (1,800) TFO,TBO,TINO,TGO,HC1,HC2,HC3
      800     FORMAT ('0',28X,'DESIGN HOT WATER TEMPERATURE TFO=',F6.2,2X,'C'/
              1             30X,'DESIGN RETURN TEMPERATURE TBO=',F6.2,2X,'C'/
```

```
FORTRAN IV-PLUS V3.0-3          16:20:36    24-Sep-81           Page 2
SDT.FTN;21                /TR:BLOCKS/WR

            2           30X,'DESIGN ROOM TEMPERATURE TINO=',F6.2,2X,'C'/
            3           30X,'RADIATOR DESIGN OUTDOOR TEMP. TGO=',F6.2,2X,'C'/
            4           30X,'HOUSE CHARACTERISTIC VALUES:'/
            5           31X,'HC1=',F8.4,2X,'HC2=',F8.4,2X,'HC3=',F8.4/)
0032            WRITE (1,1000)
0033    1000    FORMAT (' ',28X,'TG',10X,'A',10X,'B',12X,'TMIN',/)
        C  CALCULATE THE STANDARD LOGARITHMIC MEAN TEMPERATURE DIFFERENCE
0034            DTMO=(TFO-TBO)/ALOG((TFO-TINO)/(TBO-TINO))
        C  GO IN TO THE DO LOOP,CALCULATE MEAN TEM.DIFFERNCES, A, B,AND
        C  FIND OUT MIN.INDOOR TEMPERATURE FOR EACH DESIGN OUTDOOR TEM.TG
0035            DO 300 J=1,21
0036            TG(J)=-(J-1)
0037            DTM=DTMO*((TINO-TG(J))/(TINO-TGO))**.75
0038            B=DTM/(DTM-TG(J)+TINO)
0039            HK=HC1+HC2/(TINO-TG(J))
0040            A=HC3*HK/B
        C  SET THE INITIAL CONDITIONS
0041            T1=0.
0042            T2=0.
0043            TMIN=0.
0044            DO 200 I=1,N
        C  EXCEPT TEM.POINTS ABOVE TG FROM CALCULATION
0045            IF (T(I).GT.TG(J)) GO TO 200
        C  CALCULATE THE TEMPS. AT THE END OF EACH PERIOD
0046            TO=T1*EXP(-A/M)+B*(T(I)-TG(J))*(1.-EXP(-A/M))
0047            IF (TO .LT. T1) GO TO 100
0048            IF (T1.GT.T2) GO TO 100
0049            IF((TO+T2-2.*T1).NE.0.0) TM=T1-(TO-T2)**2/(8.*(TO+T2-2.*T1))
0050            IF((TO+T2-2.*T1).EQ.0.0) TM=T1
0051            IF (TM.GE.TMIN)GO TO 100
0052            TMIN=TM
0053    100     T2=T1
0054            T1=TO
0055    200     CONTINUE
        C  WRITE THE RESULTS INTO THE OUTPUT FILE
0056            WRITE (1,250) TG(J),A,B,TMIN
0057    250     FORMAT(27X,F5.1,5X,F8.6,5X,F8.6,5X,F10.6)
0058    300     CONTINUE
0059            STOP
0060            END
```

APPENDIX D: Input Data File for Program PIPES and a Printout of the Calculation Results

```
-12.,20.,60.,
15.,15.9,15.9,21.9,22.9,50.,65.,18.,0.0,55.,
20.,24.,24.,24.,24.,110.,130.,18.,1.0,35.,
15.,15.9,15.9,21.9,22.9,85.,100.,18.,0.0,55.,
20.,24.,24.,24.,24.,150.,170.,18.,1.0,35.,
25.,29.,29.,29.,29.,1200.,1225.,36.,1.0,35.,
```

Input data file for program PIPES

```
                 THE CALCULATION RESULTS OF HEAT AND PRESSURE LOSS

                 AIR TEMPERATURE: -12.000
                 THICKNESS OF THE SAND LAYER:  20.000
                 THICKNESS OF THE SOIL LAYER:  60.000
  D1      D2      D3      D4      D5      PL      PLA      Q      P      TST      DT      DP       HLS

15.000  15.900  15.900  21.900  22.900   50.00   65.00   18.00  0.000  55.000   0.018  3561.816  1365.767

20.000  24.000  24.000  24.000  24.000  110.00  130.00   18.00  1.000  35.000   0.065  1963.728  4955.753

15.000  15.900  15.900  21.900  22.900   85.00  100.00   18.00  0.000  55.000   0.031  5479.822  2321.381

20.000  24.000  24.000  24.000  24.000  150.00  170.00   18.00  1.000  35.000   0.088  2568.111  6756.414

25.000  29.000  29.000  29.000  29.000 1200.00 1225.00   36.00  1.000  35.000   0.380 22389.346 58215.055

                 WELL HEAD PRESSURE FOR WELL NO.1,PH1=  1.4791  BAR
                 WELL HEAD PRESSURE FOR WELL NO.2,PH2=  1.5044  BAR
```

A printout of the calculation result

APPENDIX E: Pump Data Files, Well Data Files and Printouts of the Calculation Results

```
6.0         INCH        SIZE   SIZE OF THE PUMP
15.0        CM          DCI    INSIDE DIAMETER OF COLUMN
5.08        CM          DEO    OUTSIDE DIAMETER OF ENCLOSING TUBE
2.54        CM          DSHAF  DIAMETER OF SHAFT
0.5         INCH        AC     AXIAL CLEARANCE OF THE PUMP
10.09       L/S         QM     TURNING POINT OF CURVE FOR THE PUMP
18.288      M           X1     CONST. OF PERFORMANCE FOR THE PUMP
23.165      M           X2
0.2416      MS/L        Y1
0.7248      MS/L        Y2
0.01        -           A      CONST. OF COLUMN FRICTION LOSS
1.76        -           B
0.4572      M           C      CONST. FOR NPSHR OF THE PUMP
0.181       MS/L        D
0.77        -           XX     CONST. FOR EFFICIENCY OF THE PUMP
0.0         -           YY
2.67        LB/FEET     WSHAF  UNIT WEIGHT OF SHAFT OF THE PUMP
2.2         LB          WIMP   IMPELER WEIGHT OF THE PUMP
0.78        SQ.INCH     ASHAF  AREA OF SHAFT OF THE PUMP
0.87        BHP/100FT   UL     MECHENICAL FRICTION OF SHAFT
2900.       RPM         RPM    RPM OF MOTOR
0.9         -           EKMOT  EFFICIENCY OF MOTOR
3.6         LB/FT       TK     THRUST CONSTANT FOR THE PUMP
52.0        KW          HPR    HORSE POWER RATING OF THE SHAFT
```

Pump data file for 6 inch pump

```
8.0         INCH        SIZE   SIZE OF THE PUMP
20.0        CM          DCI    INSIDE DIAMETER OF COLUMN
6.35        CM          DEO    OUTSIDE DIAMETER OF ENCLOSING TUBE
3.175       CM          DSHAF  DIAMETER OF SHAFT
0.75         INCH       AC     AXIAL CLEARANCE OF THE PUMP
36.59       L/S         QM     TURNING POINT OF CURVE FOR THE PUMP
33.528      M           X1     CONST. OF PERFORMANCE FOR THE PUMP
42.672      M           X2
.24993      MS/L        Y1
.44986      MS/L        Y2
.0022       -           A      CONST. FOR COLUMN FRICTION LOSS
1.81        -           B
-1.219      M           C      CONST. FOR NPSHR OF THE PUMP
0.181       MS/L        D
0.75        -           XX     CONST. FOR EFFICIENCY OF THE PUMP
0.0         -           YY
4.17        LB/FEET     WSHAF  UNIT WEIGHT OF SHAFT OF THE PUMP
5.9         LB          WIMP   IMPELER WEIGHT OF THE PUMP
1.23        SQ.INCH     ASHAF  AREA OF SHAFT OF THE PUMP
1.33        BHP/100FT   UL     MECHENICAL FRICTION OF SHAFT
2900.       RPM         RPM    RPM OF MOTOR
0.9         -           EKMOT  EFFICIENCY OF MOTOR
4.7         LB/FT       TK     THRUST CONSTANT FOR THE PUMP
98.0        KW          HPR    HORSE POWER RATING OF THE SHAFT
```

Pump data file for 8 inch pump

```
101.1      -            WNAME   THE WELL NUMBER
1.0        BAR          PA      ATMOSPHRIC PRESSURE
55.0       C            TEMP    WATER TEMPERATURE IN THE WELL
0.157      BAR          PS      SATURATED PRESSURE OF THE WATER
985.0      KG/CB.M      DENS    DENSITY OF THE WATER
50.0       M            WKV     WATER LEVEL BELOW GROUND SURFACE
1.0        M/(L/S)      FLC1    FLOW COEFFICIENT OF THE WELL
.001       M/SQ.(L/S)   FLC2
30.0       M            WKNM    ALLOWED MAX. DROW DOWN
10.0       M            HSAFE   ADDED WATER COLUMN FOR FLUCTUATION
1.47        BAR         PH      DESIGN PRESSURE AT WELL HEAD
18.0       L/S          QO      FLOWRATE ORDERED
```

Well data file for Well No. 1

```
101.2      -            WNAME   THE WELL NUMBER
1.0        BAR          PA      ATMOSPHRIC PRESSURE
55.0       C            TEMP    WATER TEMPERATURE IN THE WELL
0.157      BAR          PS      SATURATED PRESSURE OF THE WATER
985.0      KG/CB.M      DENS    DENSITY OF THE WATER
50.0       M            WKV     WATER LEVEL BELOW GROUND SURFACE
1.0        M/(L/S)      FLC1    FLOW COEFFICIENT OF THE WELL
.001       M/SQ.(L/S)   FLC2
30.0       M            WKNM    ALLOWED MAX. DROW DOWN
10.0       M            HSAFE   ADDED WATER COLUMN FOR FLUCTUATION
1.50        BAR         PH      DESIGN PRESSURE AT WELL HEAD
18.0       L/S          QO      FLOWRATE ORDERED
```

Well data file for Well No. 2

```
                 THE RESULTS OF CALCULATION
                FOR SELECTING DEEP WELL PUMP


GIVEN VALUES:
                THE NAME OF THE WELL:101.10
                ATMOSPHRIC PRESSURE:  1.00BAR
                WATER LEVEL BELOW SURFACE: 50.00M
                TEMP. OF WATER: 55.00C
                DENSITY OF WATER:985.00KG/CUB.M
                SATURATED PRESSURE:  0.16BAR
                FLOWRATE ORDERED: 18.00L/S

                FLOW COEFF. OF THE WELL:  1.00M/(L/S)
                                        0.0010M/SQ.(L/S)
                PRESSURE AT WELL HEAD:  1.47BAR


PARAMETERS OF THE PUMP CALCULATED
                TYPE OF THE PUMP:  6.00
                NUMBER OF STAGES:   9
                FLOWRATE CALCULATED: 18.01L/S
                TOTAL DYNAMIC HEAD: 85.19M
                COLUMN DIAMETER: 15.00CM
                LENGTH OF COLUMN: 96.77M
                DIAMETER OF SHAFT:  2.54CM
                DIAMETER OF ENCLOSING TUBE:  5.08CM


                ENLONGATION OF THE SHAFT:  0.05INCH
                AXIAL CLEARENCE:  0.50INCH
                TOTAL THRUST: 8334.20N
                SHAFT HORSE POWER: 21.86KW
                CALCULATED MOTOR CAPACITY: 24.28KW
                STANDARD MOTOR CAPACITY: 30.00KW
```

```
                 THE RESULTS OF CALCULATION
                FOR SELECTING DEEP WELL PUMP


GIVEN VALUES:
                THE NAME OF THE WELL:101.10
                ATMOSPHRIC PRESSURE:  1.00BAR
                WATER LEVEL BELOW SURFACE: 50.00M
                TEMP. OF WATER: 55.00C
                DENSITY OF WATER:985.00KG/CUB.M
                SATURATED PRESSURE:  0.16BAR
                FLOWRATE ORDERED: 18.00L/S

                FLOW COEFF. OF THE WELL:  1.00M/(L/S)
                                         0.0010M/SQ.(L/S)
                PRESSURE AT WELL HEAD:  1.47BAR


PARAMETERS OF THE PUMP CALCULATED
                TYPE OF THE PUMP:  8.00
                NUMBER OF STAGES:   3
                FLOWRATE CALCULATED: 18.00L/S
                TOTAL DYNAMIC HEAD: 83.34M
                COLUMN DIAMETER: 20.00CM
                LENGTH OF COLUMN: 75.77M
                DIAMETER OF SHAFT:  3.17CM
                DIAMETER OF ENCLOSING TUBE:  6.35CM


                ENLONGATION OF THE SHAFT:  0.03INCH
                AXIAL CLEARENCE:  0.75INCH
                TOTAL THRUST:10405.76N
                SHAFT HORSE POWER: 22.42KW
                CALCULATED MOTOR CAPACITY: 24.91KW
                STANDARD MOTOR CAPACITY: 30.00KW
```

```
           THE RESULTS OF CALCULATION
          FOR SELECTING DEEP WELL PUMP


GIVEN VALUES:
          THE NAME OF THE WELL:101.20
          ATMOSPHRIC PRESSURE:  1.00BAR
          WATER LEVEL BELOW SURFACE: 50.00M
          TEMP. OF WATER: 55.00C
          DENSITY OF WATER:985.00KG/CUB.M
          SATURATED PRESSURE:  0.16BAR
          FLOWRATE ORDERED: 18.00L/S

          FLOW COEFF. OF THE WELL:  1.00M/(L/S)
                                  0.0010M/SQ.(L/S)
          PRESSURE AT WELL HEAD:  1.50BAR


PARAMETERS OF THE PUMP CALCULATED
          TYPE OF THE PUMP:  6.00
          NUMBER OF STAGES:   9
          FLOWRATE CALCULATED: 18.01L/S
          TOTAL DYNAMIC HEAD: 85.50M
          COLUMN DIAMETER: 15.00CM
          LENGTH OF COLUMN: 96.77M
          DIAMETER OF SHAFT:  2.54CM
          DIAMETER OF ENCLOSING TUBE:  5.08CM


          ENLONGATION OF THE SHAFT:  0.05INCH
          AXIAL CLEARENCE:  0.50INCH
          TOTAL THRUST: 8350.24N
          SHAFT HORSE POWER: 21.93KW
          CALCULATED MOTOR CAPACITY: 24.36KW
          STANDARD MOTOR CAPACITY: 30.00KW
```

```
          THE RESULTS OF CALCULATION
          FOR SELECTING DEEP WELL PUMP


GIVEN VALUES:
          THE NAME OF THE WELL:101.20
          ATMOSPHRIC PRESSURE:  1.00BAR
          WATER LEVEL BELOW SURFACE: 50.00M
          TEMP. OF WATER: 55.00C
          DENSITY OF WATER:985.00KG/CUB.M
          SATURATED PRESSURE:  0.16BAR
          FLOWRATE ORDERED: 18.00L/S

          FLOW COEFF. OF THE WELL:  1.00M/(L/S)
                                  0.0010M/SQ.(L/S)
          PRESSURE AT WELL HEAD:  1.50BAR


PARAMETERS OF THE PUMP CALCULATED
          TYPE OF THE PUMP:  8.00
          NUMBER OF STAGES:   3
          FLOWRATE CALCULATED: 18.00L/S
          TOTAL DYNAMIC HEAD: 83.65M
          COLUMN DIAMETER: 20.00CM
          LENGTH OF COLUMN: 75.77M
          DIAMETER OF SHAFT:  3.17CM
          DIAMETER OF ENCLOSING TUBE:  6.35CM


          ENLONGATION OF THE SHAFT:  0.03INCH
          AXIAL CLEARENCE:  0.75INCH
          TOTAL THRUST:10426.71N
          SHAFT HORSE POWER: 22.49KW
          CALCULATED MOTOR CAPACITY: 24.99KW
          STANDARD MOTOR CAPACITY: 30.00KW
```

APPENDIX F: A Input Data File for Programs SDT and a Printout of the Calculation Results

```
40,         M     NUMBER OF TEMPERATURE DATA
8,          M     NUMBER OF OBSERVATIONS PER DAY(PER 24 HOURS)
-1,1        M     COLD WAVE TEMPERATURES IN SEQUENCY
-2,9
-3,9
-4,8
-4,6
-6,5
-7,3
-8,7
-12,5
-14,6
-16,0
-17,0
-18,3
-19,2
-18,9
-16,9
-18,3
-18,3
-18,0
-19,4
-19,8
-20,4
-17,4
-14,9
-16,3
-15,2
-16,4
-16,5
-15,6
-14,0
-13,9
-10,3
-9,8
-7,9
-6,2
-5,3
-4,6
-3,4
-2,1
-0,8
```

```
          THE COOLDOWN TEMPERATURE TMIN
   AS A FUNCTION  SYSTEM DESIGN TEMPERATURE TG

  THE COLD WAVE DATA:
   NUMBER OF OBSERVATIONS PER DAY M=    8
   NUMBER OF TEMPERATURES N=   40
   THE TEMPERATURE DATA RECORDED ARE:

   -1.10     -2.90     -3.90     -4.80     -4.60
   -6.50     -7.30     -8.70    -12.50    -14.60
  -16.00    -17.00    -18.30    -19.20    -18.90
  -16.90    -18.30    -18.30    -18.00    -19.40
  -19.80    -20.40    -17.40    -14.90    -16.30
  -15.20    -16.40    -16.50    -15.60    -14.00
  -13.90    -10.30     -9.80     -7.90     -6.20
   -5.30     -4.60     -3.40     -2.10     -0.80

  DESIGN HOT WATER TEMPERATURE TFO= 60.00  C
   DESIGN RETURN TEMPERATURE TBO= 30.00  C
   DESIGN ROOM TEMPERATURE TINO= 18.00  C
   RADIATOR DESIGN OUTDOOR TEMP. TGO=-12.00  C
   HOUSE CHARACTERISTIC VALUES:
    HC1=  2.4000  HC2=  3.0000  HC3=  0.2200

   TG          A           B              TMIN

   0.0     1.187252    0.475608       -8.011862
  -1.0     1.191638    0.472238       -7.506376
  -2.0     1.196052    0.469043       -7.011861
  -3.0     1.200473    0.466007       -6.525758
  -4.0     1.204887    0.463114       -6.049791
  -5.0     1.209283    0.460352       -5.585967
  -6.0     1.213651    0.457710       -5.133885
  -7.0     1.217985    0.455178       -4.689880
  -8.0     1.222281    0.452747       -4.257731
  -9.0     1.226535    0.450411       -3.842116
 -10.0     1.230744    0.448161       -3.427667
 -11.0     1.234906    0.445992       -3.017229
 -12.0     1.239020    0.443899       -2.610577
 -13.0     1.243085    0.441877       -2.211514
 -14.0     1.247101    0.439920       -1.819831
 -15.0     1.251068    0.438026       -1.435090
 -16.0     1.254987    0.436189       -1.059008
 -17.0     1.258856    0.434408       -0.715810
 -18.0     1.262678    0.432678       -0.140549
 -19.0     1.266452    0.430998        0.000000
 -20.0     1.270179    0.429363        0.000000
```