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.
CONTENTS

ABSTRACT ................................................................. 3

1 INTRODUCTION
   1.1 Scope of work ............................................. 9
   1.2 Use of computer in geothermal utilization ............ 10

2 SELECTING A DEEP WELL PUMP: PROGRAM DWPS
   2.1 Principles and Criteria for Deep Well Pump Selection... 11
       2.1.1 Introduction ........................................... 11
       2.1.2 Pump size ............................................. 12
       2.1.3 Number of stages .................................... 12
       2.1.4 Column length ....................................... 14
       2.1.5 Shaft thrust .......................................... 16
       2.1.6 Motor power capacity ................................ 16
       2.2 Computation Method ...................................... 16
           2.2.1 Use of the loop technique ........................ 16
           2.2.2 Use of subroutine ................................ 18
           2.2.3 Creating an input file ............................ 18
           2.2.4 Pump characteristics .............................. 18
           2.2.5 Arrangements of the checking procedure .......... 18
           2.2.6 Output file ......................................... 20

3 HEAT AND PRESSURE LOSSES IN GEOTHERMAL WATER TRANSMISSION
   PIPELINES: PROGRAM PIPES
   3.1 Calculation Principle and Formulae Used ................. 20
       3.1.1 Thermal resistance .................................. 20
       3.1.2 Temperature drop and heat loss of the water in the pipes .... 23
       3.1.3 Pressure loss of the water in the pipes ............ 24
   3.2 Computation Method .................................... 25
       3.2.1 Iteration method .................................... 25
       3.2.2 Index P .............................................. 25
       3.2.3 Output file .......................................... 25
       3.2.4 Limitation ........................................... 29
4 DISTRICT HEATING SYSTEM DESIGN TEMPERATURE: PROGRAM SDT

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Theoretical Basis</td>
<td>30</td>
</tr>
<tr>
<td>4.2</td>
<td>Calculation Formulae Used</td>
<td>31</td>
</tr>
<tr>
<td>4.3</td>
<td>Computation Method</td>
<td>33</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Arrangement of input file</td>
<td>33</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Calculation procedures</td>
<td>33</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Determination of system design temperature</td>
<td>35</td>
</tr>
</tbody>
</table>

5 EXAMPLES OF USING THE PROGRAMS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Calculation for Unity Lake District Heating System in Beijing</td>
<td>36</td>
</tr>
<tr>
<td>5.1.1</td>
<td>Brief description of the task</td>
<td>36</td>
</tr>
<tr>
<td>5.1.2</td>
<td>Suggested scheme and preliminary calculation</td>
<td>36</td>
</tr>
<tr>
<td>5.1.3</td>
<td>Calculation for the geothermal water pipelines</td>
<td>40</td>
</tr>
<tr>
<td>5.1.4</td>
<td>Calculation for deep well pump selection</td>
<td>41</td>
</tr>
<tr>
<td>5.2</td>
<td>Selection of the system design temperature for a own</td>
<td>42</td>
</tr>
<tr>
<td>5.2.1</td>
<td>Brief description of the task</td>
<td>42</td>
</tr>
<tr>
<td>5.2.2</td>
<td>Calculation</td>
<td>43</td>
</tr>
<tr>
<td>5.2.3</td>
<td>Interpretation of the calculation result</td>
<td>43</td>
</tr>
</tbody>
</table>

6 DISCUSSION AND CONCLUSION | 43

ACKNOWLEDGEMENTS | 45

REFERENCES | 46

APPENDICES | 47
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.1</td>
<td>Recommended flowranges of FLOWAY vertical pumps</td>
<td>12</td>
</tr>
<tr>
<td>Table 5.1</td>
<td>Main parameters of the secondary water system</td>
<td>39</td>
</tr>
<tr>
<td>Table 5.2</td>
<td>The parameters of the pipes</td>
<td>40</td>
</tr>
</tbody>
</table>

LIST OF FIGURES

<table>
<thead>
<tr>
<th>Fig.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 2-1</td>
<td>Definition for the calculation of pump</td>
</tr>
<tr>
<td>Fig. 2-2</td>
<td>Two straight lines are used to approximate the pump curve</td>
</tr>
<tr>
<td>Fig. 2-3</td>
<td>The flowchart for Program DWPS</td>
</tr>
<tr>
<td>Fig. 2-4</td>
<td>The flowchart for subroutine program SUBFLO</td>
</tr>
<tr>
<td>Fig. 3-1</td>
<td>The covering layers of the buried pipe</td>
</tr>
<tr>
<td>Fig. 3-2</td>
<td>The flowchart for program PIPES</td>
</tr>
<tr>
<td>Fig. 3-3</td>
<td>The flowchart for subroutine program HLOSS</td>
</tr>
<tr>
<td>Fig. 3-4</td>
<td>The flowchart for subroutine program PLOSS</td>
</tr>
<tr>
<td>Fig. 4-1</td>
<td>A rectangular cold wave</td>
</tr>
<tr>
<td>Fig. 4-2</td>
<td>An actual cold wave</td>
</tr>
<tr>
<td>Fig. 4-3</td>
<td>The flowchart for program SDT</td>
</tr>
<tr>
<td>Fig. 5-1</td>
<td>The Unity Lake District</td>
</tr>
<tr>
<td>Fig. 5-2</td>
<td>Suggested schematic diagram of the Unity Lake Distric Heating System</td>
</tr>
</tbody>
</table>
**LIST OF APPENDICES**

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Program DWPS and Subroutine Program SUBFLO</td>
<td>49</td>
</tr>
<tr>
<td>B</td>
<td>Program PIPES and Subroutine Programs HLOSS and PLOSS</td>
<td>55</td>
</tr>
<tr>
<td>C</td>
<td>Program SDT</td>
<td>61</td>
</tr>
<tr>
<td>D</td>
<td>An Input Data File for Program PIPES and a Printout of the Calculation Result</td>
<td>65</td>
</tr>
<tr>
<td>E</td>
<td>Pump Data Files, Well Data Files and Printouts of the Calculation Results</td>
<td>69</td>
</tr>
<tr>
<td>F</td>
<td>An Input Data File for Program SDT and a Printout of the Calculation Result</td>
<td>77</td>
</tr>
</tbody>
</table>
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, Reykjavik 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 repetitious 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 chemical 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

<table>
<thead>
<tr>
<th>Pump size</th>
<th>Column sizes</th>
<th>Flow range recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 inch</td>
<td>6 inch column pipe</td>
<td>14-40 l/s</td>
</tr>
<tr>
<td>and</td>
<td>2 inch enclosure tube</td>
<td></td>
</tr>
<tr>
<td>8 inch</td>
<td>1 3/16 inch shaft</td>
<td>50-75 l/s</td>
</tr>
<tr>
<td>10 inch</td>
<td>8 inch col. pipe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 1/2 inch encl. tube</td>
<td>85-110 l/s</td>
</tr>
<tr>
<td>12 inch</td>
<td>10 inch col. pipe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 1/2 inch encl. tube</td>
<td></td>
</tr>
</tbody>
</table>

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:

\[ P = P_h + K_v + K_n + P_d + P_f \]  

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.

$P_h$ (PH)  
Digcharge head

$K_v$ (WKV)  
Static water level

$K$ (WKN)  
Drawdown

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 function 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 function 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:

\[ P_h + K_v + K_n + P_d + P_f = (c_1 + c_2 \cdot Q) \cdot Z \tag{2-3} \]

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:

\[ L_c = K_v + K_n + h_{\text{min}} + h_{\text{saf}} \]

In this expression, \( h_{\text{saf}} \) 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. \( h_{\text{min}} \) 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 BJKH Floway Vertical Pump (Ref. 8)
expressed as:

\[ h_{\text{min}} = \frac{(P_o - P_a)}{d} + g \cdot \text{NPSHR} \]  

(2-5)

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 function of flowrate. When a linear function is used to approximate the NPSHR curve it can be calculated as:

\[ \text{NPSHR} = c + d \cdot Q \]  

(2-6)

From expressions (2-4), (2-5) and (2-6) it is clear that the column length \( L_c \) is a function 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 \( T_T \) is calculated and the elongation of the shaft \( E_a \) needs to be checked. The formula for calculating \( T_T \) 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

Start

Q > QM

Yes

X = X₂
Y = Y₂

Calculate PPHO, WKN

Set up a new function Z = f(Q) and calculate ZD,
ZD = \frac{dZ}{dQ} = f'(Q)

Q NEW = Q - Z / ZD

Q NEW - Q |< 1.0

Yes

Write Q, Q NEW on the terminal

Return
the computer to give the information on the terminal. This information advises 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

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 resistance 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 \((R_{out} \text{ or } R_{sl})\).

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:

\[
R_{ins} = \ln(D_3/D_2) / 2\pi K_{ins}
\]

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

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

\[
R_{pipe} = \ln \left(\frac{D_2}{D_1}\right) / 2\pi K_{abs}
\]

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):

\[
R_{sl} = \frac{\ln(2(h_1+r_p)/r_p)}{2 K_1} + \frac{1}{4(h_1+r_p)} \left(\frac{h_2/K_2 + h_3/K_3}{h_1+r_p}\right)
\]  

(3-1)

where, \(R_{sl}\) 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):

\[
R_{sl} = \ln\left(\frac{8(H/D)^2 - 1}{4} \right) + 4 \left(\frac{H}{D}\right) \left(\frac{4(H/D)^2 - 1}{\ln(\frac{4.5}{4} \cdot \frac{K_s}{K_1})}\right)
\]

where \( H \) is the depth of the buried pipe center and \( K_s \) 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:

\[
Q = \frac{DT_m}{R_{tot}}
\]

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

\[
DT_m = \frac{T_1 - T_2}{\ln\left(\frac{T_1 - T_a}{T_2 - T_a}\right)}
\]

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:

\[
Q_{tot} = c \cdot m \cdot \frac{T_1 - T_2}{L_p}
\]

Thus,

\[
Q = Q_{tot} \cdot \frac{1}{L_p} = c \cdot m \cdot \frac{T_1 - T_2}{L_p} = DT_m / R_{tot}
\]

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:

\[
\frac{DT}{\ln\left(\frac{T_1 - T_a}{T_1 - DT - T_a}\right)} = R_{tot} \cdot c \cdot m \cdot \frac{DT}{L_p}
\]

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

\[ H_{ls} = Q \cdot L_p \text{ (W)} \]

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):

\[ f^{-1/2} = -2 \log \left( \frac{2.5 \cdot R_e^{-1} \cdot f^{1/2} + k/3.71 \cdot D_1}{Re} \right) \]  

(3-3)

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

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

\[ f^{-1/2} = 4.0 \log \left( R_e \cdot f^{1/2} \right) - 0.4 \]  

(3-4)

The pressure loss in the pipe will be

\[ P_{ls} = 0.5 f \cdot \rho \cdot v^2 \frac{L_{adj}}{D_1} \]  

(3-5)

Here, \( \rho \) 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:

\[ \frac{1}{2} C_b \cdot \rho \cdot v^2 = \frac{1}{2} f \cdot \rho \cdot v^2 \cdot L_e / D_1 \]

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):

\[
\begin{align*}
\text{vis} &= 1.951 \times 10^{-5} / T^{0.909} \text{ (m}^2\text{/s)} \\
\text{dens} &= 1237.16 / T^{0.0537} \text{ (kg/m}^3\text{)}
\end{align*}
\]

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 "PIPEC.OUT" and printout from the file can be obtained (Appendix D).
Start

Read data file name

Set up an output file, write heading

I = 1

Read input data

Call subroutine HLOSS to calculate heat loss THL and temperature drop DT

Call subroutine PLOSS to calculate pressure loss PL

Write results THL, DT, PL

I = I + 1

Is the data finished?

Yes

Calculate total pressure loss for pipelines

Write results into output file

Stop

No

Fig. 3-2 FLOWCHART FOR PROGRAM PIPES
Read the thermal conductivity values of different materials

Is the pipe asbestos-cement pipe?

Yes
  Calculate thermal resistance of pipe wall

No
  Is the pipe buried?

Yes
  \((H_1+H_2) > D_5\)
  
  Yes
  Calculate thermal resistance of covering layers using the complicated formula
  
  No
  Calculate thermal resistance of covering layers using the simplified formula

No
  Calculate thermal resistance of insulation
  
  Calculate thermal resistance, of protecting pipe

\(\text{HL, DT, using secant iteration method}\)
  
\(\text{Calculate total heat loss on the pipe THL}\)
  
\(\text{Return}\)

Fig. 3-3 FLOWCHART FOR SUBROTINE PROGRAM HLOSS
Calculate friction coefficient for asbestos pipe
Calculate friction coefficient for plastic pipe
Calculate friction coefficient for steel pipe
Calculate pressure loss PL
Return

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.
4.1 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":

\[ T_{\text{min}} = bT_d(1-\exp(-aT_0)). \]  \hspace{1cm} (4-1)

In this expression \( T_{\text{min}} \) is the minimum room temperature 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" tempera­
ture record available based on observations made at intervals through­
out 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:

\[ b = DT_m/(DT_m - T_g + T_{\text{in}}) \] \hspace{1cm} (-)

\[ a = h_{c3} \cdot k_1 \] \hspace{1cm} \text{(day}^{-1}\text{)}

\[ k_1 = h_{c1} + h_{c2}/(T_{\text{in}} - T_g) \]

Here, \( T_g \) is the design room temperature, \( T_{\text{in}} \) 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"
DT_m = DT_m0 \times \left( \frac{(T_{in} - T_g)}{(T_{in} - T_{go})} \right)^{0.75}

DT_m0 = \frac{(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_m0 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 function 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 m² 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 utilization 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
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 maintenance.

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>District No.1</th>
<th>District No.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Requirement</td>
<td>(W/m²)</td>
<td>58*</td>
<td>58*</td>
</tr>
<tr>
<td>Building Area</td>
<td>(m²)</td>
<td>60,777</td>
<td>46,823</td>
</tr>
<tr>
<td>Total Heat Demand</td>
<td>(MW)</td>
<td>35,25</td>
<td>27,15</td>
</tr>
<tr>
<td>Temp. of Supply Water</td>
<td>(°C)</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Temp. of Return Water</td>
<td>(°C)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Water Flowrate in Secondary Water System</td>
<td>(l/s)</td>
<td>28,0</td>
<td>21,6</td>
</tr>
<tr>
<td>Temp. of Geoth. Water before Heat Exch.</td>
<td>(°C)</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Temp. of Geoth. Water after Heat Exch.</td>
<td>(°C)</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Temp. Diff. of Secondary Water in Heat Exchanger</td>
<td>(°C)</td>
<td>12,8</td>
<td>16,8</td>
</tr>
<tr>
<td>Temp. of Secondary Water from Heat Exchanger</td>
<td>(°C)</td>
<td>42,8</td>
<td>46,8</td>
</tr>
<tr>
<td>Temp. Diff. of Secondary Water in Boiler</td>
<td>(°C)</td>
<td>17,2</td>
<td>13,2</td>
</tr>
<tr>
<td>The Load of Heat Exch.</td>
<td>(MW)</td>
<td>15,05</td>
<td>15,05</td>
</tr>
<tr>
<td>The Load of Boiler</td>
<td>(MW)</td>
<td>20,2</td>
<td>12,1</td>
</tr>
</tbody>
</table>

*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, $T_{AIR}$: $-12.0$ ($^\circ$C)
2. The thickness of the sand layer, $H_1$: $20.0$ (cm)
3. The thickness of the soil layer, $H_2$: $60.0$ (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>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Unit</th>
<th>Pipe No.1</th>
<th>No.2</th>
<th>No.3</th>
<th>No.4</th>
<th>No.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner dia. of pipe</td>
<td>D1</td>
<td>(cm)</td>
<td>15.0</td>
<td>20.0</td>
<td>15.0</td>
<td>20.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Outer dia. of pipe</td>
<td>D2</td>
<td>(cm)</td>
<td>15.9</td>
<td>24.0</td>
<td>15.9</td>
<td>24.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Outer dia. of the 1st insulation</td>
<td>D3</td>
<td>(cm)</td>
<td>15.9</td>
<td>24.0</td>
<td>15.9</td>
<td>24.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Outer dia. of the 2nd insulation</td>
<td>D4</td>
<td>(cm)</td>
<td>21.9</td>
<td>24.0</td>
<td>21.9</td>
<td>24.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Outer dia. of the protecting pipe</td>
<td>D5</td>
<td>(cm)</td>
<td>22.9</td>
<td>24.0</td>
<td>22.9</td>
<td>24.0</td>
<td>29.0</td>
</tr>
<tr>
<td>Length of the pipe</td>
<td>PL</td>
<td>(m)</td>
<td>50.0</td>
<td>110.0</td>
<td>85.0</td>
<td>150.0</td>
<td>1200.0</td>
</tr>
<tr>
<td>Adjusted length of the pipe</td>
<td>PLA</td>
<td>(m)</td>
<td>65.0</td>
<td>130.0</td>
<td>100.0</td>
<td>170.0</td>
<td>1225.0</td>
</tr>
<tr>
<td>Water temp. at the inlet of the pipe</td>
<td>TST</td>
<td>($^\circ$C)</td>
<td>55.0</td>
<td>35.0</td>
<td>55.0</td>
<td>35.0</td>
<td>35.0</td>
</tr>
<tr>
<td>Flowrate</td>
<td>Q</td>
<td>(l/s)</td>
<td>18.0</td>
<td>18.0</td>
<td>18.0</td>
<td>18.0</td>
<td>36.0</td>
</tr>
<tr>
<td>Index</td>
<td>P</td>
<td>(-)</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
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:

\[
\begin{align*}
PH_1 &= P_r + DP_h + DP_1 + DP_2 + DP_5 \\
PH_2 &= P_r + DP_h + DP_2 + DP_4 + DP_5
\end{align*}
\]

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 FLOSS 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:

\[ HC1 = 2.4, \quad HC2 = 3.0, \quad HC3 = 0.22 \]

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:

\[
\begin{align*}
-1.1 & \quad -2.9 & \quad -3.9 & \quad -4.8 & \quad -4.6 & \quad -6.5 & \quad -7.3 & \quad -8.7 \\
-12.5 & \quad -14.6 & \quad -16.0 & \quad -17.0 & \quad -18.3 & \quad -19.2 & \quad -18.9 & \quad -16.9 \\
-18.3 & \quad -18.3 & \quad -18.0 & \quad -19.4 & \quad -19.8 & \quad -20.0 & \quad -17.4 & \quad -14.9 \\
-16.3 & \quad -15.2 & \quad -16.4 & \quad -16.5 & \quad -15.6 & \quad -14.0 & \quad -13.9 & \quad -10.3 \\
-9.8 & \quad -7.9 & \quad -6.2 & \quad -5.3 & \quad -4.6 & \quad -3.4 & \quad -2.1 & \quad -0.8
\end{align*}
\]

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 \(-11^\circ C\) 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 \(-3^\circ C\) and a lower temperature, \(-13^\circ C\) should be used as the system design temperature if \(-2^\circ C\) is allowed. It is also obvious that \(-12^\circ C\) could also be used as the system design temperature for the town since the corresponding cooling calculated is \(-2.6^\circ C\).

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 simplification 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 considered 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-temperature 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 SLT to estimate the system design temperatures for different towns in northern China and compare the results with the currently used values.
ACKNOWLEDGEMENTS

The author would like to express his gratitude to the organizers of the 1981 UNU Geothermal Training Program at the National Energy Authority in Iceland especially Dr. Ingvar B. Fríðleifsson and Dr. Hjalti Franzson.

The author is much indebted to Dr. Jon Steinar Gudmundsson (N.E.A. of Iceland), his supervisor, for his helpful assistance, correct guidance and comments during the training course and in the preparation of this paper.

The author is also indebted to Prof. Thorbjorn Karlsson (University of Iceland) and Associate Prof. Derek Freeston (Auckland University, New Zealand) for their valuable lectures and the constructive comments they made in the process of writing this paper.

Special thanks are due to Mr. Asmundur Jakobsson and Mr. Halldor Halldórsson (N.E.A. of Iceland) for their unlimited help and guidance in the use of the computer.

Also thanks to Mrs. Adalheidur Johannesdottir and Ms. Ingunn Sigurdardottir and Gudrun S. Jonsdottir for typing the manuscript and drawing the figures.
REFERENCES


8. Floway Vertical Pump Specifications


APPENDIX A: Program DWPS and Subroutine Program SUBFLOW
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 (DATAN.DAT).

C COMMON /BLOCK/ SIZE:G,GM,X,Y,X1,Y1,X2,Y2,FLC1,FLC2,
1 PH,WNK,WSVX,DENG,AR,BC,CL,CONST,PbHO,NZ
C INPUT THE NAME OF THE PUMP DATA FILE
0001 0002
0003 0004 10 FORMAT (' PUMP DATA FILE:',")
0005 12 ACCEPT 12+10+FILENAME
C INPUT THE NAME OF THE WELL DATA FILE
0006 0007 12 FORMAT (0,32A1)
0008 0009 WRITE (5,2) FILENAME
0010 0011 2 FORMAT (' ',32A1)
0012 0013 FILENAME(10+1)=0
C INPUT THE NAME OF THE WElL DATA FILE
0014 0015 OPEN (UNIT=1,NAME=FILENAME,TYPE='OLD',READONLY)
C INPUT THE NAME OF THE WElL DATA FILE
0016 0017 TYPE 20
0018 0019 OPEN (UNIT=2,NAME=FILENAME,TYPE='OLD',READONLY)
C READ DATA FROM PUMP DATA FILE
0020 0021 READ (1,1000) SIZE:DCI,DEH,DSHAF,AC,GX,X1,X2,Y1,Y2,
1 A,AR,BC,XX,YY,AWSHIF,WSHAF,UL,RPM,ENSH,TK,HPR
C READ DATA FROM WELL DATA FILE
0022 0023 READ (2,2000) NAME,PA,TEMFX,PS,DENS,WSVX,FLC1,FLC2,WNK,SHAFE,PH,DO
C CREATE AN OUTPUT FILE
0024 0025 OPEN (UNIT=3,NAME='DWP.S.OUT')
C WRITE HEADING LINES
0026 0027 WRITE (3,100)
0028 0029 100 FORMAT (' ',30X,'THE RESULTS OF CALCULATION'/
1 30X,'FOR SELECTING DEEP WELL PUMP'//)
C WRITE GIVEN VALUES
0030 0031 WRITE (3,102) NAME,PA,WSVX,DENS,PS,DO
C WRITE GIVEN VALUES
0032 0033 102 FORMAT (20X,'GIVEN VALUES:'//
1 30X,'THE NAME OF THE WELL:'F6.2//'F6.2','BAR'/
2 30X,'ATMOSPHERIC 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/CU.F'/
6 30X,'SATURATED PRESSURE:'F6.2,'BAR'/
7 30X,'FLOW RATE ORDERED:'F6.2,'L/S'//)
C CHECK THE MAX. DROP DOWN
0034 0035 IF (WNK .GT. WNKH) GO TO 30
GO TO 40

C ITERATION CALCULATION FOR DESIGN THE COLUMN LENGTH AND NUMBER OF STAGES.
C GIVING THE INITIAL VALUES OF COLUMN LENGTH AND FLOWRATE.

40 Q=00
C CHOOSE THE CORRECT CONSTANTS FOR PUMP CHARACTERISTICS.

IF (Q=00) 50,50,60

50 X=X1
Y=Y1
GO TO 65

60 X=X2
Y=Y2
GO TO 65

65 CL=KWIN*WIN+HSAFE+20.
C DECIDE NUMBER OF STAGES OF THE PUMP

CONST=(DCI,.01)*X2-(DDE,.01)*X2
PV=0.0286E-6*(DENS/CONST)*X2
PF=(KWIN/HWIN)*X2
TDH=10.2*PVH*(KWIN+HWIN)*DENS/1000.*PVH+PV
PDHO=X-YQ
NZ=TDH/PDHO+1.
C USE SUBROUTINE TO CALCULATE FLOWRATE.

80 CALL SUBFLO

NP=0.04
DMP=0.00
HPH=0.00E0
WPH=0.00E0

WPH=FLC1-HFLC2*X2

WPH=WPH

Z=TDH/PDHO+1.
C WRITE RESULTS.

WRITE (3,160)

160 FORMAT (2X, 'TYPE OF THE PUMP:',F6.2, 'L/S')

2 3X, 'NUMBER OF STAGES:',I4/
3 3X, 'FLOWRATE CALCULATED:'F6.2,'L/S'/
4 3X, 'TOTAL DYNAMIC HEAD:'F6.2,'H'/
5 3X, 'COLUMN DIAMETER:'F6.2,'CH'/
6 3X, 'LENGTH OF COLUMN:'F6.2,'H'/
7 3X, 'DIAMETER OF SHAFT:'F6.2,'CH'/
8 3X, 'DIAMETER OF ENCLOSING TUBE:'F6.2,'CH'/

C CALCULATION TOTAL THRUST.

TA=TDHMK/K.3048
WB=(CL/.3048)*WPH-HWIN*WIN*WIMP

C=TDHMK/K.3048

EA=(TA*CL)/(ASHAF*2.7E7)
C CHECK IF THE ENLARGEMENT IS ALLOWED.

IF (EA <.05, AC) GO TO 200

80 TO 300
FOFFRAN IV-PLUS V3.0-3 16:17:54 24-Sep-81 Page 3

0048 200 TYPE 202
0049 202 FORMAT ('THE ENLARGEMENT IS GREATER THAN ALLOWED VALUE; CHANGE THE SHAFT SIZE!'
0050 STOP

C CALCULATE MOTOR CAPACITY NEEDED
C CHOOSE THE CORRECT CONSTANTS
0071 300 EXP=XX+YY*Z
0072 301 PLS=CL#UL/30.48
0073 302 BLDPS=TTXRI#1.49E-8
0074 304 PSHAFT=(PXL#PLOS#BLOPS)/7.385

C CHECK THE SHAFT HORSEPOWER RATING
0076 310 IF (PSHAFT .GT. HPR) GO TO 310
0077 311 80 TO 400
0078 312 TYPE 312
0079 313 FORMAT ('SHAFT HORSEPOWER IS GREATER THAN ALLOWED VALUE; CHANGE THE SHAFT DIAMETER!
0080 400 PMOTOR=PSHAFT/EXPMT

C STANDARDIZATION OF THE MOTOR CAPACITY
0081 500 IF (PMOTOR .LT. 4.8) PMB=4.8
0082 501 IF (PMOTOR .LT. 4.8 .AND. PMOTOR .LE. 10.) PMB=10.
0083 502 IF (PMOTOR .LT. 10. .AND. PMOTOR .LE. 20.) PMB=20.
0084 503 IF (PMOTOR .LT. 20. .AND. PMOTOR .LE. 30.) PMB=30.
0085 504 IF (PMOTOR .LT. 30. .AND. PMOTOR .LE. 40.) PMB=40.
0086 505 IF (PMOTOR .LT. 40. .AND. PMOTOR .LE. 50.) PMB=50.

C WRITE RESULTS INTO THE OUTPUT FILE
0087 WRITE (3,500) EA+AC+TT+PSHAFT+PMOTOR+PMB
0088 500 FORMAT (20X,'ENLARGEMENT OF THE SHAFT: ',F6.2,' INCH'/
0089 1 30X,'AXIAL CLEARANCE: ',F6.2,' INCH'/
0090 2 20X,'TOTAL THRUST: ',F6.2,' N'/
0091 3 30X,'SHAFT HORSE POWER: ',F6.2,' KW'/
0092 4 30X,'CALCULATED MOTOR CAPACITY: ',F6.2,' KW'/
0093 5 30X,'STANDARD MOTOR CAPACITY: ',F6.2,' KW')

0094 STOP

0095 END
SUBROUTINE SUBFLO

COMMON/BLOCK/SIZE,G,WM,X,Y,X1,Y1,X2,Y2,FLC1,FLC2,
1
PH,WKH,WKV,DENS,A,B,CL,CONST,PDHO,NZ

C CHOOSE CORRECT CONSTANTS
0003 10  IF (Q-GM) 12;12;14
0004 12  X=X1
0005  Y=Y1
0006  GO TO 30
0007 14  X=X2
0008  Y=Y2
0009  GO TO 30

C ITERATION FOR FLOWRATE
0010 30  PDHO=X-YG
0011  WKN=FLC1&4+FLC2&4*2
0012  Z=PH*10.2+(WKN+WKV)*DENS*.001+(A#998)*CL/100.+.0926E-8*(DENS/CONST)
1  &992-PDHO#NZ
0013  ZD=FLC2&998.2*1.4652E-4*(DENS/CONST)*&C&B#998*(B-1,)
1  *FLC1#DENS*1
0014  QNEW=Q-Z/ZD

C CHECK FOR COMPLETION
0015  IF (ABS(QNEW-Q) .LT. 1.) GO TO 40

C OTHERWISE CONTINUE THE ITERATION
0016  Q=QNEW
0017  GO TO 10
0018  40  WRITE (S,50)Q,QNEW
0019  50  FORMAT('Q ',2F15.6)
0020  Q=QNEW
0021  RETURN
0022  END
APPENDIX B: Program PIPES and Subroutine Programs HLOSS and PLOSS
PROGRAM PIPES

COMMON/BLOCK1/D2,D3,D4,D5,H1,H2,TAIR,CP,GENS,PL,THL,HL
COMMON/BLOCK2/D1,TSTART,DT,P,G
COMMON/BLOCK3/PLA,PLS
BYTE FNAME(32)

TYPE 10

FORMAT('/INPUT FILE!','A')

ACCEPT 12,10,FNAME

FORMAT(Q32A1)

FNAME(I+1)=0

OPEN(UNIT=1,NAME=FNAME,TYPE='OLD',READONLY)

CALL ASSIGN(2,'PIPES.OUT')

READ(1,20)TAIR,H1,H2

WRITE(2,10)TAIR,H1,H2

FOOAT('THE CALCULATION RESULTS OF HEAT AND PRESSURE LOSS'/)

10 X,'AIR TEMPERATURE','F8.3/

2 X,'THICKNESS OF THE SAND LAYER','F8.3/

3 X,'THICKNESS OF THE SOIL LAYER','F8.3/

4 X,'D1','D2','D3','D4','D5','G','PL','PLA','QL','P','TSTART'

5 X,'D1','D2','D3','D4','D5','PL','PLA','QL','P','TSTART'

WRITE(2,52)DT,THL,H1,H2

WRITE(2,54)PLS

WRITE(2,220)PLS

WRITE(2,210)PH1,PH2

FOOAT('WELL HEAD PRESSURE FOR WELL NO.1=',F15.6,2X,'MR')

STOP

END
SUBROUTINE HLOSS
C SUBROUTINE TO CALCULATE HEAT LOSSES FROM SURFACE OF PLANES AND TEMPERATURE
C DROP OF WATER IN HOT WATER PIPELINES
0002 COMMON /BLOCK1/D2,D3,D4,D5,H1,H2,TAIR,CP,DENS,PL,THL,HL
0003 COMMON /BLOCK2/D1,TSTART,DT,P,R
C GIVES THE VALUES OF THERMAL CONDUCTIVITIES FOR DIFFERENT MATERIALS
0004 TCP=0.465
0005 TCINS1=0.040
0006 TCINS2=0.035
0007 TCPT=0.40
0008 TCSL1=0.3
0009 TCSL2=1.45
0010 CP=4186.
C IF THE PIPE IS ASBESTOS-CEMENT PIPE, THE THERMAL RESISTANCE OF THE PIPE WALL
C NEEDS TO BE CALCULATED
0011 IF (P.EQ.1.0) GO TO 5
0012 IF (P.NE.1.0) RP=0.0
0013 GO TO 10
C CALCULATE THE THERMAL RESISTANCE OF ASBESTOS-CEMENT PIPE WALL
0014 5 RP=ALOG(D2/D1)/(6.2832*TCP)
0015 RINS=0.0
0016 GO TO 20
C CALCULATE THE THERMAL RESISTANCE OF INSULATION LAYERS
0017 10 RINS=ALOG(D3/D2)/(6.2832*TCINS1)+ALOG(D4/D3)/(6.2832*TCINS2)
0018 RPT=ALOG(D5/D4)/(6.2832*TCP)
C CHECK THE PIPE IS IN OPEN AIR
0019 20 IF (H1.NE.0.0) GO TO 25
0020 IF (H1.EQ.0.0) RSL=0.0
0021 GO TO 100
C CHECK THE DEPTH OF BURYING TO CHOOSE THE CORRECT FORMULA
0022 25 IF ((H1+H2).LE. D5) GO TO 30
0023 IF ((H1+H2).GT. D5) GO TO 40
0024 30 RATIO=(H1+H2+.3805)/D5
0025 RSL=ALOG((1.3830*(H1+H2+.3805)-1.))/(4.0*RATIO*2.5+1.)/12.55664*TCSL2
0026 GO TO 100
0027 40 U=ALOG((4.0*(H1+.5*D5))/D5)/(6.2832*TCSL1)
0028 V=H2/(12.55664*(H1+.5*D5)*TCSL2)
0029 RSL=U+V
0030 GO TO 100
C CALCULATE THE TOTAL THERMAL RESISTANCE
0031 100 RTOT=RP+RINS+RPT+RSL
C ITERATION CALCULATION (SEDANT METHOD) TO FIND OUT THE TEMPERATURE DROP,
C TOTAL HEAT LOSSES AND AVERAGE HEAT LOSS PER ONE METER OF PIPE
0032 DT=10.0
0033 DT=0.05
0034 DENS=1.237/TSTART**0.05367
0035 200 Y0=DT0*CP&DENS-DT0/ALOG1(TSTART-TAIR)/(TSTART-TAIR-RT0))#PL/RTOT
0036 Y3=DT0*CP&DENS-DT1/ALOG1(TSTART-TAIR)/(TSTART-TAIR-DT0))#PL/RTOT
0037 DT2=(Y33+0.4*Y1)/Y1
0038 Y2=DT2*CP&DENS-DT2/ALOG1(TSTART-TAIR)/(TSTART-TAIR-DT2))#PL/RTOT
0039 IF (ABS(DT2-DT) .LT. .01) GO TO 300
0040 DT0=DT1
0041 DT1=DT2
0042 GO TO 200
0043 300 DT=DT2
0044  THL=DTCP*DQDENS
0045  HL=THL/PL
0046  RETURN
0047  END
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+SSETTING .05 HM AS THE ROUGHNESS OF THE
C ASBESTOS-CEMENT PIPES AND .025 FOR STEEL PIPES.
C
0002 COMMON /BLOCK2/D1,TSTART,DT,P;G
0003 COMMON /BLOCK3/PLA,PLB
C CALCULATE REYNOLDS NUMBER
0004 VEL=12.73*G/D1**2
0005 TAV=TSTART-.5*DT
0006 VIS=1.9018E-5/(TAY**1.909054)
0007 RE=VEL*D1/(VIS**100.)
C CHOOSE THE CORRECT FORMULA FOR PIPES MADE OF DIFFERENT MATERIALS
0008 IF (P,.EQ. 1.) GO TO 10
0009 IF (P,.EQ. 2.) GO TO 20
0010 IF (P,.EQ. 0.) GO TO 30
C CALCULATE FRICTION COEFFICIENT F BY USING NEWTON-RAPHSON METHOD
C FOR ASBESTOS-CEMENT PIPES
0011 10 F=.001
0012 11 Y=1./F**.5+2.5ALGB10(2.51/(RE**(5)+.00135/D1))
0013 YD=.5/F**1.5*(1+2.1802/(RE**1.000135/D1+2.51/(RE**5))))
0014 FNEW=F+Y/YD
0015 IF (ABS(FNEW-F).LT.1E-5) GO TO 100
0016 F=FNEW
0017 GO TO 11
C FOR BOTH COPPER AND PLASTIC PIPES
0018 20 F=.001
0019 21 Y=4.5ALGB10(RE**.5)-F**(-5-.5)-.4
0020 YD=.8586/F**1.5
0021 FNEW=F-Y/YD
0022 IF (ABS(FNEW-F).LT.1E-5) GO TO 100
0023 F=FNEW
0024 GO TO 21
C FOR STEEL PIPES
0025 30 F=.001
0026 31 Y=1./F**.5+2.5ALGB10(2.51/(RE**5)+.000674/D1)
0027 YD=.5/F**1.5*(1+2.1802/(RE**1.000674/D1+2.51/(RE**5))))
0028 FNEW=F+Y/YD
0029 IF (ABS(FNEW-F).LT.1E-5) GO TO 100
0030 F=FNEW
0031 GO TO 31
C CALCULATE PRESSURE LOSSES
0032 100 ADENS=1237.16/TAV**.055367
0033 PLS=50.*ADENS*VEL**2/PLA/D1
0034 RETURN
0035 END
APPENDIX C: Program SDT
C PROGRAM SDT
C PROGRAM TO ESTIMATE THE EFFECT OF A COLD WAVE ON THE INDOOR TEMPERATURE OF BUILDINGS. FROM THE RESULTS COMPUTED THE OPTIMUM SYSTEM DESIGN TEMPERATURE CAN BE DECIDED. THE FORMULA USED FOR CALCULATING THE COOLING OF HOMES IS SUITABLE FOR A RECTANGULAR COLD WAVE, BUT THIS PROGRAM CAN BE 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/HOURLY) OBSERVATION, IT IS ASSUMED THAT THE TEMPERATURES BETWEEN EVERY TWO OBSERVATIONS ARE CONSTANTS. FOR EACH SYSTEM DESIGN TEMPERATURE CALCULATED CORRESPONDING MINIMUM INDOOR TEMPERATURE IN THE PERIOD OF THE COLD WAVE, THE COLD WAVE TEMPERATURE DATA HAD BEEN EDITED IN THE INPUT FILE.
C BEFORE RUN THE PROGRAM.
C
0001 DIMENSION T(56),T0(25)
0002 BYTE FILNAM(32)
0003 C INPUT COLD WAVE DATA FILE
0004 TYPE 10
0005 FORMAT (' ', 'COLD WAVE DATA FILE: ', $)
0006 ACCEPT 11, IQ, FILNAM
0007 FORMAT (B132A1)
0008 FILNAM(IQ+1)=0
0009 OPEN (UNIT=2, FILE=FILNAM, TYPE='OLD', READONLY)
0010 C READ COLD WAVE TEMPERATURE DATA FROM INPUT DATA FILE
0011 READ (2, 12) N,M
0012 FORMAT (I5)
0013 DO 14 I=1,N
0014 READ (2, 11) T(I)
0015 FORMAT (F10.2)
0016 CONTINUE
C INPUT HOUSE CHARACTERISTIC VALUES ON TERMINAL
0017 TYPE 20
0018 FORMAT (' ', 'INPUT HC1,HC2,HC3: ', $)
0019 ACCEPT 22, HC1, HC2, HC3
0020 FORMAT (F6.2)
C INPUT DESIGN CONDITIONS ON TERMINAL
0021 TYPE 30
0022 FORMAT (' ', 'INPUT TFO,TBO,TINO,TGO: ', $)
0023 ACCEPT 32, TFO, TBO, TINO, TGO
0024 FORMAT (F6.2)
C SET UP AN OUTPUT FILE
0025 CALL ABSSIGN (1, 'SDT.OUT')
C WRITE COLUMN HEADING
0026 WRITE (1, 500)
0027 500 FORMAT (' ', 35X, 'THE COLD WAVE DATA: '/$)
0028 1 30X, 'NUMBER OF OBSERVATIONS PER DAY M=', I5/$
0029 2 30X, 'NUMBER OF TEMPERATURES N=', I5/$
0030 3 30X, 'THE TEMPERATURE DATA RECORDED ARE: '/$)
0031 WRITE (1, 700) (T(I)+I=1,N)
0032 700 FORMAT (F10.2)
0033 C WRITE THE GIVEN VALUES
0034 WRITE (1, 600) N,M
0035 600 FORMAT (' ', 28X, 'THE COLD WAVE DATA: '/$)
0036 1 30X, 'NUMBER OF OBSERVATIONS PER DAY M=', I5/$
0037 2 30X, 'NUMBER OF TEMPERATURES N=', I5/$
0038 3 30X, 'THE TEMPERATURE DATA RECORDED ARE: '/$)
0039 WRITE (1, 700) (T(I)+I=1,N)
0040 700 FORMAT (F10.2)
0041 WRITE (1, 800) TFO, TBO, TINO, TGO, HC1, HC2, HC3
0043 C WRITE COLUMN HEADING
0044 WRITE (1, 500)
0045 500 FORMAT (' ', 35X, 'THE COLD WAVE DATA: '/$)
0046 1 30X, 'NUMBER OF OBSERVATIONS PER DAY M=', I5/$
0047 2 30X, 'NUMBER OF TEMPERATURES N=', I5/$
0048 3 30X, 'THE TEMPERATURE DATA RECORDED ARE: '/$)
0049 WRITE (1, 700) (T(I)+I=1,N)
0050 700 FORMAT (F10.2)
0051 C WRITE THE GIVEN VALUES
0052 WRITE (1, 600) N,M
0053 600 FORMAT (' ', 28X, 'THE COLD WAVE DATA: '/$)
0054 1 30X, 'NUMBER OF OBSERVATIONS PER DAY M=', I5/$
0055 2 30X, 'NUMBER OF TEMPERATURES N=', I5/$
0056 3 30X, 'THE TEMPERATURE DATA RECORDED ARE: '/$)
0057 WRITE (1, 700) (T(I)+I=1,N)
0058 700 FORMAT (F10.2)
2 30X/'DESIGN ROOM TEMPERATURE TINO='8/F6.2,'/C'/
3 30X/'RADIATOR DESIGN OUTDOOR TEMP. TGO='8/F6.2,'/C'/
4 30X/'HOUSE CHARACTERISTIC VALUES'/
5 31X/'HC1='8/FB.4,'HC2='8/F8.4,'HC3='8/F8.4,'/

0032 WRITE (1,1000)
0033 1000 FORMAT (' ',2SX,'TG',10X,'A' ,10X,'B' ,12X, 'THIN''')

C CALCULATE THE STANDARD LOGARITHMIC MEAN TEMPERATURE DIFFERENCE

0034 DTKO=TFO-TGO)/ALOG(TFO-TINO)/(TBO-TINO))

C Go in to the DO LOOP:CALCULATE MEAN TEM. DIFFERENCES: 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=DTHO/(TINO-TB(J))/TINO-TGO))**.75
0038 B=DTH(DIN-TB(J)+TINO)
0039 HK=HC1+HC2/(TINO-TB(J))
0040 A=HC3*HK/B

C SET THE INITIAL CONDITIONS

0041 T1=0,
0042 T2=0,
0043 TMIN=0,
0044 DO 200 l=1,N

C EXCEPT TEM.PONTS ABOVE TO FROM CALCULATION

0045 IF (T(I),GT,TB(J)) GO TO 200

C CALCULATE THE TEMPS. AT THE END OF EACH PERIOD

0046 TD=T1*EXP(-A/M)+B*(T(I)-TB(J))*1,-EXP(-A/M))
0047 IF (TD ,LT, T1) GO TO 100
0048 IF (T(I),GT,T2) GO TO 100
0049 IF((T(I)-T2-2.0,T1),NE.0.0) TM=T1-(T(I)-T2)**2/(8.*(T(I)-T2-2.*T1))
0050 IF((T(I)-T2-2.,T1),EQ.0.0) TM=T1
0051 IF (TM,TIE,TMIN) GO TO 100
0052 TMIN=TM
0053 100 T2=T1
0054 T1=TD
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,F8.5,F5X,F8.5,F10.5)
0058 300 CONTINUE
0059 STOP
0060 END
APPENDIX D: Input Data File for Program PIPES and a Printout of the Calculation Results
Input data file for program PIPES

THE CALCULATION RESULTS OF HEAT AND PRESSURE LOSS

AIR TEMPERATURE: -12.00
THICKNESS OF THE SAND LAYER: 20.00
THICKNESS OF THE SOIL LAYER: 60.00

<table>
<thead>
<tr>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>PL</th>
<th>PLA</th>
<th>G</th>
<th>P</th>
<th>TST</th>
<th>DT</th>
<th>DP</th>
<th>HLS</th>
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<tr>
<td>15.000</td>
<td>15.900</td>
<td>15.900</td>
<td>21.900</td>
<td>22.900</td>
<td>50.00</td>
<td>65.00</td>
<td>18.00</td>
<td>0.000</td>
<td>55.000</td>
<td>0.018</td>
<td>3561.816</td>
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<td>20.000</td>
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<td>24.000</td>
<td>24.000</td>
<td>24.000</td>
<td>110.00</td>
<td>130.00</td>
<td>18.00</td>
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<td>35.000</td>
<td>0.065</td>
<td>1963.728</td>
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<td>15.900</td>
<td>15.900</td>
<td>21.900</td>
<td>22.900</td>
<td>85.00</td>
<td>100.00</td>
<td>18.00</td>
<td>0.000</td>
<td>55.000</td>
<td>0.031</td>
<td>5479.822</td>
<td>2321.381</td>
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<tr>
<td>20.000</td>
<td>24.000</td>
<td>24.000</td>
<td>24.000</td>
<td>24.000</td>
<td>150.00</td>
<td>170.00</td>
<td>18.00</td>
<td>1.000</td>
<td>35.000</td>
<td>0.088</td>
<td>2568.111</td>
<td>6756.414</td>
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<td>29.000</td>
<td>29.000</td>
<td>29.000</td>
<td>1200.00</td>
<td>1225.00</td>
<td>36.00</td>
<td>1.000</td>
<td>35.000</td>
<td>0.380</td>
<td>22389.346</td>
<td>38215.055</td>
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</table>

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
Pump data file for 6 inch pump

<table>
<thead>
<tr>
<th>6.0</th>
<th>INCH</th>
<th>SIZE</th>
<th>SIZE OF THE PUMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.0</td>
<td>CM</td>
<td>DCI</td>
<td>INSIDE DIAMETER OF COLUMN</td>
</tr>
<tr>
<td>5.06</td>
<td>CM</td>
<td>DEO</td>
<td>OUTSIDE DIAMETER OF ENCLOSING TUBE</td>
</tr>
<tr>
<td>2.54</td>
<td>CM</td>
<td>DSCHAFT</td>
<td>DIAMETER OF SHAFT</td>
</tr>
<tr>
<td>0.5</td>
<td>INCH</td>
<td>AC</td>
<td>AXIAL CLEARANCE OF THE PUMP</td>
</tr>
<tr>
<td>10.09</td>
<td>L/S</td>
<td>GM</td>
<td>TURNING POINT OF CURVE FOR THE PUMP</td>
</tr>
<tr>
<td>18.288</td>
<td>M</td>
<td>X1</td>
<td>CONST. OF PERFORMANCE FOR THE PUMP</td>
</tr>
<tr>
<td>23.163</td>
<td>M</td>
<td>X2</td>
<td></td>
</tr>
<tr>
<td>0.2416</td>
<td>MS/L</td>
<td>Y1</td>
<td></td>
</tr>
<tr>
<td>0.7248</td>
<td>MS/L</td>
<td>Y2</td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>-</td>
<td>A</td>
<td>CONST. OF COLUMN FRICTION LOSS</td>
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<tr>
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<td>-</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>0.4572</td>
<td>M</td>
<td>C</td>
<td>CONST. FOR MPShR OF THE PUMP</td>
</tr>
<tr>
<td>0.101</td>
<td>MS/L</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>0.77</td>
<td>-</td>
<td>XX</td>
<td>CONST. FOR EFFICIENCY OF THE PUMP</td>
</tr>
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Pump data file for 8 inch pump

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<td>DEO</td>
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THE RESULTS OF CALCULATION
FOR SELECTING DEEP WELL PUMP

GIVEN VALUES:

THE NAME OF THE WELL: 101.10
ATMOSPHERIC PRESSURE: 1.008BAR
WATER LEVEL BELOW SURFACE: 50.00M
TEMP. OF WATER: 55.00C
DENSITY OF WATER: 1000.00KG/CUB.M
SATURATED PRESSURE: 0.168BAR
FLOW RATE ORDERED: 10.00L/S

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

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

PARAMETERS OF THE PUMP CALCULATED

TYPE OF THE PUMP: 6.00
NUMBER OF STAGES: 9
FLOW RATE 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
ENLARGEMENT OF THE SHAFT: 0.05INCH
AXIAL CLEARANCE: 0.60INCH
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
Atmospheric pressure: 1.000 bar
Water level below surface: 50.00 m
Temp. of water: 55.00 C
Density of water: 985.00 kg/m³
Saturated pressure: 0.16 bar
Flow rate ordered: 18.00 L/s

Flow coeff. of the well: 1.00 m³/(L/s)
Flow coeff. of the well: 0.0010 m³/s (L/s)
Pressure at well head: 1.47 bar

PARAMETERS OF THE PUMP CALCULATED
Type of the pump: 8.00
Number of stages: 3
Flow rate calculated: 18.00 L/s
Total dynamic head: 83.34 m
Column diameter: 20.00 cm
Length of column: 75.77 m
Diameter of shaft: 3.17 cm
Diameter of enclosing tube: 6.35 cm

Elongation of the shaft: 0.03 inch
Axial clearance: 0.03 inch
Total thrust: 1104.05 N
Shaft horse power: 22.42 kW
Calculated motor capacity: 24.91 kW
Standard motor capacity: 30.00 kW
THE RESULTS OF CALCULATION FOR SELECTING DEEP WELL PUMP

GIVEN VALUES:

THE NAME OF THE WELL: I01.20
ATMOSPHERIC PRESSURE: 1.002BAR
WATER LEVEL BELOW SURFACE: 50.00M
TEMP. OF WATER: 55.00C
DENSITY OF WATER: 1055.00KG/CM3
SATURATED PRESSURE: 0.168BAR
FLOW RATE ORDERED: 18.00L/S

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

FLOW RATE ORDERED: 18.00L/S

PRESSURE AT WELL HEAD: 1.50BAR

PARAMETERS OF THE PUMP CALCULATED

TYPE OF THE PUMP: 6.00
NUMBER OF STAGES: 9
FLOW RATE 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

ENLARGEMENT OF THE SHAFT: 0.05INCH
AXIAL CLEARANCE: 0.50INCH
TOTAL THRUST: 6350.24N
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: IGl.20
ATMOSPHERIC PRESSURE: 1.00BAR
WATER LEVEL BELOW SURFACE: 50.00M
TEMP. OF WATER: 55.00C
DENSITY OF WATER: 1950.00KG/CUB.M
SATURATED PRESSURE: 0.16BAR
FLOW RATE ORDERED: 10.00L/S

FLOW COEFF. OF THE WELL: 1.00L/1(S)
PRESSURE AT WELL HEAD: 1.50BAR

PARAMETERS OF THE PUMP CALCULATED:

TYPE OF THE PUMP: 8.00
NUMBER OF STAGES: 3
FLOW RATE CALCULATED: 10.00L/S
TOTAL DYNAMIC HEAD: 53.65M
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 CLEARANCE: 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
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THE COOL DOWN TEMPERATURE THIN
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:

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DESIGN HOT WATER TEMPERATURE THD = 60.00 °C
DESIGN RETURN TEMPERATURE THB = 36.00 °C
DESIGN ROOM TEMPERATURE THQ = 18.00 °C
RADIATOR DESIGN OUTDOOR TEMP. TSO = -12.00 °C
HOUSE CHARACTERISTIC VALUES:
HC1 = 2.4000 HC2 = 3.0000 HC3 = 0.2200

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