NATIONAL BUREAU OF STANDARDS REPORT

10 194

HEAT TRANSFER ANALYSIS OF UNDERGROUND HEAT DISTRIBUTION SYSTEMS

Interim Report to

The General Services Administration and the Tri-Services

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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Executive Summary

This interim report presents the results of an in-depth heat transfer analysis of hot and cold piping systems intended for placement underground. The planning and implementation of field experiments to validate or invalidate the analysis given is currently underway.

The analytic approach was to evaluate the use of steady-state heat transfer principles and then to extend these principles to include transient heat transfer effects due to initial cooling or heating and due to changing outdoor temperatures. Earth temperature and changes in earth temperature with season and depth were identified as being of prime importance.

Extensive tables and graphs for use by engineers for estimation and decision were developed with the aid of the NBS computer facilities. Listings of the computer programs developed are included together with sample problems and solutions. The results allow quantitative estimates of heat transfer of insulated and uninsulated buried pipes that include a broad range of the variables of pipe fluid temperature, depth, pipe size, insulation thickness, types of insulation, thermal properties of soils, and the temperatures of the earth surrounding the pipes.

Especially derived for this report were equations to accommodate systems of several pipes at different temperatures with variable spacing and complex relationships involving seasonal effects.

This report contains the means for predicting the thermal performance of underground pipes containing chilled water, hot fluids, or a combination of hot and cold fluids. Experimental validation is needed.

1. Introduction

Underground heat distribution systems for a complex of buildings have been widely used in the United States for the past several decades. Generally, a heat transfer analysis for the underground pipe network is considered less important than other technical problems such as the possibility of failure of the piping system from corrosion, thermal expansion difficulties, or moisture penetration through the thermal insulation. This is largely because many of the underground installations are designed to distribute steam or hot water and the pipes are purposely well insulated. Thus, heat loss from these pipes is usually small when compared with the total heat energy being transmitted through the pipe providing the thermal insulation is not damaged and rendered ineffective by leaking pipe fluid or from ground moisture. Thus, main emphasis is placed on the preservation of a dry insulation around the pipe, corrosion protection of the conduit which houses the piping system and the design of the piping system to minimize stress caused by the thermal expansion and contraction.

Only recently underground chilled water distribution systems began to gain popular acceptance for district cooling. The economic consideration as to whether the chilled water pipes should be insulated or not has required a careful reevaluation of the heat transfer problem[1/].

Some underground chilled water pipes are currently installed uninsulated allowing a considerable savings in capital investment especially for a large district cooling system. The uninsulated chilled water system appears justified on the following basis:

a. Ground temperature is not severely affected by the presence of a deeply buried uninsulated chilled water pipe and soil ecology and plant life are not unduly affected.

b. Heat gain from the surrounding earth to large size chilled water pipes is usually a very small part of the total refrigeration load and increases in the temperature of the chilled water being circulated in the underground piping network are not significant.

Although the first point is unquestionably valid, the second point may not be as valid particularly when the pipe diameter is small, long lengths of pipe are used and when the earth surrounding the pipe remains warm and conductive for long periods of time.

The main question, therefore, is under what conditions is it necessary to insulate underground chilled water pipes? If insulation becomes necessary how much is needed? These questions are the concern of this report.

This report presents the first of a two-phase study. The first phase, a technical and mathematical analysis for underground pipe heat transfer is given here with special emphasis on the periodic nature of the ground surface temperature and the cooling effects for the multiple pipe system situations. This study was done using a computerized simulation of underground pipe systems by solving governing differential equations.

The second phase of the program is to validate or invalidate the mathematical model developed in the first phase of the study by conducting field measurements on an actual chilled water pipe installation.

2. Theoretical Background for Underground Pipe Heat Transfer

Except for the work of London[2/], very few papers have been published in the past treating the realistic conditions applicable to the analysis of underground pipe heat transfer. Most of the analytical solutions readily available for estimating heat transfer to and from underground pipes are either steady-state solutions for a pipe at shallow depths or several transient heat conduction solutions for a single deep underground pipe. All of these solutions are based upon the assumption that the earth surrounding the pipe is homogeneous, the thermal properties of the earth are constant and that the temperature of the earth at reasonable distances from the pipe is constant and unaffected by the existence of the pipe.

These assumptions are unrealistic because thermal properties as well as earth temperatures change with respect to time and space. This is because of the seasonal change of the earth surface temperature and also due to movement of the soil moisture or ground water around the pipe.

Analytical solutions which take into account these realistic situations are extremely difficult to obtain and are not expected to be available in the near future. Therefore, the approach here was to examine steady heat transfer theories in the light of transient (inclusive of periodic) boundary conditions to provide approximate but reasonable solutions for many practical problems.

2.1 Single Shallow Pipe System (Figure 1)

The solution for steady-state heat conduction from an underground pipe installed horizontally at a finite depth in homogeneous soil can be found in several heat transfer texts[3, 4]. This solution is based upon the potential flow theory and is obtained by the use of the "mirror-image" technique[3]. According to this technique, the heat loss Q from the unit length of the pipe of temperature T_p to the undisturbed ground at an average temperature T_G can be expressed in consistent units as follows:

$$Q = \frac{2\pi k_s (T_p - T_G)}{\ln\left\{\frac{d}{r} + \sqrt{\left(\frac{d}{r}\right)^2 - 1}\right\}} \qquad (1)$$

where k_s = thermal conductivity of earth surrounding the pipe

d = depth of the pipe measured from the ground surface to the centerline of the pipe

r = external radius of the pipe where the pipe temperature is T_p

ℓ_n = natural logarithm

Another form of the above equation, usually cited is

$$Q = \frac{2\pi k_s (T_P - T_G)}{\ln\left(\frac{2d}{r}\right)} \qquad (2)$$

which is an approximate representation of equation (1) when d/r >> 1, or when the radius of the pipe is sufficiently smaller than the depth.

Equations (1) and (2) were developed for the outside surface temperature of the pipe and the average temperature of the undisturbed earth far away from the pipe.

When the pipe is insulated, a term for the thermal resistance of the insulation layer must be added to the above equations. If the pipe is uninsulated and the pipe material has the high thermal resistance, such as non-metalic pipes, the thermal resistance term for the pipe wall should also be included in the pipe heat transfer equation in such a way that

$$Q = K_P (T_F - T_G) \qquad (3)$$

$$\frac{1}{K_P} = \frac{1}{2\pi k_s}\left\{\frac{k_s}{r_w h_w} + \frac{k_s}{k_w}\ln\left(\frac{r-t}{r_w}\right) + \frac{k_s}{k_I}\ln\left(\frac{r}{r-t}\right) + \ln\left(\frac{d}{r} + \sqrt{\left(\frac{d}{r}\right)^2 - 1}\right)\right\}$$

in consistent units where

K_p = pipe heat transfer factor

T_F = pipe fluid temperature

T_G = undisturbed average earth temperature surrounding the pipe

r_w = inside radius of the pipe

r = external radius of the insulation

t = thickness of the pipe insulation

h_w = heat transfer coefficient of the pipe fluid

k_s = thermal conductivity of the earth surrounding the pipe

k_w = thermal conductivity of the pipe wall

k_I = thermal conductivity of the pipe insulation

In the above expression for the pipe heat transfer factor, K_p, it is customary for the case of metallic pipes to ignore the terms involving h_w and k_w because of their very small numerical value. Even for the non-metallic pipes, the term involving h_w is usually neglected unless the pipe fluid velocity is extremely small.

Since equation (3) is very frequently used to evaluate the effectiveness of the insulation, the values of K_p for the several combinations of parameters that can constitute an underground metallic pipe system were calculated, indexed and tabulated as shown in Tables SSHT-1 through 120. A listing of the Fortran program used, called GSA, is given in Appendix A, pp. 7-8. These tables should be useful for a quick approximation of the insulation effectiveness under a specified condition. Sample calculation procedures described in a later section illustrate the use of these tables. For the preparation of these tables the following values for the essential parameters were selected and used:

- k_s: From Figure 2 the range of thermal conductivity values for most dry and moist soils can be obtained. Values of thermal conductivity selected were 5, 7.5, 10, 12 or 15 (Btu/hr, ft^2, F/in.).
- k_I: Thermal conductivities values selected were .15, .2, .25, .3, .35, .4, .65 and 1.0 (Btu/hr ft^2, F/in.). This range of values covers many of the materials that are typical for underground pipe insulation such as expanded polyurethane, cellular glass, calcium silicate, and others (see Table A).
- t: Thicknesses of insulation selected for underground metallic pipes were 0, 1, 1.5, 2, 2.5, 3, 4, and 6 inches.
- r: Pipe radii for the uninsulated metallic pipes were determined from the nominal pipe sizes of 3, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, 20, 24, 30, 36, and 42 inches.
- d: The common depth of the underground pipes are considered to be 4, 6 and 8 ft.

In addition to a metallic pipe system, separate tables SSHTP 1 through 15 were prepared for the plastic (fiberglas/epoxy), cement asbestos (transite), and concrete pipes.

These types of non-metallic pipes are usually used for a chilled water distribution system without additional insulation. Because the walls of these pipes have a large thermal resistance as compared to metals they are treated as special cases of the insulated metallic pipe. The thermal conductivity k_I used for the calculation of the fiberglas/epoxy was 2.5, Btu/hr, ft^2, F/in, 5.5 for cement asbestos and 12.0 for reinforced concrete pipes.

2.2 Multiple Pipe Systems (Figure 3)

The foregoing discussion and the SSHT and SSHTP tables are for a single isolated underground pipe. In practice, several pipes may be installed in the same vicinity. Thus, heat transfer around each pipe is affected by the presence of its neighbor. The steady-state heat transfer for a multiple pipe system was explored in detail during this study and is presented in this report because little information was available from reference material. The multiple pipe system considered in this section is shown schematically in Figure 3. The undisturbed earth temperature is designated by T_G whereas the earth temperature at any point (X, -Y) in the region of pipe heat transfer is designated by T.

By denoting the exterior radius of the k-th pipe by r_k, the heat transfer surface of that pipe can be expressed as

$$(X - a_k)^2 + (Y + d_k)^2 = r_k^2 \tag{5}$$

Or with the use of the polar coordinate system

$$\begin{aligned} X &= a_k + r_k \sin\theta \\ Y &= r_k \cos\theta - d_k \end{aligned} \tag{6}$$

where θ is the angular position of a point on the heat transfer surface around the k-th pipe as shown in Figure 3. By substituting (6) into (4), the surface temperature for the k-th pipe can be obtained as a function of θ as follows:

$$T_k(\theta) - T_G = \sum_{i=1}^{M} \frac{Q_i}{4\pi k_s} \ln \left\{ \frac{(a_k - a_i + r_k \sin\theta)^2 + (r_k \cos\theta - d_k - d_i)^2}{(a_k - a_i + r_k \sin\theta)^2 + (r_k \cos\theta - d_k + d_i)^2} \right\} \tag{7}$$

By denoting further that

$$A_{ki}^2 = \frac{(a_k - a_i)^2 + (d_k - d_i)^2}{r_k^2}$$

$$A_{ki}'^2 = \frac{(a_k - a_i)^2 + (d_k + d_i)^2}{r_k^2}$$

The difference in temperature $T - T_G$, due to M number of heat sources (or sinks) can be obtained by the mirror image technique employed for the single pipe problem in consistent units is as follows:

$$T - T_G = \sum_{i=1}^{M} \frac{Q_i}{4\pi k_s} \ln \left\{ \frac{(X-a_i)^2 + (Y-d_i)^2}{(X-a_i)^2 + (Y+d_i)^2} \right\} \tag{4}$$

where Q_i = strength of the i-th heat source (if plus) or sink (if minus). It is the total heat loss (if plus) or heat gain (if minus) of the i-th pipe per unit length.

k_s = thermal conductivity of earth surrounding all the pipes

a_i and d_i = coordinates of the center of the i-th pipe referring to an arbitrary origin of the coordinate system (X, -Y). If, or instance, the coordinates were so chosen that $X_1 = 0$ and $Y_1 = -d_1$, the origin of the coordinates for the multiple pipe system would be at the ground surface above the centerline of the first pipe.

$$\tan \varphi_{ik} = \frac{a_k - a_i}{d_k - d_i} \tag{8}$$

$$\tan \varphi'_{ik} = \frac{a_k - a_i}{d_k + d_i}$$

equation (7) becomes

$$T_k(\theta) - T_G = \sum_{\substack{i=1 \\ i \neq k}}^{M} \frac{Q_i}{4\pi k_s} \ln \left\{ \frac{A'^2_{ik} - 2A'_{ik} \cos(\theta + \varphi'_{ik}) + 1}{A^2_{ik} - 2A_{ik} \cos(\theta + \varphi_{ik}) + 1} \right\}$$

$$+ \frac{Q_k}{4\pi k_s} \ln \left\{ 1 - 4\frac{d_k}{r_k} \cos\theta + \left(\frac{2d_k}{r_k} \right)^2 \right\} \tag{9}$$

The average surface temperature of the k-th pipe is, therefore, obtained by integrating equation (9) with respect to θ as follows:

$$T_k - T_G = \frac{1}{2\pi}\int_0^{2\pi} \{T_k(\theta) - T_G\}\, d\theta$$

$$= \frac{1}{4\pi k_s} \sum_{\substack{i=1 \\ i \neq k}}^{M} Q_i \ln\left(\frac{A'_{ik}}{A_{ik}}\right)^2$$

$$+ \frac{Q_k}{4\pi k_s} \ln\left(\frac{2 d_k}{r_k}\right)^2 \qquad (10)$$

This equation is consistent with the approximate solution for the case of the single pipe heat transfer (equation 21) if M = 1.

By defining matrix elements $P_{i,k}$ in such a manner that

$$P_{i,k} = \ln\left(\frac{A'_{ik}}{A_{ik}}\right)^2$$

$$P_{kk} = \ln\left(\frac{2d_k}{r_k}\right)^2 \qquad (11)$$

the values of Q_1, Q_2 ... Q_M can now be obtained as a solution of the following simultaneous equations.

$$\frac{1}{4\pi k_s}\begin{vmatrix} P_{11} & P_{12} & \cdots & P_{1M} \\ P_{21} & P_{22} & \cdots & P_{2M} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ P_{M1} & P_{M2} & \cdots & P_{MM} \end{vmatrix} \bullet \begin{vmatrix} Q_1 \\ Q_2 \\ \\ \\ \\ Q_M \end{vmatrix} = \begin{vmatrix} T_1 - T_G \\ T_2 - T_G \\ \\ \\ \\ T_M - T_G \end{vmatrix} \qquad (12)$$

provided that the values of T_1, T_2 ... T_M are known.

The above equations are for bare steel pipe systems where the average exterior pipe surface temperature may safely be approximated as equal to the pipe fluid temperature.

When the system includes non-metallic pipes or insulated pipes, the external surface temperatures (pipe-earth interface temperatures) T_1, T_2 ... T_M must be calculated first. Assuming, for the time being, that the values of T_1, T_2 ... T_M are known as well as the pipe fluid temperatures, T_{F1}, T_{F2} ... T_{FM}, the heat transfer from the pipes Q_1, Q_2 ... Q_M are then calculated by

$$Q_k = C_k (T_{Fk} - T_k) \tag{13}$$

where C_k = is the heat transfer coefficient for the k-th pipe for use with the thermal resistance between the pipe fluid and the external radius of the pipe or pipe and insulation where it interfaces with soil. The value of C_k may be calculated by

$$\frac{1}{C_k} = \frac{1}{2\pi} \left\{ \frac{1}{k_{Ik}} \ln\left(\frac{r_k}{r_{Ik}}\right) + \frac{1}{k_{mk}} \ln\left(\frac{r_{Ik}}{r_{mk}}\right) + \frac{1}{r_{mk} h_w} \right\} \tag{14}$$

In equation (14), $k_{I,k}$ and $k_{m,k}$ are the thermal conductivities of insulation and wall for the k-th pipe whereas $r_{I,k}$ and $r_{m,k}$ are the external radii of the insulation and the wall, respectively.

The symbol h_w refers to the heat transfer coefficient between the pipe fluid and the pipe wall. The value of h_w is usually very high unless the pipe fluid velocity is extremely small and consequently the last term of equation (14) is usually neglected.

By substituting equation (13) into (12) and rearranging the terms with respect to the pipe average surface temperature T_1, T_2 ... T_M, the following simultaneous equations can be derived

$$\begin{vmatrix} P_{11}' & P_{12}' & \cdots & P_{1M}' \\ P_{21}' & P_{22}' & \cdots & P_{2M}' \\ \vdots & & & \\ P_{M1}' & P_{M2}' & \cdots & P_{MM}' \end{vmatrix} \cdot \begin{vmatrix} T_1 \\ T_2 \\ \vdots \\ T_M \end{vmatrix} = \begin{vmatrix} B_1 \\ B_2 \\ \vdots \\ B_M \end{vmatrix} \qquad (15)$$

where

$$P'_{ik} = \frac{C_k P_{ik}}{4\pi k_s}$$

$$P'_{kk} = 1 + \frac{C_k P_{kk}}{4\pi k_s}$$

$$B_i = T_G + \frac{1}{4\pi k_s} \sum_{k=1}^{M} C_k P_{ik} T_{Fk}$$

The solution of (15) yields a set of pipe-soil interface temperatures T_1, T_2 ... T_M, thus permitting the calculation of pipe heat transfer by equation (13).

When equation (15) is to be solved for the multiple pipe system where some of the pipes are non-insulated steel pipes, fictitious insulation of arbitrary thickness with the thermal conductivity identical to the surrounding soil may be assumed for the bare pipes. This procedure is necessary because the values of $P'_{i,k}$ and B_i are meaningless otherwise.

Computer programs have been developed during the course of this study to implement this derivation for the multiple pipe system. The Fortran listing of this program is included in Appendix A marked MULT, pp. 11-13. Since the number of combinations to include the varieties of pipe sizes, types of insulation, soil characteristics, pipe temperature and arrangement of multiple pipes are enormous, only a limited number of sample cases were solved. A sample case selected is illustrated in Figures (4) and (5) with the results of the calculations given in Figure 5 to show relative effect between heat transfer and distance between pipes. The values in parenthesis indicate percentage change from case 5 where each pipe is considered to be a single separate pipe system.

Appendix B gives the analytical development for transient heat transfer as compared with the foregoing which applies to steady-state heat transfer.

2.3 Pipes in an Underground Conduit (Figure 6)

When a group of pipes (some insulated and others non-insulated) are installed in the unvented underground conduit such as illustrated in Figure 3, the following heat balance equation in consistent units would approximate the overall heat transfer process

$$\sum_{k=1}^{M} 2\pi r_k U_k (T_{fk} - T_a) = K (T_a - T_G) \qquad (16)$$

where M = total number of pipes in the conduit

r_k = outside radius of insulated or non-insulated pipes (k-th pipe)

U_k = overall heat transfer coefficient of the k-th pipe calculated by the following formula

$$\frac{1}{U_k} = \frac{r_k}{k_{Ik}} \ln\left(\frac{r_k}{r_k - t_k}\right) + \frac{1}{h_a}$$

$k_{I,k}$ = thermal conductivity of the insulation around the k-th pipe

t_k = thickness of the insulation around the k-th pipe

h_a = outside surface heat transfer coefficient around the pipe (if no data are available, it may be approximated by 1.5 Btu/hr, ft^2, °F)

T_{fk} = temperature of the k-th pipe

T_a = air temperature in the conduit

T_G = undisturbed ground temperature surrounding the conduit

K = overall heat transfer factor of the conduit calculated by

$$\frac{1}{K} = \frac{1}{2\pi k_s}\left\{\frac{k_s}{(R-t)h_a} + \frac{k_s}{k_w}\ln\left(\frac{R}{R-t}\right) + \ln\left(\left(\frac{d}{R}\right) + \sqrt{\left(\frac{d}{R}\right)^2 - 1}\right)\right\} \quad (18)$$

k_s = thermal conductivity of earth surrounding the conduit

R = outside radius of the conduit*/

k_w = effective thermal conductivity of the conduit wall

t = thickness of the conduit wall

d = depth of the conduit, distance between the ground surface and the center-line of the conduit

In equation (17) and (18) the thermal resistances across the walls of the metallic pipe and metallic conduit were neglected from the formulas. If the metallic pipe or conduit is uninsulated, terms such as

$\frac{r_k}{k_{Ik}} \ln\left(\frac{r_k}{r_k - t_k}\right)$ or $\frac{k_s}{k_w} \ln\left(\frac{R}{R-t}\right)$ may be dropped. For

the uninsulated non-metallic pipes or conduit, the wall thickness, and its thermal conductivity value should be retained for the values for t_k and t and k_{Ik} and k_w, respectively.

Solving for T_a from equation (16) and rearranging it, the heat transfer from k-th pipe in the conduit can be obtained as follows

$$Q_k = 2\pi r_k U_k (T_{fk} - T_a) \qquad (19)$$

where

$$T_a = \frac{K T_G + \sum_{k=1}^{M} 2\pi r_k U_k T_{fk}}{K + \sum_{k=1}^{M} 2\pi r_k U_k} \qquad (20)$$

*/ If the conduit is square in cross section instead of circular, equivalent radius may be approximated by R = 0.56 W, where W is the external width of the square conduit[1].

If the conduit is ventilated and the ventilation mass flow rate is known to be G, lb/hr, equation (20) may be modified to yield

$$T_a = \frac{\sum_{k=1}^{M} 2\pi r_k U_k T_{fk} + \frac{G C_p}{L} T_v + K T_G}{\sum_{k=1}^{M} 2\pi r_k U_k + \frac{G C_p}{L} + K} \qquad (21)$$

where C_p = specific heat of air

T_v = the ventilation air temperature

L = total vented length of the conduit

Data on ventilation rates for underground conduits is extremely scarce. Possible natural ventilation (without the wind effects) for a vented underground conduit system may be estimated as follows:

The theoretical natural draft, chimney effect, for an underground conduit of d ft depth may be calculated by [9]

$$\Delta P = 0.52 \cdot P_B \cdot d \left(\frac{1}{T_o} - \frac{1}{T_a} \right) \qquad (22)$$

where Δp = draft in inches of water

P_B = atmospheric pressure in psi

d = depth of the conduit, in ft

T_o = absolute temperature of outdoor air, Rankin

T_a = absolute temperature of conduit air, Rankin

Also, the pressure drop of ventilation air flowing within an underground conduit can be calculated by

$$\Delta P = \left(C_i + C_o + \frac{fL}{D}\right) \cdot \left(\frac{V}{4005}\right)^2 \left(\frac{\rho}{0.075}\right) \tag{23}$$

where C_i = entrance pressure loss coefficient

C_o = exist pressure loss coefficient

f = frictional pressure loss coefficient

L = length of the pipe between two consecutive vents along the pipe, ft.

D = hydraulic diameter of the air passage within the conduit, ft.

V = velocity of the air flow, ft/min.

ρ = density of the air within the conduit, lb/ft^3

By noting that the net ventilation flow G (lb/hr) can be expressed by

$$G = 60 \rho V A_c \tag{24}$$

where A_c represents the cross sectional area for air passage within the conduit, and by combining equations (22), (23), and (24), it is possible to write

$$G = 240{,}300 \rho A_c \sqrt{\frac{0.52 P_B d \left(\frac{1}{T_o} - \frac{1}{T_a}\right)}{\left(C_i + C_o + \frac{fL}{D}\right)\left(\frac{\rho}{0.075}\right)}} \tag{25}$$

For evaluation of G it is necessary to have data on C_i, C_o, and f. Moreover, equation (21) requires calculation of the value of T_a, conduit air temperature. Thus, the process of estimating the air temperature in a vented conduit requires iterative procedures which are cumbersome for manual calculation. Several sample calculations were done for this report using a computer program called VENT. The Fortran listing for the VENT program is given in Appendix A, pp. 14-16. Figure 21 shows conduit air temperature plotted against the loss coefficient $C = C_i + C_o$, for the situation as shown in Figure 21.

2.4 Underground Pipe in an Insulated Trench (Figures 7 and 8)

In some installations, pipes are installed in a trench and an insulating material is poured over and around the pipes as illustrated in Figures 7 and 8. The insulating material may or may not be hardened after the insulation is covered by earth. For the case of a single pipe system (Figure 7), a square region insulated in the trench may be treated as an equivalent annular ring of exterior radius 0.56 W and whereby W denotes the exterior width of the insulated region. The formulas and tables discussed in Section 2.1 can then be used to approximate the pipe heat transfer. For the case shown in Figure 8, or the multiple pipe system, the computational method developed in Section 2.2 can be used if the insulated region is assumed to consist of two equivalent annular zones such as shown by the dotted circles in Figure 8. This assumption can be expected to yield erroneous results if the distance(s) between the pipes is very small as compared with the total dimensions of the insulated zone. The precision can be improved, however, in the following manner. Repeat the above calculation on the premise that uninsulated pipes are buried in soil whose thermal properties are equal to those of the insulating material. The actual pipe heat transfer value should lie between the two sets of values thus calculated.

3. Earth Temperature Data

When evaluating underground pipe heat transfer, it is essential that the temperature of the earth surrounding the pipe be known.

It has been customary, when designing a heating pipe system to assume that the earth temperature is equal to the well water temperature for any given region and that the well water temperature is close to the annual average air temperature. This concept appears reasonable as long as the annual average heat transfer from the heat distribution system is what is desired to be estimated. Moreover, well water temperature data, such as that compiled by Collins[5/], are readily available for many localities in the United States. If, however, the maximum heat loss or heat gain of the underground pipes are desired, the well water temperature, which is the annual average earth temperature, is not adequate[6/]. This is because the majority of the underground pipes are installed at the depth less than 10 ft from the surface where the seasonal change of the ambient air temperature affects the heat transfer process.

Penrod's data[7/] shows, for instance, at a depth of 10 ft the temperature of the earth at Lexington, Kentucky is at its minimum in April, approximately 50 °F, and, is at its maximum in October, approximately 65 °F. Thus, it is considered to be impractical to evaluate the maximum heat gain to a chilled water pipe which was buried at the depth of 5' on the basis of the well water temperature, or on the annual average air temperature, which in this particular example is 58 °F.

According to reference [6], the annual earth temperature cycle, T, of a given thermal diffusivity α, may be approximated by a simple harmonic function such as

$$T = A - B e^{-\sqrt{\frac{\pi}{\alpha P}}\, y} \cos\left(\frac{2\pi t}{P} - \phi - \sqrt{\frac{\pi}{\alpha P}}\, y\right) \tag{26}$$

where y = depth

P = period of the annual cycle, 365 days

t = time in days

A = annual average earth temperature ~ well water temperature

B = amplitude of the earth surface temperature cycle

Ø = phase angles of the earth temperature cycle relative to a datum point

Reference [6] lists the values of A, B and Ø for various earth temperature stations in the United States.

The thermal diffusivity appearing in equation (22) is dependent upon the type of soil and its moisture content as shown, for example, in Figure (9).

The average earth temperature, T_G, as used in previous discussions can be evaluated by taking the integrated average of equation (22) to the depth of interest. Since the center-line depth for most underground pipes is at around 10 ft., the integrated average temperature for $0 \leq y \leq 10$ ft. were obtained for many places in the United States where the earth temperature records were maintained. The results of this integration calculation are presented in Tables TG-1 through TG-11, pp. 5-26 for Winter (January 1), Spring (April 1), Summer (July 1) and Fall (October 1), representing the seasonal average values. Also, indicated in these tables are the annual average values (year) as well as the eleven values of thermal diffusivity used for the calculations. Reference [6] shows that the majority of the thermal diffusivity values deduced from the measured earth temperatures in the United States are in the neighborhood of 0.025 ft^2/hr. It is recommended, therefore, that the earth temperature table for $\alpha = 0.025$, TG-5, be used for the first approximation when there is no accurate information available as to the nature of the soil surrounding the pipe.

4. Numerical Solution (Finite Difference Solution) to Study the Effect of Daily Outdoor Air Temperature Cycle Upon the Underground Pipe Heat Transfer

The foregoing analyses of underground pipe heat transfer were made with the assumption that the temperature at the earth's surface was constant with respect to time. Also, the effects of temperature oscillations with respect to the depth due to the diurnal cycle were neglected. The inclusion of a periodic temperature condition at the ground surface above a pipe which is buried at a relatively shallow depth, makes the solution of the heat transfer equations extremely complex. In fact, to the authors' knowledge, no mathematical formula for such a condition has been reported in the literature.

Numerical solutions of the finite difference heat conduction equation were obtained for this report for cases of a single chilled water pipe of diameter 2' buried at the depth of 2' and 3' (from the surface to the center line of the pipe, minimum earth cover 1'). Figure 10 shows the scheme of the finite difference grid used for this analysis. The listing of the Fortran computer program called, PIPE, is given in Appendix A, pp. 1-6. The earth surrounding the pipe was assumed to have a thermal conductivity of 0.75 Btu/hr, ft^2, °F/ft and a thermal diffusivity of 0.025 ft^2/hr. The initial undisturbed earth temperature condition was calculated by an equation similar to (26) for Washington, D. C. summer conditions.

The hottest day temperature cycle for Washington, D. C. reported in reference [6] was used to simulate the ground surface temperature

In order to be reliable, the finite difference calculation requires a large number of grids, or a very fine grid size and very small time steps, all of which increase the number of computations. For example, the sample calculations mentioned above had to be iterated for the time step of 0.02 hr to obtain the minimum grid size of 0.1 ft. The computer time required to perform the heat transfer calculation for a period of more than a few days becomes prohibitively large. However, the computer program developed for this analysis is available for any other condition if a detailed analysis of this type is desired.

The necessarily limited analysis made during this study reveals, however, that it is reasonable to ignore the effect of the diurnal change of the earth surface temperature for a chilled water underground pipe installation at depths of 3' or more.

Consequently the steady state formula developed in the previous chapters can be used to evaluate most ground pipe heat transfer problems as long as the seasonal average earth temperature around the pipes is properly evaluated.

5. Sample Problems and Solutions

This section presents some typical heat transfer problems and solutions to illustrate the use of the formulas and tables developed in Section 2.

oscillation condition.

For this calculation it was assumed that at time zero chilled water at 40 °F was suddenly put through the 2' diameter steel pipe which had been installed at the depth of 2' and had assumed an equilibrium temperature with the surrounding earth. The earth temperature profiles for elapsed times of approximately 12, 18, 24, 48 and 72 hours are shown in Figures (11) through (15), respectively. The numbers and symbols printed on these figures correspond to temperatures as follows: 0, 40 F; 2, 50 F; 4, 60 F; 6, 70 F; 8, 80 F; and *, 90 F. Figure (16) shows the pipe heat gain as a function of time and clearly indicates the oscillating nature of the heat gain for the 2' depth pipe after the effects of initial cooling have been absorbed. The same figure also shows that the heat transfer for the 3' depth pipe is, however, relatively unaffected by the surface temperature oscillation. This figure also shows that the heat gain of the pipe attains eventually a steady-state or steady periodic value, the average of which is closely approximated by the single pipe heat transfer formula introduced in Section 2.1 if the average earth temperature T_G is assumed to be the average air temperature during the period studied.

Problem 1

Calculate the maximum heat gain of a chilled water pipe (water temperature 45 °F) installed in Tucson, Arizona. The earth around this 16" diameter bare steel pipe is sandy clay of 16% moisture content. The minimum earth cover over the pipe is 36" and the pipe runs 2000 ft. Also estimate the possible reduction of heat gain if 4" thick expanded polyurethane insulation was applied around the same pipe.

Solution 1

1. From Figure 2 the thermal conductivity of sandy clay soil of 16% moisture content is k_s = .7 x 12 = 8.4 Btu - in/hr, ft^2, °F.
2. From Figure 9, the thermal diffusivity of the same soil is 0.02 ft^2/hr.
3. The maximum earth temperature for Tucson, Arizona for $\alpha = 0.02$ is T_G = 80 °F (Table TG-4).
4. Table SSHT 25 may be used if $K_s = 8.4$ is approximated by $K_s = 7.5$ and depth of 44" (= 8" + 36") is approximated by 4'. The pipe heat transfer factor K_p for the 16" pipe is 1.585 Btu/hr, ft for a bare pipe and 0.176 for the 4" insulation of $k_I = 0.15$ (expanded polyurethane).
5. The maximum heat gain of the bare pipe is

   Q = KP * (TG - TP) * L =

   1.585 x (80 - 45) x 2000 = 111,000 Btu/hr

   The maximum heat gain of the insulated pipe is

   0.176 x (80 - 45) x 2000 = 12,300 Btu/hr

   The reduction of heat gain by the insulation is 98,700 Btu/hr.

Problem 2 (Figure 17)

Evaluate the heat gain of a double pipe system, one pipe is for the supply of 42 °F chilled water and another is for the return of 57 °F water. These two pipes are bare steel pipes of 24" diameter, and both are installed at the depth of 72" from the ground surface to the center-lines of the pipes and separated by a distance of 4' on center. Assume that the average undisturbed earth temperature around the pipe is 68 °F and the thermal conductivity of the earth is 5 Btu - in/hr, ft^2, °F.

Solution 2

Setting the origin of the coordinate system to be as shown in Figure 17, the constants indicated in Formulas (8) and (11) can be numerically evaluated as follows:

$$a_1 = 0 \quad , \quad a_2 = 4$$

$$d_1 = d_2 = -6$$

$$r_1 = r_2 = 1$$

$$A_{12}^2 = 16, \qquad A_{12}'^2 = 160$$

$$P_{12} = P_{21} = \frac{1}{4\pi\left(\frac{5}{12}\right)} \ln\left(\frac{160}{16}\right) = 0.440$$

$$P_{11} = P_{22} = \frac{1}{4\pi\left(\frac{5}{12}\right)} \ln\left(\frac{12}{1}\right)^2 = 0.949$$

$$T_1 - T_G = 42 - 66 = -34$$

$$T_2 - T_G = 57 - 66 = -9$$

The pipe heat transfer Q_1 and Q_2 can then be solved from the following simultaneous equation (12)

$$0.949\, Q_1 + 0.440\, Q_2 = -34$$
$$0.440\, Q_1 + 0.949\, Q_2 = -9$$

The solutions to these equations are

$$Q_1 = -26.6 \qquad \text{Btu/hr, ft}$$
$$Q_2 = 2.84$$

If these two pipes are separated far away so that each pipe is considered the single pipe system, Q_1 would have been -25.3 Btu/hr, ft and Q_2 = -9.48 Btu/hr ft. It is interesting to observe that the supply chilled water pipe, 42 F, gains more heat by being in the vicinity of the return water pipe, 57 F, and the return water pipe actually loses heat instead of gaining it from the warmer earth.

The total system heat gain for the double pipe system is, however, 23.76 Btu/hr, ft, much less than 34.76 Btu/hr, ft had they been separated far away from each other.

Thus, there is a definite advantage by installing the chilled water lines near each other. The advantage will be offset, however, if the two pipes are too close together because then the supply water would be warmed up too much before it reaches its destination by gaining heat from the return pipe.

Figure 17 also includes a table showing the effect of distance on heat transfer rates between the two pipes for values of 4', 5', 10' and infinity and earth thermal conductivities of 10 and 5 Btu in/hr, ft^2, °F.

6. Temperature Profile Around Underground Pipes

Sometimes more important than the heat transfer rates of an underground pipe system is the temperature in the earth surrounding the pipes. The steady-state temperature of the earth around pipes can be calculated by equation (4) if the heat transfer value Q_i of the same equation had been obtained from equation (22) or by (13) and (14). Using these equations sample calculations were done to illustrate the temperature profile around two chilled water buried pipes as shown schematically in Figure 17, Cases 4 and 6. The temperature profile results for Case 6 are shown in Figures 18 and 20. Figure 18 shows a two-dimensional plot of the isotherms around these pipes. Figure 20 shows the same temperature distribution profile plotted in a three-dimensional manner. Heights on the peaks represent deviations from the average earth temperature. The higher the peak the lower the temperature from the average ground temperature. This type of representation allows a clearer visualization of temperature coupling effect as compared with the conventional two-dimensional representation as shown in Figure 18. The listing of the Fortran computer program for Figure 20 is given in Appendix A, pp. 9-10, and is called PIPLOT. It should be noted that the effect of the chilled water pipes is felt, as illustrated, for a considerable distance away from the pipes. Figure 19 shows a similar plot for Case 4, Figure 17. Similar temperature contours can be obtained for hot water or steam pipes using PIPLOT.

7. Conclusions

The existing engineering methods for evaluating heat transfer to and from underground pipes are believed to be improved in this study and were computerized for rapid calculation in the following respects:

1. Seasonal average earth temperature data (from surface to approximately 10 ft depth) for underground piping distribution systems were developed for selected stations in the United States and for selected values of the thermal diffusivity of earth (type and moisture content of soil). These data will permit the accurate appraisal of the maximum heat gain of chilled water systems as well as the maximum heat loss of the hot water or steam pipes.
2. Calculation methods were developed for approximating heat transfer of multiple pipe systems where several pipes of different temperatures, insulations, and sizes are installed in the same vicinity in such a manner that heat transfer of each pipe is affected by its neighboring pipes.
3. Data were developed for evaluating thermal properties of various soils according to their types and moisture contents.

4. Extensive tables were developed to help engineers approximate the effect of insulation around single underground pipes with respect to their depths, sizes, insulation thicknesses, types of insulation, thermal property of soil and the temperature of the earth surrounding the pipes. From these tables quantitative estimates can be produced to allow decisions to be made as to the necessity for thermal insulation and, if required, the amount needed.

8. References

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[5] Collins, W. D., "Temperature of Water Available for Industrial Use in the United States", U. S. Geological Survey, Water Supply Paper 520-F, 1925.

[6] Kusuda, T., and Achenbach, P. R., "Earth Temperature and Thermal Diffusivity at Selected Stations in the United States", ASHRAE Transactions, 1965, and more detailed data in NBS Report 8972 of the same title.

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[8] Kusuda, T., "Simultaneous Weather Characteristics in Six Selected Cities in the United States", NBS Report 9483, 1968.

[9] ASHRAE Handbook of Fundamentals, p. 406, 1967.

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Table A

Illustrative Thermal Conductivities for Some Pipe Insulation Materials

Insulating Materials	Thermal Conductivity, k_I Btu/hr, ft^2, °F/in.			
	Temperature Level			
	50 °F	100 °F	200 °F	300 °F
Cellular Glass	0.38	0.42	0.48	0.55
Cork Board	0.27	0.29		
Calcium Silicate	0.30	0.32	0.37	0.42
Expanded Polyurethane	0.16	0.18	0.21	
Expanded Polystyrene	0.25	0.26		
Mineral Fiber (Rock, slag, or glass)	0.22	0.24	0.29	
Lightweight Concrete (Perlite, Vermiculite, etc., 30 psf		0.9		
Sawdust		0.48		
Sand		2.1		

Tables SSHT-1 through SSHT-120 Heat Transfer Factors for a
Single Metallic Pipe System

Tables SSHTP-1 through SSHTP-15 Heat Transfer Factors for a
Single Non-Metallic Pipe System

Index for Entering SSHT Tables to Establish

the KP Value for Specific Combinations of k_s, k_I and d

SSHT Table Numbers

k_s = 5.0

d \ k_I	.15	.2	.25	.3	.35	.4	.65	1.0
4	1	4	7	10	13	16	19	22
6	2	5	8	11	14	17	20	23
8	3	6	9	12	15	18	21	24

k_s = 7.5

d \ k_I	.15	.2	.25	.3	.35	.4	.65	1.0
4	25	28	31	34	37	40	43	46
6	26	29	32	35	38	41	44	47
8	27	30	33	36	39	42	45	48

k_s = 10.0

d \ k_I	.15	.2	.25	.3	.35	.4	.65	1.0
4	49	52	55	58	61	64	67	70
6	50	53	56	59	62	65	68	71
8	51	54	57	60	63	66	69	72

k_s = 12.5

d \ k_I	.15	.2	.25	.3	.35	.4	.65	1.0
4	73	76	79	82	85	88	91	94
6	74	77	80	83	86	89	92	95
8	75	78	81	84	87	90	93	96

k_s = 15.0

d \ k_I	.15	.2	.25	.3	.35	.4	.65	1.0
4	97	100	103	106	109	112	115	118
6	98	101	104	107	110	113	116	119
8	99	102	105	108	111	114	117	120

Index for Entering SSHTP Tables for Non-Metallic Pipe to Establish KP Values for Specific Combinations of k_s, k_I and d

	d \ k_I	2.5	5.5	12.0
k_s = 5.0	4	1	1	1
	6	2	2	2
	8	3	3	3
k_s = 7.5	4	4	4	4
	6	5	5	5
	8	6	6	6
k_s = 10.0	4	7	7	7
	6	8	8	8
	8	9	9	9
k_s = 12.0	4	10	10	10
	6	11	11	11
	8	12	12	12
k_s = 15.0	4	13	13	13
	6	14	14	14
	8	15	15	15

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.654	.141	.109	.091	.080	.072	.062	.050
4.50	.698	.167	.129	.108	.094	.084	.071	.057
5.56	.739	.194	.150	.124	.108	.096	.081	.064
6.62	.778	.220	.170	.140	.122	.108	.090	.071
7.62	.812	.243	.188	.155	.134	.119	.099	.077
8.62	.844	.266	.205	.170	.146	.130	.108	.084
9.62	.875	.288	.223	.184	.159	.140	.116	.090
10.75	.909	.312	.242	.200	.172	.152	.126	.097
12.75	.967	.353	.274	.227	.195	.173	.142	.108
14.00	1.002	.378	.295	.244	.210	.185	.152	.116
16.00	1.057	.417	.326	.270	.232	.205	.168	.127
18.00	1.110	.454	.357	.296	.255	.225	.184	.139
20.00	1.163	.491	.387	.322	.277	.244	.200	.150
24.00	1.269	.563	.446	.372	.320	.282	.231	.173
30.00	1.430	.669	.534	.446	.385	.339	.277	.206
36.00	1.599	.774	.621	.520	.449	.396	.323	.240
42.00	1.783	.882	.709	.595	.514	.454	.370	.274

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.138	.107	.090	.079	.071	.061	.050
4.50	.630	.163	.127	.106	.092	.083	.070	.057
5.56	.663	.189	.146	.122	.106	.095	.080	.064
6.62	.694	.213	.165	.137	.119	.106	.089	.070
7.62	.721	.235	.182	.152	.131	.117	.098	.077
8.62	.746	.255	.199	.165	.143	.127	.106	.083
9.62	.771	.276	.215	.179	.155	.137	.114	.089
10.75	.797	.297	.233	.194	.167	.149	.123	.09[illegible]
12.75	.840	.335	.263	.219	.190	.168	.139	.107
14.00	.866	.357	.282	.235	.203	.180	.148	.114
16.00	.907	.391	.310	.259	.224	.199	.164	.125
18.00	.946	.424	.338	.283	.245	.217	.179	.136
20.00	.983	.456	.365	.306	.265	.235	.193	.147
24.00	1.057	.517	.417	.351	.305	.270	.222	.168
30.00	1.163	.604	.491	.416	.362	.322	.265	.200
36.00	1.269	.687	.563	.479	.418	.372	.306	.231
42.00	1.375	.769	.634	.541	.473	.421	.348	.261

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.136	.106	.089	.078	.071	.061	.050
4.50	.589	.160	.125	.105	.092	.082	.070	.056
5.56	.618	.185	.144	.120	.105	.094	.079	.063
6.62	.645	.208	.162	.135	.118	.105	.088	.070
7.62	.668	.229	.179	.149	.129	.115	.097	.076
8.62	.690	.248	.195	.162	.141	.125	.105	.082
9.62	.710	.267	.210	.175	.152	.135	.113	.088
10.75	.732	.288	.227	.190	.164	.146	.121	.094
12.75	.769	.323	.256	.214	.186	.165	.137	.105
14.00	.791	.343	.273	.229	.199	.176	.146	.112
16.00	.824	.375	.300	.252	.219	.194	.161	.123
18.00	.856	.405	.326	.274	.238	.212	.175	.134
20.00	.887	.434	.350	.296	.258	.229	.189	.144
24.00	.946	.489	.398	.338	.295	.262	.217	.165
30.00	1.029	.566	.466	.397	.348	.310	.257	.195
36.00	1.110	.638	.529	.454	.399	.357	.296	.225
42.00	1.190	.707	.591	.509	.449	.402	.334	.254

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.654	.176	.139	.117	.103	.094	.080	.066
4.50	.698	.208	.164	.138	.121	.109	.093	.075
5.56	.739	.240	.188	.158	.138	.124	.105	.084
6.62	.778	.270	.212	.178	.155	.139	.117	.093
7.62	.812	.297	.234	.196	.171	.153	.128	.101
8.62	.844	.323	.255	.214	.186	.166	.139	.109
9.62	.875	.348	.276	.231	.201	.179	.150	.117
10.75	.909	.375	.298	.250	.217	.194	.161	.126
12.75	.967	.422	.337	.283	.246	.219	.182	.141
14.00	1.002	.450	.360	.303	.263	.234	.195	.150
16.00	1.057	.494	.397	.334	.291	.259	.215	.165
18.00	1.110	.536	.432	.365	.318	.283	.234	.179
20.00	1.163	.577	.467	.395	.344	.307	.254	.194
24.00	1.269	.658	.536	.455	.397	.353	.292	.222
30.00	1.430	.775	.637	.542	.474	.423	.350	.265
36.00	1.599	.894	.737	.630	.552	.492	.407	.308
42.00	1.783	1.015	.840	.719	.630	.562	.465	.351

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.172	.136	.115	.102	.092	.079	.065
4.50	.630	.202	.159	.135	.119	.107	.091	.074
5.56	.663	.231	.183	.154	.135	.122	.103	.083
6.62	.694	.259	.206	.173	.152	.136	.115	.092
7.62	.721	.284	.226	.190	.166	.149	.126	.099
8.62	.746	.308	.245	.207	.181	.162	.136	.107
9.62	.771	.330	.264	.223	.195	.174	.146	.115
10.75	.797	.355	.285	.241	.210	.188	.157	.123
12.75	.840	.396	.320	.271	.237	.212	.177	.138
14.00	.866	.421	.341	.289	.253	.226	.189	.146
16.00	.907	.458	.373	.318	.278	.249	.208	.160
18.00	.946	.494	.405	.345	.303	.271	.226	.174
20.00	.983	.529	.435	.372	.327	.292	.244	.188
24.00	1.057	.595	.494	.424	.373	.334	.279	.215
30.00	1.163	.689	.577	.499	.440	.395	.331	.254
36.00	1.269	.779	.658	.571	.505	.455	.381	.292
42.00	1.375	.868	.736	.641	.570	.513	.431	.331

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.168	.134	.114	.101	.091	.079	.065
4.50	.589	.197	.157	.133	.117	.106	.090	.073
5.56	.618	.226	.179	.152	.133	.120	.102	.082
6.62	.645	.252	.201	.170	.149	.134	.114	.091
7.62	.668	.275	.220	.186	.163	.147	.124	.098
8.62	.690	.297	.239	.202	.177	.159	.134	.106
9.62	.710	.319	.257	.218	.191	.171	.144	.113
10.75	.732	.341	.276	.234	.205	.184	.155	.121
12.75	.769	.379	.309	.263	.231	.207	.173	.136
14.00	.791	.402	.329	.280	.246	.221	.185	.144
16.00	.824	.436	.359	.307	.270	.242	.203	.158
18.00	.856	.469	.387	.333	.293	.263	.220	.171
20.00	.887	.500	.415	.357	.315	.283	.237	.184
24.00	.946	.558	.468	.405	.358	.322	.271	.210
30.00	1.029	.640	.542	.472	.420	.379	.319	.247
36.00	1.110	.716	.612	.536	.478	.432	.365	.283
42.00	1.190	.789	.679	.597	.535	.485	.410	.318

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.654	.208	.166	.142	.125	.114	.098	.081
4.50	.698	.244	.195	.165	.146	.132	.113	.092
5.56	.739	.279	.223	.189	.167	.150	.128	.103
6.62	.778	.313	.250	.212	.186	.168	.142	.114
7.62	.812	.342	.275	.233	.204	.184	.155	.124
8.62	.844	.371	.298	.253	.222	.199	.168	.133
9.62	.875	.398	.321	.273	.239	.215	.181	.143
10.75	.909	.428	.347	.295	.258	.232	.195	.153
12.75	.967	.478	.390	.332	.291	.261	.219	.171
14.00	1.002	.508	.416	.355	.311	.279	.234	.182
16.00	1.057	.555	.456	.390	.343	.307	.257	.200
18.00	1.110	.601	.495	.425	.373	.335	.280	.217
20.00	1.163	.645	.534	.459	.404	.362	.303	.235
24.00	1.269	.731	.609	.525	.463	.416	.348	.269
30.00	1.430	.857	.720	.623	.551	.496	.415	.319
36.00	1.599	.984	.831	.721	.639	.575	.482	.370
42.00	1.783	1.116	.945	.822	.729	.657	.550	.422

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.201	.162	.139	.123	.112	.097	.080
4.50	.630	.235	.189	.161	.143	.129	.111	.091
5.56	.663	.268	.216	.184	.162	.147	.125	.102
6.62	.694	.298	.241	.205	.181	.163	.139	.112
7.62	.721	.325	.264	.225	.198	.179	.152	.121
8.62	.746	.351	.285	.244	.215	.193	.164	.130
9.62	.771	.375	.306	.262	.231	.208	.176	.139
10.75	.797	.401	.329	.282	.248	.224	.189	.149
12.75	.840	.445	.367	.315	.279	.251	.212	.167
14.00	.866	.471	.390	.336	.297	.267	.226	.177
16.00	.907	.511	.426	.367	.325	.293	.247	.194
18.00	.946	.549	.460	.398	.353	.318	.268	.210
20.00	.983	.585	.492	.427	.379	.342	.289	.226
24.00	1.057	.655	.555	.484	.431	.390	.330	.257
30.00	1.163	.753	.645	.566	.506	.459	.389	.303
36.00	1.269	.848	.731	.645	.578	.525	.446	.348
42.00	1.375	.940	.815	.722	.649	.591	.503	.393

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.197	.159	.137	.121	.111	.096	.079
4.50	.589	.229	.185	.158	.140	.127	.110	.090
5.56	.618	.260	.211	.180	.159	.144	.124	.100
6.62	.645	.289	.235	.201	.178	.161	.137	.110
7.62	.668	.314	.256	.219	.194	.175	.149	.120
8.62	.690	.337	.277	.237	.210	.189	.161	.129
9.62	.710	.360	.296	.254	.225	.203	.172	.137
10.75	.732	.384	.317	.273	.242	.218	.185	.147
12.75	.769	.424	.353	.305	.270	.244	.207	.164
14.00	.791	.448	.374	.324	.287	.260	.220	.174
16.00	.824	.484	.406	.353	.314	.284	.241	.190
18.00	.856	.517	.437	.381	.339	.307	.261	.205
20.00	.887	.550	.467	.408	.364	.330	.280	.220
24.00	.946	.610	.523	.460	.411	.374	.318	.250
30.00	1.029	.695	.601	.532	.479	.436	.372	.293
36.00	1.110	.774	.675	.601	.542	.495	.425	.335
42.00	1.190	.849	.746	.667	.604	.553	.475	.376

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.654	.236	.191	.164	.146	.133	.116	.096
4.50	.698	.275	.223	.191	.169	.154	.133	.109
5.56	.739	.313	.254	.218	.193	.175	.150	.122
6.62	.778	.349	.284	.243	.215	.194	.166	.134
7.62	.812	.381	.311	.266	.235	.213	.181	.145
8.62	.844	.411	.337	.289	.255	.230	.196	.156
9.62	.875	.440	.362	.310	.274	.248	.210	.167
10.75	.909	.472	.389	.334	.296	.267	.226	.179
12.75	.967	.525	.435	.375	.332	.299	.253	.200
14.00	1.002	.557	.463	.400	.354	.319	.270	.213
16.00	1.057	.606	.507	.439	.389	.351	.297	.233
18.00	1.110	.653	.549	.476	.423	.382	.323	.253
20.00	1.163	.700	.590	.513	.456	.412	.349	.273
24.00	1.269	.790	.671	.585	.521	.472	.399	.312
30.00	1.430	.922	.789	.692	.618	.560	.474	.370
36.00	1.599	1.056	.908	.799	.715	.648	.550	.428
42.00	1.783	1.195	1.030	.908	.814	.739	.627	.488

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.228	.186	.160	.143	.131	.114	.094
4.50	.630	.264	.215	.185	.165	.150	.130	.107
5.56	.663	.299	.245	.211	.187	.170	.146	.119
6.62	.694	.331	.272	.234	.208	.189	.162	.131
7.62	.721	.360	.297	.256	.227	.206	.176	.142
8.62	.746	.386	.320	.276	.245	.222	.190	.153
9.62	.771	.412	.342	.296	.263	.238	.203	.163
10.75	.797	.439	.367	.318	.282	.256	.218	.174
12.75	.840	.485	.407	.354	.316	.286	.244	.194
14.00	.866	.512	.432	.376	.335	.304	.259	.206
16.00	.907	.553	.469	.410	.366	.333	.283	.225
18.00	.946	.593	.505	.443	.396	.360	.307	.243
20.00	.983	.630	.540	.475	.425	.387	.330	.261
24.00	1.057	.702	.606	.535	.481	.439	.375	.297
30.00	1.163	.803	.700	.622	.562	.513	.440	.349
36.00	1.269	.900	.790	.706	.639	.585	.504	.399
42.00	1.375	.995	.878	.788	.715	.656	.566	.449

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.222	.182	.157	.141	.129	.112	.093
4.50	.589	.256	.210	.182	.162	.148	.128	.106
5.56	.618	.289	.238	.206	.183	.167	.144	.118
6.62	.645	.320	.264	.228	.203	.185	.159	.129
7.62	.668	.346	.287	.249	.222	.201	.173	.140
8.62	.690	.371	.309	.268	.239	.217	.186	.150
9.62	.710	.394	.330	.287	.256	.232	.199	.160
10.75	.732	.419	.352	.307	.274	.249	.213	.171
12.75	.769	.460	.390	.341	.305	.277	.237	.190
14.00	.791	.485	.412	.361	.323	.294	.252	.201
16.00	.824	.521	.446	.392	.352	.321	.275	.219
18.00	.856	.556	.478	.422	.380	.346	.297	.237
20.00	.887	.589	.509	.451	.406	.371	.318	.254
24.00	.946	.651	.568	.505	.457	.418	.360	.287
30.00	1.029	.737	.649	.581	.528	.485	.419	.335
36.00	1.110	.817	.725	.653	.596	.549	.476	.382
42.00	1.190	.894	.798	.722	.661	.610	.531	.427

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.654	.262	.214	.185	.166	.152	.132	.110
4.50	.698	.303	.248	.215	.191	.174	.151	.125
5.56	.739	.344	.282	.244	.217	.197	.170	.139
6.62	.778	.381	.314	.272	.242	.219	.189	.153
7.62	.812	.414	.343	.297	.264	.239	.205	.166
8.62	.844	.446	.371	.321	.285	.259	.222	.178
9.62	.875	.476	.397	.344	.306	.278	.238	.191
10.75	.909	.509	.426	.370	.329	.299	.255	.204
12.75	.967	.564	.475	.414	.369	.335	.285	.228
14.00	1.002	.597	.504	.440	.393	.356	.304	.242
16.00	1.057	.648	.550	.481	.430	.391	.333	.265
18.00	1.110	.697	.595	.522	.467	.424	.362	.287
20.00	1.163	.745	.638	.561	.503	.457	.390	.309
24.00	1.269	.838	.722	.638	.573	.522	.446	.352
30.00	1.430	.975	.847	.751	.677	.617	.528	.417
36.00	1.599	1.114	.972	.865	.781	.713	.611	.482
42.00	1.783	1.258	1.102	.982	.888	.812	.696	.549

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.251	.207	.180	.162	.148	.130	.108
4.50	.630	.289	.239	.208	.186	.170	.148	.122
5.56	.663	.326	.271	.235	.210	.192	.166	.136
6.62	.694	.360	.300	.261	.233	.212	.183	.150
7.62	.721	.389	.326	.284	.253	.231	.199	.162
8.62	.746	.417	.350	.306	.273	.249	.214	.174
9.62	.771	.443	.374	.327	.292	.266	.229	.185
10.75	.797	.471	.399	.350	.313	.285	.245	.198
12.75	.840	.518	.442	.388	.349	.318	.273	.220
14.00	.866	.546	.468	.412	.370	.337	.290	.233
16.00	.907	.588	.506	.448	.403	.368	.317	.254
18.00	.946	.628	.544	.482	.435	.397	.342	.274
20.00	.983	.667	.580	.515	.465	.426	.367	.294
24.00	1.057	.740	.648	.579	.525	.481	.416	.333
30.00	1.163	.843	.745	.669	.610	.561	.486	.390
36.00	1.269	.942	.838	.757	.691	.638	.555	.446
42.00	1.375	1.039	.930	.843	.772	.713	.622	.501

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.245	.203	.177	.159	.146	.128	.107
4.50	.589	.281	.233	.203	.182	.167	.145	.121
5.56	.618	.315	.263	.229	.205	.188	.163	.134
6.62	.645	.346	.290	.253	.227	.207	.180	.147
7.62	.668	.373	.314	.275	.247	.225	.195	.159
8.62	.690	.399	.337	.296	.265	.242	.209	.170
9.62	.710	.423	.359	.315	.283	.259	.223	.181
10.75	.732	.448	.382	.337	.303	.277	.239	.193
12.75	.769	.490	.422	.372	.336	.307	.265	.214
14.00	.791	.515	.445	.394	.355	.325	.281	.227
16.00	.824	.552	.480	.426	.386	.354	.306	.247
18.00	.856	.587	.513	.457	.415	.381	.330	.266
20.00	.887	.621	.544	.487	.443	.407	.353	.285
24.00	.946	.683	.604	.544	.496	.457	.397	.321
30.00	1.029	.770	.687	.623	.570	.528	.461	.374
36.00	1.110	.851	.765	.697	.641	.595	.522	.424
42.00	1.190	.929	.840	.768	.709	.659	.580	.473

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	[illegible]
3.50	.654	.285	.235	.205	.184	.169	.148	.1[illegible]
4.50	.698	.328	.272	.237	.212	.194	.169	.1[illegible]
5.56	.739	.370	.308	.268	.240	.219	.190	.156
6.62	.778	.409	.342	.298	.266	.243	.210	.172
7.62	.812	.444	.372	.324	.290	.265	.228	.186
8.62	.844	.476	.401	.350	.313	.286	.246	.2[illegible]
9.62	.875	.507	.429	.375	.336	.306	.263	.21[illegible]
10.75	.909	.541	.459	.402	.360	.328	.282	[illegible]
12.75	.967	.597	.510	.448	.402	.367	.315	.25[illegible]
14.00	1.002	.631	.541	.476	.428	.390	.336	.2[illegible]
16.00	1.057	.683	.588	.519	.468	.427	.367	.[illegible]
18.00	1.110	.734	.634	.562	.506	.463	.398	.[illegible]
20.00	1.163	.783	.679	.603	.544	.498	.429	.3[illegible]
24.00	1.269	.878	.767	.684	.619	.567	.489	.3[illegible]
30.00	1.430	1.019	.896	.802	.728	.669	.578	.4[illegible]
36.00	1.599	1.161	1.027	.922	.839	.771	.667	.[illegible]
42.00	1.783	1.311	1.162	1.046	.953	.877	.759	.[illegible]

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.272	.227	.199	.179	.165	.145	.122
4.50	.630	.312	.261	.228	.205	.188	.165	.137
5.56	.663	.350	.294	.257	.231	.212	.184	.153
6.62	.694	.385	.325	.284	.256	.234	.203	.167
7.62	.721	.415	.352	.309	.278	.254	.220	.181
8.62	.746	.443	.377	.332	.299	.273	.237	.194
9.62	.771	.470	.402	.354	.319	.292	.253	.206
10.75	.797	.499	.428	.378	.341	.312	.270	.220
12.75	.840	.546	.472	.419	.378	.347	.300	.244
14.00	.866	.575	.498	.443	.401	.368	.319	.258
16.00	.907	.617	.538	.480	.435	.400	.347	.281
18.00	.946	.658	.577	.516	.469	.431	.374	.303
20.00	.983	.697	.613	.550	.501	.461	.401	.325
24.00	1.057	.771	.683	.616	.563	.519	.453	.367
30.00	1.163	.875	.783	.710	.651	.603	.528	.429
36.00	1.269	.976	.878	.800	.737	.684	.600	.489
42.00	1.375	1.075	.972	.889	.820	.763	.671	.548

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.265	.222	.194	.176	.162	.142	.120
4.50	.589	.302	.254	.223	.201	.184	.162	.135
5.56	.618	.337	.285	.250	.226	.207	.181	.150
6.62	.645	.369	.313	.276	.249	.228	.199	.164
7.62	.668	.397	.339	.299	.269	.247	.215	.177
8.62	.690	.423	.362	.320	.289	.265	.231	.189
9.62	.710	.447	.385	.341	.308	.283	.246	.202
10.75	.732	.473	.409	.363	.329	.302	.263	.215
12.75	.769	.515	.449	.400	.363	.334	.291	.237
14.00	.791	.540	.472	.422	.384	.353	.308	.251
16.00	.824	.578	.508	.456	.415	.383	.334	.272
18.00	.856	.613	.542	.488	.446	.411	.359	.293
20.00	.887	.647	.574	.519	.475	.439	.384	.313
24.00	.946	.710	.635	.577	.530	.491	.431	.353
30.00	1.029	.797	.720	.658	.607	.565	.498	.409
36.00	1.110	.879	.799	.734	.680	.634	.562	.463
42.00	1.190	.957	.875	.807	.750	.701	.623	.515

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.654	.372	.321	.288	.263	.245	.219	.188
4.50	.698	.421	.365	.327	.299	.278	.247	.210
5.56	.739	.468	.407	.365	.334	.310	.276	.233
6.62	.778	.510	.446	.401	.367	.341	.302	.255
7.62	.812	.547	.481	.433	.397	.368	.326	.274
8.62	.844	.582	.514	.463	.425	.395	.350	.293
9.62	.875	.616	.545	.493	.452	.420	.372	.312
10.75	.909	.651	.579	.524	.482	.448	.397	.332
12.75	.967	.711	.636	.578	.532	.496	.439	.367
14.00	1.002	.747	.670	.610	.563	.524	.465	.388
16.00	1.057	.802	.722	.660	.610	.569	.505	.422
18.00	1.110	.855	.773	.708	.656	.612	.544	.454
20.00	1.163	.907	.823	.755	.700	.655	.583	.487
24.00	1.269	1.008	.919	.847	.788	.738	.659	.550
30.00	1.430	1.159	1.063	.984	.918	.861	.771	.645
36.00	1.599	1.313	1.209	1.122	1.049	.986	.885	.742
42.00	1.783	1.476	1.363	1.267	1.187	1.117	1.003	.841

SSHT= 20

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.352	.306	.275	.253	.236	.212	.182
4.50	.630	.396	.346	.311	.286	.266	.238	.204
5.56	.663	.436	.383	.346	.318	.296	.264	.225
6.62	.694	.473	.417	.378	.348	.324	.289	.245
7.62	.721	.505	.447	.406	.374	.348	.311	.263
8.62	.746	.534	.476	.432	.399	.372	.332	.280
9.62	.771	.562	.502	.458	.423	.394	.352	.297
10.75	.797	.591	.531	.485	.448	.419	.374	.315
12.75	.840	.640	.578	.530	.491	.460	.411	.347
14.00	.866	.669	.606	.557	.517	.484	.433	.366
16.00	.907	.712	.649	.598	.556	.522	.468	.395
18.00	.946	.754	.689	.637	.594	.558	.501	.424
20.00	.983	.794	.728	.675	.630	.593	.533	.451
24.00	1.057	.869	.802	.747	.700	.660	.595	.505
30.00	1.163	.976	.907	.849	.799	.755	.684	.583
36.00	1.269	1.080	1.008	.947	.894	.847	.770	.659
42.00	1.375	1.183	1.109	1.044	.988	.938	.855	.733

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.339	.296	.267	.246	.230	.207	.179
4.50	.589	.379	.333	.301	.277	.259	.232	.199
5.56	.618	.416	.368	.333	.307	.287	.257	.220
6.62	.645	.449	.399	.363	.335	.313	.280	.239
7.62	.668	.478	.426	.388	.359	.336	.300	.256
8.62	.690	.504	.452	.413	.382	.357	.320	.272
9.62	.710	.529	.476	.436	.404	.378	.339	.288
10.75	.732	.555	.501	.460	.427	.400	.359	.305
12.75	.769	.598	.543	.501	.466	.438	.393	.334
14.00	.791	.623	.568	.525	.489	.460	.413	.351
16.00	.824	.660	.605	.561	.524	.493	.445	.378
18.00	.856	.696	.640	.595	.557	.526	.475	.404
20.00	.887	.729	.674	.628	.589	.556	.503	.430
24.00	.946	.792	.736	.689	.649	.615	.558	.478
30.00	1.029	.880	.823	.775	.733	.696	.635	.547
36.00	1.110	.963	.905	.855	.812	.773	.708	.612
42.00	1.190	1.043	.984	.933	.887	.847	.779	.676

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.654	.450	.404	.371	.347	.327	.299	.263
4.50	.698	.501	.452	.416	.388	.367	.334	.293
5.56	.739	.549	.497	.459	.429	.405	.369	.322
6.62	.778	.592	.539	.498	.466	.441	.401	.349
7.62	.812	.630	.575	.533	.500	.472	.430	.374
8.62	.844	.665	.610	.566	.531	.503	.458	.398
9.62	.875	.699	.643	.598	.562	.532	.484	.421
10.75	.909	.735	.678	.632	.595	.563	.514	.446
12.75	.967	.796	.737	.690	.650	.617	.563	.490
14.00	1.002	.832	.773	.724	.684	.649	.593	.516
16.00	1.057	.888	.828	.778	.735	.699	.640	.557
18.00	1.110	.943	.881	.829	.785	.748	.685	.597
20.00	1.163	.996	.933	.880	.835	.795	.730	.637
24.00	1.269	1.100	1.035	.979	.931	.888	.818	.714
30.00	1.430	1.255	1.186	1.127	1.074	1.027	.948	.831
36.00	1.599	1.416	1.343	1.278	1.220	1.169	1.082	.950
42.00	1.783	1.588	1.508	1.438	1.375	1.319	1.223	1.075

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.594	.421	.380	.351	.329	.312	.286	.253
4.50	.630	.465	.422	.391	.366	.347	.318	.280
5.56	.663	.506	.462	.428	.402	.381	.349	.306
6.62	.694	.542	.497	.463	.435	.412	.377	.331
7.62	.721	.574	.528	.492	.464	.440	.403	.353
8.62	.746	.603	.557	.520	.491	.466	.427	.375
9.62	.771	.631	.584	.547	.516	.491	.450	.395
10.75	.797	.660	.613	.575	.544	.518	.475	.417
12.75	.840	.708	.661	.623	.590	.562	.517	.454
14.00	.866	.736	.689	.650	.617	.589	.542	.477
16.00	.907	.780	.733	.693	.659	.630	.581	.511
18.00	.946	.821	.774	.733	.699	.668	.618	.545
20.00	.983	.860	.813	.772	.737	.706	.654	.577
24.00	1.057	.936	.888	.847	.810	.778	.723	.640
30.00	1.163	1.044	.996	.953	.914	.880	.821	.730
36.00	1.269	1.149	1.100	1.055	1.015	.979	.916	.818
42.00	1.375	1.254	1.203	1.157	1.115	1.077	1.010	.905

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.557	.402	.365	.338	.317	.301	.277	.246
4.50	.589	.442	.403	.375	.352	.334	.307	.272
5.56	.618	.479	.439	.409	.385	.366	.336	.296
6.62	.645	.512	.471	.440	.415	.394	.362	.320
7.62	.668	.540	.499	.467	.441	.420	.386	.340
8.62	.690	.566	.525	.492	.466	.443	.408	.360
9.62	.710	.590	.549	.516	.489	.466	.429	.378
10.75	.732	.615	.574	.541	.513	.490	.451	.398
12.75	.769	.657	.616	.582	.554	.529	.489	.432
14.00	.791	.681	.641	.607	.578	.553	.512	.453
16.00	.824	.718	.678	.644	.614	.589	.546	.484
18.00	.856	.753	.713	.678	.648	.622	.578	.514
20.00	.887	.786	.746	.711	.681	.655	.609	.542
24.00	.946	.848	.808	.774	.743	.715	.668	.597
30.00	1.029	.935	.896	.861	.829	.801	.751	.674
36.00	1.110	1.017	.978	.943	.910	.881	.829	.748
42.00	1.190	1.097	1.058	1.022	.989	.959	.905	.819

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.150	.114	.095	.083	.074	.063	.051
4.50	1.046	.180	.136	.112	.097	.087	.073	.058
5.56	1.109	.211	.159	.131	.112	.100	.083	.066
6.62	1.167	.241	.181	.148	.127	.112	.093	.073
7.62	1.218	.268	.202	.164	.141	.124	.102	.079
8.62	1.266	.295	.222	.180	.154	.136	.111	.086
9.62	1.313	.321	.241	.196	.167	.147	.120	.092
10.75	1.364	.349	.263	.214	.182	.160	.130	.099
12.75	1.450	.399	.301	.244	.208	.182	.148	.112
14.00	1.503	.429	.324	.263	.223	.196	.159	.119
16.00	1.585	.476	.360	.293	.249	.217	.176	.131
18.00	1.665	.522	.396	.322	.273	.239	.193	.143
20.00	1.745	.568	.432	.351	.298	.260	.210	.155
24.00	1.903	.656	.502	.409	.347	.302	.243	.179
30.00	2.145	.787	.605	.494	.419	.365	.293	.215
36.00	2.399	.917	.707	.578	.491	.428	.343	.250
42.00	2.675	1.049	.811	.664	.564	.491	.393	.286

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.890	.148	.113	.094	.082	.074	.063	.051
4.50	.944	.177	.135	.111	.096	.086	.072	.058
5.56	.995	.207	.157	.129	.111	.099	.082	.065
6.62	1.041	.235	.178	.146	.125	.111	.092	.072
7.62	1.082	.261	.197	.162	.139	.122	.101	.079
8.62	1.120	.286	.217	.177	.152	.134	.110	.085
9.62	1.156	.310	.235	.192	.164	.145	.119	.091
10.75	1.195	.337	.256	.209	.179	.157	.129	.098
12.75	1.260	.383	.292	.238	.203	.178	.146	.110
14.00	1.300	.411	.313	.256	.218	.192	.156	.118
16.00	1.360	.454	.347	.284	.242	.212	.173	.130
18.00	1.418	.495	.380	.312	.266	.233	.189	.141
20.00	1.475	.536	.413	.339	.289	.253	.205	.153
24.00	1.585	.614	.476	.392	.334	.293	.237	.176
30.00	1.745	.726	.568	.469	.401	.351	.284	.210
36.00	1.903	.834	.656	.544	.466	.409	.330	.243
42.00	2.063	.939	.744	.618	.530	.465	.376	.276

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE OD(INCHES)	INSULATION THICKNESS (INCHES) .000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.146	.112	.093	.082	.073	.062	.051
4.50	.883	.175	.133	.110	.096	.085	.072	.058
5.56	.927	.204	.155	.128	.110	.098	.082	.065
6.62	.967	.231	.176	.144	.124	.110	.092	.072
7.62	1.002	.256	.195	.160	.137	.121	.101	.078
8.62	1.035	.280	.213	.175	.150	.132	.109	.084
9.62	1.065	.304	.231	.190	.162	.143	.118	.091
10.75	1.098	.329	.251	.206	.176	.155	.127	.097
12.75	1.154	.372	.285	.234	.200	.176	.144	.109
14.00	1.186	.399	.306	.251	.215	.189	.154	.117
16.00	1.236	.439	.339	.278	.238	.209	.170	.128
18.00	1.284	.478	.370	.305	.261	.229	.186	.140
20.00	1.330	.515	.401	.330	.283	.248	.202	.151
24.00	1.418	.587	.460	.380	.326	.287	.233	.174
30.00	1.544	.688	.544	.453	.389	.342	.278	.206
36.00	1.665	.784	.625	.522	.450	.396	.322	.239
42.00	1.784	.877	.704	.590	.509	.449	.366	.271

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.192	.148	.123	.108	.097	.083	.067
4.50	1.046	.229	.175	.146	.127	.113	.096	.077
5.56	1.109	.266	.204	.168	.146	.130	.109	.086
6.62	1.167	.302	.231	.191	.164	.146	.122	.096
7.62	1.218	.335	.256	.211	.182	.161	.134	.104
8.62	1.266	.367	.281	.231	.198	.176	.145	.112
9.62	1.313	.397	.305	.251	.215	.190	.157	.121
10.75	1.364	.431	.331	.272	.234	.206	.169	.130
12.75	1.450	.489	.377	.310	.266	.234	.192	.146
14.00	1.503	.525	.405	.333	.285	.251	.206	.156
16.00	1.585	.580	.449	.370	.317	.279	.227	.172
18.00	1.665	.633	.492	.406	.348	.306	.249	.187
20.00	1.745	.686	.534	.441	.378	.332	.270	.203
24.00	1.903	.788	.618	.511	.438	.385	.313	.233
30.00	2.145	.939	.740	.614	.527	.463	.376	.279
36.00	2.399	1.089	.863	.718	.616	.542	.439	.324
42.00	2.675	1.242	.987	.822	.706	.621	.503	.370

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.890	.188	.145	.122	.107	.096	.082	.067
4.50	.944	.223	.172	.143	.125	.112	.095	.076
5.56	.995	.259	.199	.166	.144	.128	.108	.086
6.62	1.041	.293	.226	.187	.162	.144	.120	.095
7.62	1.082	.324	.249	.206	.178	.158	.132	.103
8.62	1.120	.353	.273	.226	.194	.172	.143	.111
9.62	1.156	.382	.295	.244	.210	.186	.154	.119
10.75	1.195	.413	.320	.265	.228	.202	.166	.128
12.75	1.260	.466	.363	.300	.259	.228	.188	.144
14.00	1.300	.497	.389	.322	.277	.245	.201	.153
16.00	1.360	.547	.429	.356	.307	.271	.222	.168
18.00	1.418	.594	.468	.389	.335	.296	.243	.183
20.00	1.475	.640	.506	.422	.363	.321	.263	.198
24.00	1.585	.727	.580	.485	.419	.370	.303	.227
30.00	1.745	.853	.686	.576	.499	.441	.361	.270
36.00	1.903	.973	.788	.665	.577	.511	.419	.313
42.00	2.063	1.091	.889	.752	.654	.580	.476	.355

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.185	.144	.121	.106	.095	.082	.067
4.50	.883	.220	.170	.142	.124	.111	.094	.076
5.56	.927	.254	.197	.164	.142	.127	.107	.085
6.62	.967	.287	.222	.184	.160	.142	.119	.094
7.62	1.002	.316	.245	.203	.176	.156	.130	.102
8.62	1.035	.344	.267	.222	.192	.170	.142	.110
9.62	1.065	.371	.289	.240	.207	.184	.152	.118
10.75	1.098	.401	.313	.260	.224	.199	.164	.127
12.75	1.154	.450	.353	.294	.254	.225	.185	.142
14.00	1.186	.480	.378	.315	.272	.241	.198	.152
16.00	1.236	.525	.416	.347	.300	.265	.218	.166
18.00	1.284	.569	.452	.378	.327	.290	.238	.181
20.00	1.330	.611	.488	.409	.354	.313	.258	.195
24.00	1.418	.690	.556	.468	.406	.360	.296	.224
30.00	1.544	.802	.652	.552	.481	.427	.352	.265
36.00	1.665	.907	.744	.633	.553	.492	.406	.306
42.00	1.784	1.008	.832	.712	.623	.555	.459	.346

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.229	.179	.150	.132	.119	.102	.083
4.50	1.046	.272	.212	.177	.154	.139	.118	.095
5.56	1.109	.316	.245	.204	.177	.159	.134	.107
6.62	1.167	.357	.277	.230	.200	.178	.149	.118
7.62	1.218	.394	.306	.254	.220	.196	.163	.128
8.62	1.266	.429	.334	.278	.240	.213	.177	.138
9.62	1.313	.464	.362	.301	.260	.230	.191	.148
10.75	1.364	.502	.392	.326	.281	.250	.207	.160
12.75	1.450	.567	.445	.370	.319	.283	.233	.179
14.00	1.503	.606	.477	.397	.343	.303	.250	.191
16.00	1.585	.667	.527	.439	.379	.335	.276	.210
18.00	1.665	.726	.575	.480	.415	.367	.302	.229
20.00	1.745	.783	.623	.521	.451	.399	.327	.248
24.00	1.903	.896	.717	.602	.521	.461	.378	.285
30.00	2.145	1.062	.856	.720	.624	.553	.453	.340
36.00	2.399	1.227	.994	.839	.728	.645	.528	.395
42.00	2.675	1.397	1.135	.959	.833	.738	.604	.450

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.890	.224	.176	.148	.130	.118	.101	.083
4.50	.944	.265	.207	.174	.152	.137	.116	.094
5.56	.995	.306	.239	.200	.174	.156	.132	.105
6.62	1.041	.344	.269	.225	.196	.175	.147	.116
7.62	1.082	.378	.296	.248	.215	.192	.161	.127
8.62	1.120	.411	.323	.270	.234	.209	.174	.136
9.62	1.156	.443	.349	.291	.253	.225	.188	.146
10.75	1.195	.477	.377	.315	.273	.243	.202	.157
12.75	1.260	.535	.425	.356	.309	.275	.228	.176
14.00	1.300	.570	.454	.381	.331	.294	.244	.187
16.00	1.360	.623	.499	.420	.365	.324	.268	.205
18.00	1.418	.674	.543	.457	.398	.354	.292	.223
20.00	1.475	.724	.585	.494	.430	.382	.316	.241
24.00	1.585	.818	.667	.565	.493	.439	.363	.276
30.00	1.745	.953	.783	.668	.585	.521	.432	.327
36.00	1.903	1.082	.896	.768	.674	.602	.499	.378
42.00	2.063	1.208	1.007	.866	.761	.681	.565	.428

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.221	.173	.147	.129	.117	.100	.082
4.50	.883	.260	.204	.172	.150	.135	.115	.093
5.56	.927	.299	.235	.197	.172	.154	.131	.105
6.62	.967	.335	.264	.221	.193	.173	.145	.115
7.62	1.002	.368	.290	.243	.212	.189	.159	.125
8.62	1.035	.399	.315	.265	.230	.206	.172	.135
9.62	1.065	.429	.340	.285	.248	.221	.185	.145
10.75	1.098	.461	.367	.308	.268	.239	.199	.155
12.75	1.154	.515	.412	.347	.302	.269	.224	.173
14.00	1.186	.547	.439	.371	.323	.288	.239	.185
16.00	1.236	.596	.481	.407	.355	.316	.263	.202
18.00	1.284	.642	.522	.442	.386	.344	.286	.220
20.00	1.330	.687	.561	.477	.417	.372	.309	.237
24.00	1.418	.772	.635	.543	.476	.425	.354	.270
30.00	1.544	.890	.740	.636	.560	.502	.418	.319
36.00	1.665	1.000	.839	.726	.641	.575	.480	.367
42.00	1.784	1.107	.935	.812	.719	.647	.542	.414

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.264	.208	.176	.155	.140	.121	.099
4.50	1.046	.312	.245	.207	.181	.163	.139	.112
5.56	1.109	.360	.283	.237	.207	.186	.158	.126
6.62	1.167	.405	.319	.267	.233	.208	.176	.139
7.62	1.218	.446	.351	.294	.256	.229	.192	.152
8.62	1.266	.485	.383	.321	.279	.249	.208	.164
9.62	1.313	.522	.413	.347	.301	.269	.224	.175
10.75	1.364	.563	.447	.375	.326	.290	.242	.188
12.75	1.450	.633	.505	.424	.369	.328	.273	.211
14.00	1.503	.675	.540	.454	.395	.352	.292	.225
16.00	1.585	.741	.595	.502	.436	.388	.322	.247
18.00	1.665	.804	.649	.548	.477	.424	.351	.269
20.00	1.745	.866	.701	.593	.517	.460	.381	.291
24.00	1.903	.986	.804	.682	.595	.530	.439	.334
30.00	2.145	1.163	.955	.814	.711	.634	.524	.397
36.00	2.399	1.340	1.106	.945	.827	.738	.610	.462
42.00	2.675	1.523	1.260	1.079	.946	.844	.698	.526

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.890	.257	.204	.173	.153	.138	.119	.098
4.50	.944	.302	.239	.202	.178	.160	.137	.111
5.56	.995	.347	.275	.232	.203	.183	.155	.125
6.62	1.041	.389	.308	.260	.227	.204	.172	.137
7.62	1.082	.426	.339	.286	.250	.224	.188	.149
8.62	1.120	.461	.368	.310	.271	.243	.204	.161
9.62	1.156	.495	.396	.335	.292	.261	.219	.172
10.75	1.195	.532	.427	.361	.315	.282	.236	.185
12.75	1.260	.594	.480	.406	.355	.317	.265	.206
14.00	1.300	.631	.511	.434	.379	.339	.283	.220
16.00	1.360	.687	.560	.477	.417	.373	.311	.241
18.00	1.418	.741	.607	.518	.454	.406	.339	.261
20.00	1.475	.794	.653	.558	.490	.438	.366	.282
24.00	1.585	.893	.741	.636	.560	.502	.419	.322
30.00	1.745	1.034	.866	.748	.660	.593	.496	.381
36.00	1.903	1.169	.986	.856	.758	.682	.572	.439
42.00	2.063	1.301	1.104	.962	.854	.770	.646	.496

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.253	.201	.171	.151	.137	.118	.097
4.50	.883	.296	.235	.199	.175	.158	.136	.110
5.56	.927	.338	.269	.228	.200	.180	.153	.123
6.62	.967	.378	.302	.255	.224	.201	.170	.136
7.62	1.002	.413	.331	.280	.245	.220	.186	.148
8.62	1.035	.446	.358	.303	.266	.238	.201	.159
9.62	1.065	.478	.385	.327	.286	.256	.216	.170
10.75	1.098	.512	.414	.352	.308	.276	.232	.182
12.75	1.154	.569	.463	.395	.346	.310	.260	.203
14.00	1.186	.603	.493	.420	.369	.331	.277	.216
16.00	1.236	.654	.538	.460	.405	.363	.304	.237
18.00	1.284	.703	.581	.499	.439	.394	.331	.256
20.00	1.330	.750	.623	.536	.473	.425	.356	.276
24.00	1.418	.837	.702	.607	.537	.484	.406	.314
30.00	1.544	.960	.813	.708	.629	.568	.478	.370
36.00	1.665	1.074	.918	.804	.717	.649	.548	.424
42.00	1.784	1.184	1.019	.896	.802	.727	.616	.477

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.297	.236	.201	.177	.161	.139	.114
4.50	1.046	.349	.277	.235	.207	.186	.160	.130
5.56	1.109	.400	.318	.269	.236	.212	.181	.145
6.62	1.167	.449	.357	.302	.264	.237	.201	.160
7.62	1.218	.492	.393	.332	.290	.260	.220	.174
8.62	1.266	.534	.427	.361	.316	.283	.238	.188
9.62	1.313	.574	.460	.389	.340	.305	.256	.201
10.75	1.364	.617	.497	.420	.368	.329	.276	.216
12.75	1.450	.691	.559	.474	.415	.371	.310	.242
14.00	1.503	.735	.597	.507	.444	.397	.332	.258
16.00	1.585	.804	.656	.558	.489	.437	.365	.283
18.00	1.665	.871	.713	.609	.534	.477	.398	.307
20.00	1.745	.936	.770	.658	.577	.517	.431	.332
24.00	1.903	1.063	.879	.754	.663	.594	.495	.380
30.00	2.145	1.248	1.041	.897	.790	.708	.591	.453
36.00	2.399	1.435	1.203	1.039	.917	.823	.687	.525
42.00	2.675	1.627	1.369	1.185	1.047	.940	.785	.598

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT, [illegible]

THERMAL CONDUCTIVITY OF INSULATION KI= .350 BTU/HR,S[illegible]

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)						
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.[illegible]
3.50	.890	.288	.230	.197	.174	.158	[illegible]
4.50	.944	.336	.269	.229	.202	.183	[illegible]
5.56	.995	.384	.308	.262	.230	.208	[illegible]
6.62	1.041	.429	.344	.293	.257	.232	[illegible]
7.62	1.082	.468	.377	.321	.282	.254	[illegible]
8.62	1.120	.506	.409	.348	.306	[illegible]	[illegible]
9.62	1.156	.541	.439	.374	.329	.295	[illegible]
10.75	1.195	.580	.472	.403	.354	.318	[illegible]
12.75	1.260	.645	.528	.452	.398	.357	[illegible]
14.00	1.300	.683	.562	.482	.424	.381	[illegible]
16.00	1.360	.742	.614	.528	.465	.418	[illegible]
18.00	1.418	.798	.664	.572	.505	.454	[illegible]
20.00	1.475	.852	.712	.615	.544	[illegible]	[illegible]
24.00	1.585	.955	.804	.698	.619	[illegible]	[illegible]
30.00	1.745	1.101	.936	.817	.728	[illegible]	[illegible]
36.00	1.903	1.240	1.063	.932	.833	[illegible]	[illegible]
42.00	2.063	1.377	1.187	1.045	.936	[illegible]	[illegible]

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.282	.226	.194	.172	.156	.135	.112
4.50	.883	.328	.264	.225	.199	.181	.155	.127
5.56	.927	.374	.301	.257	.227	.205	.175	.142
6.62	.967	.416	.336	.286	.253	.228	.194	.156
7.62	1.002	.453	.367	.313	.276	.249	.211	.169
8.62	1.035	.487	.397	.339	.299	.269	.228	.182
9.62	1.065	.521	.426	.364	.321	.289	.245	.194
10.75	1.098	.556	.456	.391	.345	.311	.263	.208
12.75	1.154	.615	.509	.437	.386	.348	.294	.232
14.00	1.186	.650	.540	.465	.411	.371	.313	.246
16.00	1.236	.704	.587	.508	.450	.406	.343	.269
18.00	1.284	.754	.633	.549	.487	.440	.372	.291
20.00	1.330	.802	.676	.588	.523	.473	.400	.313
24.00	1.418	.892	.759	.664	.592	.536	.454	.355
30.00	1.544	1.017	.875	.770	.690	.627	.533	.417
36.00	1.665	1.134	.984	.871	.783	.713	.609	.477
42.00	1.784	1.247	1.088	.968	.874	.797	.682	.536

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	[illegible]
3.50	.981	.327	.262	.224	.199	.181	.156	[illegible]
4.50	1.046	.382	.306	.261	.231	.209	.179	[illegible]
5.56	1.109	.437	.351	.299	.263	.238	.203	[illegible]
6.62	1.167	.488	.393	.334	.294	.265	.225	[illegible]
7.62	1.218	.534	.431	.367	.323	.290	.246	[illegible]
8.62	1.266	.577	.468	.398	.350	.315	.266	[illegible]
9.62	1.313	.619	.503	.429	.377	.339	.286	[illegible]
10.75	1.364	.665	.542	.462	.407	.365	.308	[illegible]
12.75	1.450	.742	.608	.520	.458	.411	.346	[illegible]
14.00	1.503	.788	.648	.555	.489	.439	.370	[illegible]
16.00	1.585	.860	.711	.610	.538	.483	.406	.317
18.00	1.665	.929	.771	.664	.586	.527	.442	[illegible]
20.00	1.745	.997	.831	.716	.633	.569	.478	[illegible]
24.00	1.903	1.128	.946	.819	.725	.653	.549	[illegible]
30.00	2.145	1.321	1.117	.971	.862	.777	.653	[illegible]
36.00	2.399	1.515	1.287	1.123	.998	.901	.758	[illegible]
42.00	2.675	1.716	1.463	1.279	1.138	1.028	.865	[illegible]

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.890	.316	.255	.219	.195	.177	.154	.127
4.50	.944	.368	.297	.254	.225	.205	.176	.144
5.56	.995	.418	.338	.290	.256	.232	.199	.161
6.62	1.041	.465	.378	.323	.286	.258	.220	.178
7.62	1.082	.506	.413	.353	.312	.282	.240	.192
8.62	1.120	.545	.446	.382	.338	.305	.259	.207
9.62	1.156	.582	.478	.411	.363	.327	.278	.221
10.75	1.195	.622	.513	.441	.390	.352	.298	.237
12.75	1.260	.689	.572	.494	.437	.394	.334	.264
14.00	1.300	.728	.607	.525	.465	.420	.356	.280
16.00	1.360	.789	.662	.574	.509	.460	.390	.306
18.00	1.418	.847	.714	.621	.552	.499	.423	.332
20.00	1.475	.902	.764	.666	.593	.537	.455	.357
24.00	1.585	1.008	.860	.754	.673	.610	.518	.406
30.00	1.745	1.157	.997	.879	.788	.716	.610	.478
36.00	1.903	1.300	1.128	.999	.899	.819	.699	.549
42.00	2.063	1.440	1.257	1.118	1.008	.920	.787	.619

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.309	.250	.215	.192	.175	.152	.126
4.50	.883	.358	.291	.250	.222	.202	.174	.143
5.56	.927	.405	.330	.284	.251	.228	.196	.159
6.62	.967	.449	.367	.316	.280	.253	.217	.175
7.62	1.002	.488	.400	.344	.305	.276	.236	.190
8.62	1.035	.524	.432	.372	.330	.298	.254	.204
9.62	1.065	.558	.462	.399	.353	.320	.272	.218
10.75	1.098	.595	.494	.427	.379	.343	.292	.233
12.75	1.154	.656	.549	.476	.423	.383	.326	.259
14.00	1.186	.691	.581	.505	.450	.407	.347	.275
16.00	1.236	.746	.631	.550	.491	.445	.379	.300
18.00	1.284	.797	.678	.593	.530	.481	.410	.324
20.00	1.330	.846	.723	.635	.568	.516	.440	.348
24.00	1.418	.938	.808	.714	.641	.584	.499	.394
30.00	1.544	1.065	.928	.824	.744	.680	.583	.461
36.00	1.665	1.184	1.040	.929	.842	.771	.664	.527
42.00	1.784	1.298	1.147	1.030	.936	.860	.742	.590

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.448	.373	.326	.294	.270	.237	.200
4.50	1.046	.515	.430	.376	.338	.310	.271	.225
5.56	1.109	.580	.486	.425	.381	.349	.304	.251
6.62	1.167	.639	.538	.471	.423	.387	.335	.276
7.62	1.218	.692	.584	.512	.460	.421	.364	.298
8.62	1.266	.741	.629	.552	.496	.453	.392	.320
9.62	1.313	.789	.672	.590	.531	.485	.420	.341
10.75	1.364	.840	.718	.632	.569	.520	.450	.365
12.75	1.450	.926	.796	.704	.634	.580	.501	.405
14.00	1.503	.977	.843	.747	.674	.617	.533	.430
16.00	1.585	1.056	.916	.814	.736	.674	.582	.470
18.00	1.665	1.133	.987	.879	.796	.730	.631	.508
20.00	1.745	1.207	1.056	.942	.854	.784	.679	.546
24.00	1.903	1.352	1.190	1.067	.970	.891	.773	.622
30.00	2.145	1.566	1.388	1.250	1.140	1.050	.912	.734
36.00	2.399	1.783	1.588	1.434	1.311	1.210	1.052	.847
42.00	2.675	2.011	1.796	1.626	1.488	1.374	1.197	.963

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.0
3.50	.890	.428	.359	.316	.285	.263	.232	.195
4.50	.944	.489	.412	.362	.326	.300	.263	.22
5.56	.995	.547	.462	.407	.367	.337	.294	.245
6.62	1.041	.599	.510	.449	.405	.372	.324	.268
7.62	1.082	.645	.551	.486	.439	.403	.351	.289
8.62	1.120	.688	.590	.522	.472	.433	.377	.309
9.62	1.156	.729	.628	.556	.503	.462	.402	.329
10.75	1.195	.772	.668	.593	.537	.493	.429	.351
12.75	1.260	.844	.735	.656	.595	.547	.476	.399
14.00	1.300	.887	.775	.693	.630	.579	.505	.412
16.00	1.360	.951	.836	.750	.683	.629	.549	.447
18.00	1.418	1.013	.894	.804	.734	.677	.591	.482
20.00	1.475	1.071	.950	.857	.784	.724	.633	.516
24.00	1.585	1.183	1.056	.958	.879	.814	.713	.582
30.00	1.745	1.341	1.207	1.101	1.014	.942	.829	.679
36.00	1.903	1.492	1.352	1.239	1.145	1.067	.942	.773
42.00	2.063	1.642	1.495	1.374	1.274	1.189	1.053	.866

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.415	.350	.309	.280	.258	.228	.193
4.50	.883	.472	.400	.352	.319	.294	.258	.217
5.56	.927	.526	.447	.395	.357	.329	.288	.240
6.62	.967	.574	.491	.435	.393	.362	.317	.263
7.62	1.002	.616	.530	.470	.425	.391	.342	.283
8.62	1.035	.655	.566	.503	.456	.420	.367	.303
9.62	1.065	.692	.600	.534	.485	.447	.390	.322
10.75	1.098	.731	.637	.568	.517	.476	.416	.342
12.75	1.154	.795	.697	.625	.570	.526	.460	.378
14.00	1.186	.833	.733	.659	.602	.556	.487	.399
16.00	1.236	.889	.788	.711	.650	.601	.527	.433
18.00	1.284	.942	.839	.759	.696	.645	.567	.465
20.00	1.330	.993	.888	.806	.741	.687	.605	.497
24.00	1.418	1.087	.980	.894	.825	.767	.677	.558
30.00	1.544	1.219	1.107	1.017	.943	.880	.781	.646
36.00	1.665	1.342	1.227	1.133	1.054	.987	.879	.730
42.00	1.784	1.460	1.342	1.244	1.161	1.090	.974	.811

SSHT= 46

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.566	.489	.438	.402	.374	.335	.287
4.50	1.046	.639	.555	.498	.456	.424	.378	.322
5.56	1.109	.709	.619	.556	.510	.473	.421	.357
6.62	1.167	.773	.678	.610	.560	.520	.462	.390
7.62	1.218	.829	.730	.658	.604	.561	.498	.420
8.62	1.266	.881	.779	.704	.647	.601	.533	.448
9.62	1.313	.931	.826	.748	.688	.640	.568	.476
10.75	1.364	.985	.877	.796	.733	.682	.605	.507
12.75	1.450	1.075	.963	.877	.809	.754	.669	.560
14.00	1.503	1.129	1.014	.926	.855	.797	.708	.593
16.00	1.585	1.211	1.093	1.001	.926	.865	.769	.644
18.00	1.665	1.291	1.170	1.074	.995	.930	.829	.694
20.00	1.745	1.369	1.244	1.145	1.063	.995	.887	.743
24.00	1.903	1.522	1.390	1.284	1.195	1.121	1.002	.839
30.00	2.145	1.748	1.606	1.489	1.391	1.307	1.172	.984
36.00	2.399	1.980	1.826	1.698	1.590	1.496	1.344	1.130
42.00	2.675	2.225	2.058	1.917	1.797	1.694	1.524	1.282

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.309	.250	.215	.192	.175	.152	.126
4.50	.883	.358	.291	.250	.222	.202	.174	.143
5.56	.927	.405	.330	.284	.251	.228	.196	.159
6.62	.967	.449	.367	.316	.280	.253	.217	.175
7.62	1.002	.488	.400	.344	.305	.276	.236	.190
8.62	1.035	.524	.432	.372	.330	.298	.254	.204
9.62	1.065	.558	.462	.399	.353	.320	.272	.218
10.75	1.098	.595	.494	.427	.379	.343	.292	.233
12.75	1.154	.656	.549	.476	.423	.383	.326	.259
14.00	1.186	.691	.581	.505	.450	.407	.347	.275
16.00	1.236	.746	.631	.550	.491	.445	.379	.300
18.00	1.284	.797	.678	.593	.530	.481	.410	.324
20.00	1.330	.846	.723	.635	.568	.516	.440	.348
24.00	1.418	.938	.808	.714	.641	.584	.499	.394
30.00	1.544	1.065	.928	.824	.744	.680	.583	.461
36.00	1.665	1.184	1.040	.929	.842	.771	.664	.527
42.00	1.784	1.298	1.147	1.030	.936	.860	.742	.590

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.448	.373	.326	.294	.270	.237	.200
4.50	1.046	.515	.430	.376	.338	.310	.271	.225
5.56	1.109	.580	.486	.425	.381	.349	.304	.251
6.62	1.167	.639	.538	.471	.423	.387	.335	.276
7.62	1.218	.692	.584	.512	.460	.421	.364	.298
8.62	1.266	.741	.629	.552	.496	.453	.392	.320
9.62	1.313	.789	.672	.590	.531	.485	.420	.341
10.75	1.364	.840	.718	.632	.569	.520	.450	.365
12.75	1.450	.926	.796	.704	.634	.580	.501	.405
14.00	1.503	.977	.843	.747	.674	.617	.533	.430
16.00	1.585	1.056	.916	.814	.736	.674	.582	.470
18.00	1.665	1.133	.987	.879	.796	.730	.631	.508
20.00	1.745	1.207	1.056	.942	.854	.784	.679	.546
24.00	1.903	1.352	1.190	1.067	.970	.891	.773	.622
30.00	2.145	1.566	1.388	1.250	1.140	1.050	.912	.734
36.00	2.399	1.783	1.588	1.434	1.311	1.210	1.052	.847
42.00	2.675	2.011	1.796	1.626	1.488	1.374	1.197	.963

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT.F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT.F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.890	.428	.359	.316	.285	.263	.232	.195
4.50	.944	.489	.412	.362	.326	.300	.263	.220
5.56	.995	.547	.462	.407	.367	.337	.294	.245
6.62	1.041	.599	.510	.449	.405	.372	.324	.268
7.62	1.082	.645	.551	.486	.439	.403	.351	.289
8.62	1.120	.688	.590	.522	.472	.433	.377	.309
9.62	1.156	.729	.628	.556	.503	.462	.402	.329
10.75	1.195	.772	.668	.593	.537	.493	.429	.351
12.75	1.260	.844	.735	.656	.595	.547	.476	.389
14.00	1.300	.887	.775	.693	.630	.579	.505	.412
16.00	1.360	.951	.836	.750	.683	.629	.549	.447
18.00	1.418	1.013	.894	.804	.734	.677	.591	.482
20.00	1.475	1.071	.950	.857	.784	.724	.633	.516
24.00	1.585	1.183	1.056	.958	.879	.814	.713	.582
30.00	1.745	1.341	1.207	1.101	1.014	.942	.829	.679
36.00	1.903	1.492	1.352	1.239	1.145	1.067	.942	.773
42.00	2.063	1.642	1.495	1.374	1.274	1.189	1.053	.866

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.415	.350	.309	.280	.258	.228	.193
4.50	.883	.472	.400	.352	.319	.294	.258	.217
5.56	.927	.526	.447	.395	.357	.329	.288	.240
6.62	.967	.574	.491	.435	.393	.362	.317	.263
7.62	1.002	.616	.530	.470	.425	.391	.342	.283
8.62	1.035	.655	.566	.503	.456	.420	.367	.303
9.62	1.065	.692	.600	.534	.485	.447	.390	.322
10.75	1.098	.731	.637	.568	.517	.476	.416	.342
12.75	1.154	.795	.697	.625	.570	.526	.460	.378
14.00	1.186	.833	.733	.659	.602	.556	.487	.399
16.00	1.236	.889	.788	.711	.650	.601	.527	.433
18.00	1.284	.942	.839	.759	.696	.645	.567	.465
20.00	1.330	.993	.888	.806	.741	.687	.605	.497
24.00	1.418	1.087	.980	.894	.825	.767	.677	.558
30.00	1.544	1.219	1.107	1.017	.943	.880	.781	.646
36.00	1.665	1.342	1.227	1.133	1.054	.987	.879	.730
42.00	1.784	1.460	1.342	1.244	1.161	1.090	.974	.811

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.981	.566	.489	.438	.402	.374	.335	.287
4.50	1.046	.639	.555	.498	.456	.424	.378	.322
5.56	1.109	.709	.619	.556	.510	.473	.421	.357
6.62	1.167	.773	.678	.610	.560	.520	.462	.390
7.62	1.218	.829	.730	.658	.604	.561	.498	.420
8.62	1.266	.881	.779	.704	.647	.601	.533	.448
9.62	1.313	.931	.826	.748	.688	.640	.568	.476
10.75	1.364	.985	.877	.796	.733	.682	.605	.507
12.75	1.450	1.075	.963	.877	.809	.754	.669	.560
14.00	1.503	1.129	1.014	.926	.855	.797	.708	.593
16.00	1.585	1.211	1.093	1.001	.926	.865	.769	.644
18.00	1.665	1.291	1.170	1.074	.995	.930	.829	.694
20.00	1.745	1.369	1.244	1.145	1.063	.995	.887	.743
24.00	1.903	1.522	1.390	1.284	1.195	1.121	1.002	.839
30.00	2.145	1.748	1.606	1.489	1.391	1.307	1.172	.984
36.00	2.399	1.980	1.826	1.698	1.590	1.496	1.344	1.130
42.00	2.675	2.225	2.058	1.917	1.797	1.694	1.524	1.282

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.890	.534	.466	.419	.386	.360	.323	.279
4.50	.944	.600	.525	.474	.436	.406	.364	.312
5.56	.995	.661	.582	.526	.484	.451	.403	.344
6.62	1.041	.716	.634	.574	.529	.493	.440	.374
7.62	1.082	.763	.679	.616	.569	.531	.474	.402
8.62	1.120	.808	.721	.656	.606	.566	.505	.428
9.62	1.156	.849	.761	.694	.642	.600	.536	.454
10.75	1.195	.893	.804	.735	.681	.637	.569	.482
12.75	1.260	.967	.875	.803	.746	.699	.626	.529
14.00	1.300	1.010	.917	.844	.785	.736	.659	.558
16.00	1.360	1.075	.981	.906	.844	.793	.712	.602
18.00	1.418	1.137	1.042	.965	.901	.847	.762	.646
20.00	1.475	1.197	1.100	1.021	.955	.900	.811	.688
24.00	1.585	1.310	1.211	1.129	1.060	1.001	.904	.769
30.00	1.745	1.472	1.369	1.283	1.209	1.145	1.039	.887
36.00	1.903	1.627	1.522	1.431	1.352	1.284	1.169	1.002
42.00	2.063	1.782	1.672	1.577	1.494	1.421	1.297	1.115

SSHT= 48

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	.836	.514	.450	.407	.375	.351	.316	.273
4.50	.883	.574	.506	.458	.422	.395	.354	.305
5.56	.927	.630	.558	.506	.467	.437	.392	.335
6.62	.967	.680	.605	.551	.509	.476	.427	.364
7.62	1.002	.723	.646	.590	.546	.511	.458	.390
8.62	1.035	.762	.685	.626	.580	.543	.487	.415
9.62	1.065	.799	.721	.661	.613	.575	.516	.439
10.75	1.098	.838	.759	.697	.648	.608	.546	.465
12.75	1.154	.903	.822	.759	.707	.665	.598	.509
14.00	1.186	.940	.859	.794	.742	.698	.629	.536
16.00	1.236	.996	.915	.849	.795	.749	.676	.577
18.00	1.284	1.049	.967	.900	.845	.797	.721	.616
20.00	1.330	1.100	1.017	.949	.892	.843	.765	.654
24.00	1.418	1.194	1.111	1.042	.983	.931	.847	.727
30.00	1.544	1.326	1.242	1.170	1.108	1.054	.963	.831
36.00	1.665	1.450	1.365	1.291	1.227	1.170	1.074	.930
42.00	1.784	1.570	1.483	1.408	1.341	1.281	1.180	1.026

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPF

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.155	.117	.097	.084	.075	.064	.051
4.50	1.395	.188	.140	.115	.099	.088	.074	.059
5.56	1.479	.221	.164	.134	.115	.102	.084	.066
6.62	1.556	.253	.188	.152	.130	.115	.095	.076
7.62	1.624	.283	.209	.169	.144	.127	.104	.080
8.62	1.689	.312	.231	.186	.158	.139	.113	.087
9.62	1.751	.340	.252	.203	.172	.150	.123	.093
10.75	1.818	.372	.275	.221	.187	.164	.133	.101
12.75	1.934	.427	.316	.254	.214	.187	.151	.113
14.00	2.004	.460	.341	.274	.231	.201	.162	.121
16.00	2.113	.513	.381	.306	.258	.224	.180	.134
18.00	2.220	.565	.420	.337	.284	.246	.198	.146
20.00	2.326	.615	.458	.368	.310	.269	.215	.158
24.00	2.538	.716	.535	.430	.362	.313	.250	.183
30.00	2.860	.863	.648	.521	.438	.380	.302	.219
36.00	3.199	1.010	.760	.613	.515	.446	.354	.255
42.00	3.566	1.159	.874	.705	.592	.512	.406	.292

SSHT= 50

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.154	.116	.096	.084	.075	.063	.051
4.50	1.259	.185	.139	.114	.098	.088	.073	.059
5.56	1.327	.217	.162	.132	.114	.101	.084	.066
6.62	1.388	.248	.185	.151	.129	.114	.094	.073
7.62	1.442	.277	.206	.167	.143	.125	.103	.080
8.62	1.493	.304	.227	.184	.156	.137	.112	.086
9.62	1.541	.332	.247	.200	.170	.149	.121	.093
10.75	1.593	.361	.269	.218	.185	.162	.132	.100
12.75	1.681	.413	.308	.249	.211	.184	.149	.112
14.00	1.733	.444	.332	.268	.227	.198	.160	.120
16.00	1.813	.493	.369	.299	.252	.220	.177	.132
18.00	1.891	.541	.406	.328	.278	.242	.195	.144
20.00	1.967	.587	.442	.358	.302	.263	.212	.156
24.00	2.113	.677	.513	.416	.351	.306	.245	.180
30.00	2.326	.807	.615	.500	.423	.368	.295	.215
36.00	2.538	.933	.716	.583	.494	.430	.344	.250
42.00	2.751	1.057	.814	.665	.564	.491	.392	.285

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.152	.115	.096	.083	.075	.063	.051
4.50	1.178	.183	.138	.113	.098	.087	.073	.058
5.56	1.237	.215	.161	.132	.113	.100	.083	.066
6.62	1.290	.245	.183	.149	.128	.113	.093	.073
7.62	1.336	.273	.204	.166	.141	.125	.103	.079
8.62	1.380	.299	.224	.182	.155	.136	.112	.086
9.62	1.421	.326	.244	.198	.168	.147	.121	.092
10.75	1.465	.354	.265	.215	.183	.160	.131	.099
12.75	1.538	.404	.303	.246	.208	.182	.148	.112
14.00	1.582	.433	.326	.264	.224	.196	.159	.119
16.00	1.648	.480	.362	.294	.249	.217	.176	.131
18.00	1.712	.525	.397	.323	.273	.239	.192	.143
20.00	1.774	.568	.432	.351	.297	.259	.209	.155
24.00	1.891	.653	.499	.406	.345	.301	.242	.178
30.00	2.059	.772	.595	.487	.413	.361	.290	.213
36.00	2.220	.886	.688	.565	.481	.420	.337	.246
42.00	2.379	.996	.778	.641	.546	.477	.384	.280

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.200	.152	.127	.110	.099	.084	.068
4.50	1.395	.241	.182	.150	.130	.116	.097	.078
5.56	1.479	.282	.212	.174	.150	.133	.111	.087
6.62	1.556	.321	.242	.198	.169	.150	.124	.097
7.62	1.624	.358	.269	.219	.187	.165	.136	.106
8.62	1.689	.393	.295	.241	.205	.181	.149	.114
9.62	1.751	.428	.322	.262	.223	.196	.160	.123
10.75	1.818	.466	.351	.285	.243	.213	.174	.132
12.75	1.934	.532	.401	.326	.277	.242	.197	.149
14.00	2.004	.572	.432	.351	.298	.261	.212	.159
16.00	2.113	.635	.481	.391	.331	.290	.234	.175
18.00	2.220	.696	.528	.430	.365	.318	.257	.191
20.00	2.326	.757	.576	.468	.397	.347	.280	.207
24.00	2.538	.875	.669	.545	.462	.403	.324	.239
30.00	2.860	1.049	.806	.658	.559	.487	.391	.286
36.00	3.199	1.223	.943	.771	.655	.571	.457	.333
42.00	3.566	1.399	1.082	.885	.752	.655	.524	.381

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE, F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.197	.151	.125	.109	.098	.084	.068
4.50	1.259	.236	.179	.148	.128	.115	.097	.077
5.50	1.327	.276	.209	.172	.148	.132	.110	.087
6.62	1.388	.314	.237	.195	.167	.148	.123	.096
7.62	1.442	.348	.263	.216	.185	.163	.135	.105
8.62	1.493	.381	.289	.236	.202	.178	.147	.113
9.62	1.541	.414	.314	.256	.219	.193	.158	.122
10.75	1.593	.450	.341	.279	.238	.209	.171	.131
12.75	1.681	.511	.389	.318	.271	.238	.194	.147
14.00	1.733	.547	.418	.341	.291	.255	.208	.157
16.00	1.813	.605	.463	.379	.323	.283	.230	.173
18.00	1.891	.660	.507	.416	.354	.311	.252	.188
20.00	1.967	.714	.551	.452	.385	.337	.273	.204
24.00	2.113	.818	.635	.522	.446	.391	.316	.234
30.00	2.326	.968	.757	.625	.534	.468	.379	.280
36.00	2.538	1.111	.875	.725	.621	.545	.440	.324
42.00	2.751	1.252	.992	.824	.707	.620	.502	.369

SSHT= 54

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.195	.149	.125	.109	.098	.083	.067
4.50	1.178	.233	.178	.147	.128	.114	.096	.077
5.56	1.237	.272	.206	.170	.147	.131	.109	.086
6.62	1.290	.308	.234	.192	.166	.147	.122	.096
7.62	1.336	.342	.260	.213	.183	.162	.134	.104
8.62	1.380	.374	.284	.233	.200	.176	.146	.113
9.62	1.421	.405	.308	.253	.216	.191	.157	.121
10.75	1.465	.439	.335	.274	.235	.207	.170	.130
12.75	1.538	.497	.381	.312	.267	.235	.192	.146
14.00	1.582	.531	.408	.335	.287	.252	.206	.156
16.00	1.648	.585	.452	.371	.317	.279	.227	.171
18.00	1.712	.637	.493	.406	.347	.305	.248	.186
20.00	1.774	.687	.534	.441	.377	.331	.269	.202
24.00	1.891	.783	.613	.507	.435	.382	.311	.231
30.00	2.059	.918	.726	.604	.519	.456	.371	.275
36.00	2.220	1.046	.834	.696	.600	.528	.430	.318
42.00	2.379	1.169	.938	.787	.679	.599	.488	.361

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.242	.186	.155	.136	.122	.104	.084
4.50	1.395	.289	.221	.183	.159	.142	.120	.096
5.56	1.479	.337	.257	.212	.183	.163	.137	.108
6.62	1.556	.383	.292	.240	.207	.184	.153	.120
7.62	1.624	.425	.324	.266	.229	.202	.168	.131
8.62	1.689	.466	.355	.292	.250	.221	.183	.141
9.62	1.751	.506	.386	.317	.271	.239	.197	.152
10.75	1.818	.549	.420	.344	.295	.260	.213	.163
12.75	1.934	.624	.478	.392	.335	.295	.241	.183
14.00	2.004	.670	.514	.422	.361	.317	.259	.196
16.00	2.113	.741	.571	.468	.400	.352	.286	.216
18.00	2.220	.810	.626	.514	.440	.386	.314	.235
20.00	2.326	.878	.680	.560	.478	.420	.341	.255
24.00	2.538	1.010	.787	.649	.555	.487	.395	.293
30.00	2.860	1.205	.945	.781	.668	.586	.475	.351
36.00	3.199	1.400	1.102	.913	.782	.686	.554	.408
42.00	3.566	1.598	1.262	1.046	.897	.786	.635	.466

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.238	.183	.153	.134	.121	.103	.084
4.50	1.259	.283	.217	.181	.157	.141	.119	.095
5.56	1.327	.329	.252	.209	.181	.161	.135	.107
6.62	1.388	.372	.286	.236	.204	.181	.151	.119
7.62	1.442	.412	.316	.261	.225	.199	.166	.129
8.62	1.493	.450	.346	.285	.245	.217	.180	.140
9.62	1.541	.487	.375	.309	.266	.235	.194	.150
10.75	1.593	.527	.406	.335	.288	.254	.210	.161
12.75	1.681	.595	.461	.381	.327	.288	.237	.181
14.00	1.733	.636	.494	.408	.351	.309	.254	.193
16.00	1.813	.700	.546	.452	.388	.342	.280	.212
18.00	1.891	.761	.596	.494	.425	.374	.306	.231
20.00	1.967	.821	.646	.536	.461	.406	.332	.250
24.00	2.113	.935	.741	.617	.531	.468	.382	.286
30.00	2.326	1.099	.878	.734	.634	.560	.457	.341
36.00	2.538	1.256	1.010	.849	.734	.649	.530	.395
42.00	2.751	1.409	1.141	.961	.833	.737	.602	.448

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.235	.182	.152	.133	.120	.102	.083
4.50	1.178	.279	.215	.179	.156	.140	.118	.095
5.56	1.237	.323	.249	.206	.179	.160	.134	.107
6.62	1.290	.365	.281	.233	.201	.179	.150	.118
7.62	1.336	.403	.311	.257	.222	.197	.164	.128
8.62	1.380	.439	.339	.281	.242	.215	.178	.139
9.62	1.421	.474	.367	.304	.262	.232	.192	.149
10.75	1.465	.512	.397	.329	.283	.251	.207	.160
12.75	1.538	.576	.450	.373	.321	.284	.234	.179
14.00	1.582	.615	.481	.399	.344	.304	.250	.191
16.00	1.648	.674	.530	.441	.380	.336	.276	.209
18.00	1.712	.731	.577	.481	.415	.367	.301	.228
20.00	1.774	.785	.623	.520	.449	.397	.326	.246
24.00	1.891	.889	.711	.596	.516	.457	.374	.282
30.00	2.059	1.035	.837	.705	.612	.543	.445	.334
36.00	2.220	1.172	.956	.810	.705	.626	.514	.386
42.00	2.379	1.304	1.071	.911	.795	.707	.582	.437

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.281	.218	.183	.160	.144	.123	.100
4.50	1.395	.335	.258	.215	.188	.168	.142	.114
5.56	1.479	.389	.299	.249	.216	.193	.162	.129
6.62	1.556	.440	.339	.281	.243	.216	.181	.142
7.62	1.624	.487	.375	.311	.268	.238	.198	.155
8.62	1.689	.532	.411	.340	.293	.260	.215	.167
9.62	1.751	.576	.445	.368	.317	.281	.232	.180
10.75	1.818	.624	.483	.400	.344	.304	.251	.193
12.75	1.934	.706	.549	.454	.391	.345	.284	.217
14.00	2.004	.756	.589	.488	.419	.370	.304	.232
16.00	2.113	.833	.652	.540	.465	.410	.336	.255
18.00	2.220	.909	.713	.592	.509	.449	.368	.278
20.00	2.326	.982	.774	.643	.554	.488	.399	.300
24.00	2.538	1.126	.892	.744	.641	.565	.461	.346
30.00	2.860	1.338	1.067	.892	.769	.679	.554	.413
36.00	3.199	1.549	1.241	1.040	.898	.793	.646	.480
42.00	3.566	1.765	1.419	1.190	1.029	.908	.739	.548

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.275	.214	.180	.158	.143	.122	.100
4.50	1.259	.326	.253	.212	.185	.166	.141	.113
5.56	1.327	.377	.293	.244	.212	.190	.160	.127
6.62	1.388	.426	.330	.275	.239	.213	.178	.141
7.62	1.442	.469	.365	.303	.263	.234	.195	.153
8.62	1.493	.511	.398	.331	.286	.254	.212	.165
9.62	1.541	.551	.430	.358	.309	.275	.228	.177
10.75	1.593	.595	.466	.387	.335	.297	.246	.190
12.75	1.681	.669	.526	.439	.379	.336	.278	.213
14.00	1.733	.714	.563	.470	.406	.360	.297	.227
16.00	1.813	.782	.620	.518	.448	.397	.327	.250
18.00	1.891	.848	.675	.566	.490	.434	.357	.272
20.00	1.967	.912	.729	.612	.530	.470	.387	.293
24.00	2.113	1.034	.833	.702	.609	.540	.445	.336
30.00	2.326	1.208	.982	.832	.724	.643	.530	.399
36.00	2.538	1.374	1.126	.958	.836	.744	.613	.461
42.00	2.751	1.538	1.268	1.082	.946	.843	.695	.523

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.271	.212	.178	.157	.142	.121	.099
4.50	1.178	.321	.250	.209	.183	.164	.140	.113
5.56	1.237	.370	.288	.241	.210	.188	.158	.126
6.62	1.290	.416	.324	.271	.235	.210	.177	.140
7.62	1.336	.457	.358	.298	.259	.231	.193	.152
8.62	1.380	.497	.389	.325	.282	.251	.209	.164
9.62	1.421	.535	.420	.351	.304	.271	.225	.175
10.75	1.465	.576	.454	.379	.329	.292	.243	.188
12.75	1.538	.645	.512	.428	.371	.330	.273	.211
14.00	1.582	.686	.546	.458	.397	.353	.292	.225
16.00	1.648	.750	.600	.504	.438	.389	.322	.246
18.00	1.712	.810	.651	.549	.477	.424	.350	.268
20.00	1.774	.868	.701	.592	.515	.458	.379	.289
24.00	1.891	.978	.796	.675	.589	.525	.434	.330
30.00	2.059	1.131	.931	.795	.696	.621	.514	.390
36.00	2.220	1.275	1.059	.909	.798	.713	.592	.449
42.00	2.379	1.414	1.182	1.019	.897	.804	.668	.507

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE H= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.318	.248	.209	.184	.166	.142	.116
4.50	1.395	.377	.294	.246	.215	.193	.164	.132
5.56	1.479	.436	.339	.283	.247	.221	.186	.149
6.62	1.556	.492	.383	.320	.278	.248	.208	.164
7.62	1.624	.543	.423	.353	.306	.272	.228	.179
8.62	1.689	.592	.462	.385	.333	.297	.247	.193
9.62	1.751	.639	.500	.417	.361	.320	.266	.207
10.75	1.818	.691	.542	.451	.391	.347	.288	.222
12.75	1.934	.779	.614	.512	.443	.393	.325	.250
14.00	2.004	.832	.657	.549	.475	.421	.348	.266
16.00	2.113	.915	.726	.607	.525	.465	.384	.293
18.00	2.220	.995	.793	.664	.575	.509	.419	.319
20.00	2.326	1.074	.858	.720	.624	.553	.455	.345
24.00	2.538	1.227	.987	.830	.720	.638	.525	.396
30.00	2.860	1.452	1.176	.993	.862	.765	.628	.472
36.00	3.199	1.677	1.365	1.155	1.005	.892	.732	.549
42.00	3.566	1.907	1.557	1.321	1.150	1.020	.838	.626

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.310	.244	.206	.181	.164	.141	.115
4.50	1.259	.366	.287	.241	.211	.190	.162	.131
5.56	1.327	.422	.331	.277	.242	.217	.184	.147
6.62	1.388	.474	.372	.312	.272	.243	.205	.162
7.62	1.442	.521	.410	.343	.299	.267	.224	.176
8.62	1.493	.566	.446	.374	.325	.290	.242	.190
9.62	1.541	.609	.481	.403	.351	.313	.261	.204
10.75	1.593	.655	.520	.436	.379	.338	.281	.219
12.75	1.681	.734	.586	.492	.428	.381	.317	.245
14.00	1.733	.781	.625	.526	.458	.407	.338	.261
16.00	1.813	.854	.687	.579	.504	.449	.372	.286
18.00	1.891	.923	.746	.631	.550	.489	.406	.311
20.00	1.967	.990	.804	.681	.594	.529	.439	.335
24.00	2.113	1.118	.915	.779	.681	.607	.503	.384
30.00	2.326	1.300	1.074	.919	.806	.720	.598	.455
36.00	2.538	1.474	1.227	1.055	.928	.830	.690	.525
42.00	2.751	1.645	1.377	1.188	1.047	.939	.781	.594

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.305	.241	.204	.180	.162	.140	.115
4.50	1.178	.359	.283	.238	.209	.188	.161	.130
5.56	1.237	.412	.325	.273	.239	.215	.182	.146
6.62	1.290	.462	.365	.307	.268	.240	.202	.161
7.62	1.336	.506	.401	.337	.294	.263	.221	.175
8.62	1.380	.549	.435	.366	.319	.285	.239	.188
9.62	1.421	.589	.469	.395	.344	.307	.257	.201
10.75	1.465	.632	.505	.426	.371	.331	.277	.216
12.75	1.538	.706	.567	.479	.418	.373	.311	.241
14.00	1.582	.749	.604	.511	.446	.398	.332	.257
16.00	1.648	.815	.662	.561	.491	.438	.365	.281
18.00	1.712	.878	.717	.610	.533	.477	.397	.306
20.00	1.774	.938	.769	.656	.575	.514	.428	.329
24.00	1.891	1.052	.870	.746	.656	.587	.489	.376
30.00	2.059	1.212	1.013	.874	.771	.692	.578	.443
36.00	2.220	1.361	1.147	.995	.881	.793	.664	.509
42.00	2.379	1.504	1.277	1.112	.988	.891	.748	.574

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.353	.278	.235	.207	.187	.161	.132
4.50	1.395	.416	.327	.275	.241	.217	.185	.150
5.56	1.479	.480	.377	.317	.277	.248	.210	.168
6.62	1.556	.540	.425	.356	.311	.278	.234	.186
7.62	1.624	.594	.468	.392	.342	.305	.256	.202
8.62	1.689	.646	.510	.428	.372	.332	.278	.218
9.62	1.751	.696	.551	.462	.402	.358	.299	.234
10.75	1.818	.751	.596	.500	.435	.387	.323	.251
12.75	1.934	.844	.673	.566	.492	.438	.364	.281
14.00	2.004	.900	.720	.606	.527	.469	.389	.300
16.00	2.113	.987	.793	.669	.582	.518	.429	.329
18.00	2.220	1.072	.865	.730	.636	.566	.469	.359
20.00	2.326	1.154	.935	.791	.689	.613	.508	.387
24.00	2.538	1.315	1.072	.909	.794	.707	.585	.445
30.00	2.860	1.551	1.273	1.085	.948	.845	.699	.530
36.00	3.199	1.787	1.475	1.260	1.103	.984	.814	.615
42.00	3.566	2.030	1.681	1.438	1.261	1.125	.930	.702

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.343	.272	.231	.204	.185	.159	.131
4.50	1.259	.403	.319	.270	.237	.214	.183	.148
5.50	1.327	.463	.366	.309	.271	.243	.207	.166
6.62	1.388	.518	.411	.347	.303	.272	.230	.183
7.62	1.442	.568	.452	.381	.333	.298	.251	.199
8.62	1.493	.615	.491	.414	.362	.324	.272	.214
9.62	1.541	.660	.528	.446	.390	.349	.292	.229
10.75	1.593	.709	.570	.481	.421	.376	.315	.246
12.75	1.681	.792	.640	.542	.474	.423	.354	.275
14.00	1.733	.841	.682	.578	.506	.452	.378	.293
16.00	1.813	.916	.747	.635	.556	.497	.415	.321
18.00	1.891	.989	.810	.691	.605	.541	.452	.349
20.00	1.967	1.058	.870	.744	.653	.585	.488	.376
24.00	2.113	1.191	.987	.848	.746	.669	.558	.429
30.00	2.326	1.379	1.154	.997	.881	.791	.661	.508
36.00	2.538	1.559	1.315	1.141	1.011	.909	.762	.585
42.00	2.751	1.735	1.473	1.283	1.139	1.026	.861	.661

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.337	.268	.228	.201	.183	.157	.130
4.50	1.178	.395	.313	.266	.234	.211	.181	.147
5.56	1.237	.451	.359	.304	.267	.240	.204	.165
6.62	1.290	.504	.402	.340	.298	.268	.227	.181
7.62	1.336	.551	.441	.373	.327	.293	.248	.197
8.62	1.380	.595	.478	.405	.355	.318	.268	.212
9.62	1.421	.637	.513	.435	.381	.342	.288	.227
10.75	1.465	.683	.552	.469	.411	.368	.309	.243
12.75	1.538	.759	.618	.526	.462	.414	.347	.271
14.00	1.582	.804	.657	.561	.492	.441	.370	.288
16.00	1.648	.872	.717	.614	.540	.484	.406	.315
18.00	1.712	.937	.775	.665	.586	.526	.441	.342
20.00	1.774	.999	.830	.715	.630	.566	.475	.368
24.00	1.891	1.117	.936	.810	.716	.645	.541	.419
30.00	2.059	1.280	1.084	.944	.839	.757	.638	.493
36.00	2.220	1.433	1.224	1.072	.956	.865	.730	.566
42.00	2.379	1.579	1.358	1.195	1.069	.969	.821	.637

SSHT= 67

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.498	.406	.350	.312	.285	.248	.206
4.50	1.395	.579	.472	.406	.361	.329	.284	.233
5.56	1.479	.658	.537	.462	.410	.372	.320	.261
6.62	1.556	.731	.599	.515	.457	.414	.355	.287
7.62	1.624	.796	.655	.564	.500	.453	.387	.311
8.62	1.689	.858	.708	.610	.541	.490	.418	.335
9.62	1.751	.918	.760	.656	.581	.526	.448	.358
10.75	1.818	.982	.816	.705	.626	.566	.481	.384
12.75	1.934	1.090	.911	.790	.702	.635	.539	.428
14.00	2.004	1.155	.969	.841	.748	.677	.575	.455
16.00	2.113	1.256	1.058	.921	.820	.742	.631	.498
18.00	2.220	1.352	1.145	.999	.891	.807	.686	.540
20.00	2.326	1.447	1.230	1.076	.960	.870	.740	.582
24.00	2.538	1.630	1.395	1.225	1.096	.995	.846	.665
30.00	2.860	1.900	1.638	1.445	1.296	1.179	1.004	.788
36.00	3.199	2.173	1.883	1.666	1.498	1.364	1.163	.912
42.00	3.566	2.456	2.135	1.893	1.705	1.553	1.325	1.038

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.480	.393	.341	.305	.279	.243	.203
4.50	1.259	.554	.455	.393	.351	.320	.278	.229
5.56	1.327	.626	.516	.446	.398	.362	.312	.256
6.62	1.388	.692	.573	.496	.442	.401	.345	.281
7.62	1.442	.750	.623	.540	.481	.437	.375	.304
8.62	1.493	.805	.671	.583	.519	.472	.404	.326
9.62	1.541	.857	.717	.624	.556	.505	.433	.348
10.75	1.593	.912	.767	.668	.596	.542	.464	.372
12.75	1.681	1.005	.851	.744	.665	.605	.518	.414
14.00	1.733	1.060	.901	.789	.706	.642	.550	.439
16.00	1.813	1.143	.977	.859	.770	.701	.601	.479
18.00	1.891	1.222	1.050	.926	.832	.758	.650	.518
20.00	1.967	1.298	1.121	.991	.892	.814	.698	.556
24.00	2.113	1.443	1.256	1.116	1.008	.921	.792	.631
30.00	2.326	1.648	1.447	1.293	1.173	1.076	.928	.740
36.00	2.538	1.844	1.630	1.465	1.333	1.225	1.060	.846
42.00	2.751	2.037	1.810	1.633	1.489	1.372	1.190	.951

SSHT= 69

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.468	.385	.334	.300	.275	.240	.201
4.50	1.178	.538	.444	.385	.345	.315	.274	.226
5.56	1.237	.605	.502	.435	.389	.355	.307	.252
6.62	1.290	.667	.555	.482	.431	.393	.339	.277
7.62	1.336	.720	.602	.524	.469	.427	.368	.299
8.62	1.380	.771	.647	.564	.505	.460	.396	.321
9.62	1.421	.818	.690	.603	.540	.491	.423	.342
10.75	1.465	.868	.736	.644	.577	.526	.452	.365
12.75	1.538	.952	.813	.714	.641	.585	.503	.405
14.00	1.582	1.001	.858	.756	.680	.620	.534	.429
16.00	1.648	1.075	.927	.820	.739	.675	.581	.467
18.00	1.712	1.145	.993	.881	.795	.728	.627	.503
20.00	1.774	1.211	1.055	.939	.850	.779	.672	.539
24.00	1.891	1.336	1.173	1.050	.954	.876	.758	.609
30.00	2.059	1.509	1.338	1.206	1.100	1.014	.881	.710
36.00	2.220	1.670	1.493	1.352	1.239	1.145	.999	.807
42.00	2.379	1.825	1.641	1.493	1.372	1.272	1.113	.902

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.308	.649	.547	.482	.437	.403	.356	.301
4.50	1.395	.741	.627	.553	.500	.460	.405	.339
5.56	1.479	.831	.706	.622	.562	.517	.453	.377
6.62	1.556	.912	.778	.688	.622	.571	.499	.414
7.62	1.624	.984	.843	.746	.675	.620	.541	.447
8.62	1.689	1.052	.905	.802	.726	.667	.582	.479
9.62	1.751	1.117	.964	.856	.775	.713	.621	.510
10.75	1.818	1.186	1.028	.915	.829	.763	.665	.545
12.75	1.934	1.303	1.137	1.015	.922	.848	.739	.604
14.00	2.004	1.373	1.201	1.075	.977	.900	.785	.641
16.00	2.113	1.481	1.302	1.168	1.064	.981	.856	.698
18.00	2.220	1.585	1.399	1.259	1.149	1.060	.925	.755
20.00	2.326	1.686	1.494	1.347	1.231	1.137	.994	.810
24.00	2.538	1.883	1.679	1.520	1.393	1.289	1.129	.920
30.00	2.860	2.174	1.951	1.775	1.632	1.513	1.328	1.083
36.00	3.199	2.471	2.228	2.033	1.873	1.740	1.530	1.249
42.00	3.566	2.783	2.517	2.301	2.123	1.974	1.738	1.419

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.187	.618	.525	.465	.422	.391	.346	.294
4.50	1.259	.701	.598	.530	.481	.444	.392	.330
5.56	1.327	.780	.669	.594	.539	.497	.438	.366
6.62	1.388	.852	.734	.653	.593	.547	.481	.401
7.62	1.442	.914	.791	.705	.641	.591	.519	.431
8.62	1.493	.973	.845	.755	.687	.634	.556	.461
9.62	1.541	1.027	.897	.803	.731	.675	.592	.490
10.75	1.593	1.086	.952	.854	.779	.720	.632	.522
12.75	1.681	1.183	1.044	.940	.860	.795	.699	.577
14.00	1.733	1.240	1.098	.991	.908	.841	.739	.610
16.00	1.813	1.327	1.181	1.070	.982	.911	.802	.661
18.00	1.891	1.409	1.260	1.145	1.053	.978	.862	.712
20.00	1.967	1.488	1.336	1.217	1.122	1.043	.921	.761
24.00	2.113	1.638	1.481	1.356	1.253	1.168	1.034	.856
30.00	2.326	1.850	1.686	1.552	1.441	1.347	1.198	.994
36.00	2.538	2.055	1.883	1.741	1.622	1.520	1.356	1.129
42.00	2.751	2.257	2.077	1.927	1.799	1.690	1.512	1.262

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.115	.597	.510	.453	.413	.383	.340	.289
4.50	1.178	.675	.579	.515	.469	.434	.384	.324
5.56	1.237	.748	.645	.575	.523	.484	.427	.359
6.62	1.290	.814	.706	.630	.574	.531	.468	.392
7.62	1.336	.870	.758	.679	.619	.573	.505	.421
8.62	1.380	.923	.808	.725	.662	.613	.540	.450
9.62	1.421	.972	.855	.769	.703	.651	.574	.477
10.75	1.465	1.025	.904	.815	.747	.692	.610	.507
12.75	1.538	1.110	.987	.894	.821	.762	.673	.559
14.00	1.582	1.161	1.035	.940	.864	.803	.710	.590
16.00	1.648	1.236	1.109	1.010	.931	.867	.767	.638
18.00	1.712	1.307	1.178	1.077	.995	.927	.823	.684
20.00	1.774	1.374	1.244	1.140	1.056	.986	.876	.729
24.00	1.891	1.501	1.368	1.260	1.171	1.097	.978	.816
30.00	2.059	1.676	1.540	1.427	1.333	1.252	1.122	.941
36.00	2.220	1.841	1.702	1.585	1.485	1.399	1.259	1.060
42.00	2.379	2.000	1.857	1.735	1.631	1.541	1.391	1.175

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.158	.119	.098	.085	.076	.064	.052
4.50	1.674	.192	.142	.116	.100	.089	.074	.059
5.56	1.775	.226	.167	.136	.116	.102	.085	.067
6.62	1.867	.260	.191	.154	.131	.116	.095	.074
7.62	1.949	.291	.213	.172	.146	.128	.105	.081
8.62	2.026	.321	.236	.189	.160	.140	.114	.087
9.62	2.101	.351	.257	.206	.174	.152	.124	.094
10.75	2.182	.384	.281	.225	.190	.166	.134	.101
12.75	2.321	.442	.324	.259	.218	.189	.153	.114
14.00	2.405	.477	.350	.280	.235	.204	.164	.122
16.00	2.536	.533	.391	.313	.262	.227	.182	.135
18.00	2.664	.588	.432	.345	.289	.251	.200	.147
20.00	2.792	.643	.473	.377	.316	.274	.218	.160
24.00	3.045	.749	.553	.441	.369	.319	.254	.184
30.00	3.432	.907	.672	.537	.449	.387	.307	.221
36.00	3.839	1.064	.790	.631	.528	.455	.360	.258
42.00	4.280	1.223	.909	.727	.608	.524	.413	.295

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.157	.118	.097	.084	.075	.064	.052
4.50	1.511	.189	.141	.115	.099	.088	.074	.059
5.56	1.592	.223	.165	.134	.115	.102	.085	.066
6.62	1.666	.255	.189	.153	.130	.115	.095	.074
7.62	1.731	.285	.211	.170	.145	.127	.104	.080
8.62	1.791	.314	.232	.187	.159	.139	.114	.087
9.62	1.849	.343	.253	.204	.172	.151	.123	.093
10.75	1.912	.375	.276	.222	.188	.164	.133	.101
12.75	2.017	.430	.317	.255	.215	.187	.151	.113
14.00	2.079	.463	.342	.275	.231	.201	.162	.121
16.00	2.176	.515	.382	.306	.258	.224	.180	.133
18.00	2.269	.567	.420	.337	.284	.246	.197	.146
20.00	2.360	.617	.459	.368	.310	.269	.215	.158
24.00	2.536	.714	.533	.429	.361	.313	.249	.182
30.00	2.792	.855	.643	.518	.436	.377	.300	.218
36.00	3.045	.992	.749	.605	.509	.441	.351	.254
42.00	3.301	1.127	.855	.692	.583	.505	.401	.289

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.156	.117	.097	.084	.075	.064	.051
4.50	1.413	.188	.140	.115	.099	.088	.074	.059
5.56	1.484	.220	.164	.134	.114	.101	.084	.066
6.62	1.548	.252	.187	.152	.130	.114	.094	.073
7.62	1.603	.282	.209	.169	.144	.126	.104	.080
8.62	1.655	.310	.230	.185	.157	.138	.113	.086
9.62	1.705	.338	.250	.202	.171	.150	.122	.093
10.75	1.758	.368	.273	.220	.186	.163	.132	.100
12.75	1.846	.421	.313	.252	.213	.186	.150	.113
14.00	1.898	.453	.337	.271	.229	.200	.161	.120
16.00	1.978	.503	.375	.302	.255	.222	.178	.133
18.00	2.055	.552	.412	.332	.280	.244	.196	.145
20.00	2.128	.599	.449	.362	.305	.265	.213	.157
24.00	2.269	.691	.520	.420	.355	.308	.246	.181
30.00	2.470	.822	.624	.506	.427	.371	.296	.216
36.00	2.664	.948	.724	.588	.497	.432	.345	.251
42.00	2.855	1.070	.821	.669	.567	.493	.393	.285

DEFINITION G=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.205	.155	.128	.111	.100	.085	.068
4.50	1.674	.247	.185	.152	.131	.117	.098	.078
5.56	1.775	.290	.217	.177	.152	.135	.112	.088
6.62	1.867	.332	.247	.201	.172	.152	.125	.098
7.62	1.949	.370	.276	.224	.191	.168	.138	.107
8.62	2.026	.408	.303	.246	.209	.183	.150	.115
9.62	2.101	.445	.331	.267	.227	.199	.162	.124
10.75	2.182	.485	.361	.292	.247	.216	.176	.133
12.75	2.321	.556	.414	.334	.283	.247	.200	.150
14.00	2.405	.599	.447	.360	.305	.266	.215	.161
16.00	2.536	.667	.498	.402	.339	.296	.238	.177
18.00	2.664	.733	.549	.443	.374	.325	.261	.193
20.00	2.792	.798	.599	.483	.408	.355	.284	.210
24.00	3.045	.926	.697	.563	.475	.413	.330	.242
30.00	3.432	1.115	.844	.682	.576	.500	.399	.290
36.00	3.839	1.303	.989	.801	.676	.586	.467	.338
42.00	4.280	1.493	1.136	.921	.777	.674	.536	.386

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.202	.153	.127	.111	.099	.084	.068
4.50	1.511	.243	.183	.151	.130	.116	.098	.078
5.56	1.592	.285	.214	.175	.150	.133	.111	.088
6.62	1.666	.325	.243	.199	.170	.150	.124	.097
7.62	1.731	.362	.271	.220	.188	.166	.137	.106
8.62	1.791	.397	.298	.242	.206	.181	.149	.114
9.62	1.849	.432	.324	.263	.224	.196	.161	.123
10.75	1.912	.471	.353	.286	.243	.213	.174	.132
12.75	2.017	.536	.403	.327	.278	.243	.197	.149
14.00	2.079	.576	.434	.352	.299	.261	.212	.159
16.00	2.176	.639	.482	.391	.332	.290	.234	.175
18.00	2.269	.699	.530	.430	.365	.318	.257	.191
20.00	2.360	.758	.576	.468	.397	.346	.279	.207
24.00	2.536	.873	.667	.543	.461	.402	.323	.238
30.00	2.792	1.037	.798	.652	.554	.483	.388	.284
36.00	3.045	1.196	.926	.759	.646	.563	.452	.330
42.00	3.301	1.352	1.052	.865	.736	.643	.516	.376

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.200	.152	.127	.110	.099	.084	.068
4.50	1.413	.240	.182	.150	.129	.115	.097	.077
5.56	1.484	.281	.212	.174	.149	.133	.111	.087
6.62	1.548	.320	.241	.197	.169	.149	.124	.097
7.62	1.603	.356	.267	.218	.187	.165	.136	.105
8.62	1.655	.390	.294	.239	.204	.180	.148	.114
9.62	1.705	.424	.319	.260	.221	.195	.160	.122
10.75	1.758	.461	.347	.283	.241	.211	.173	.131
12.75	1.846	.524	.396	.322	.274	.240	.196	.148
14.00	1.898	.562	.426	.346	.295	.258	.210	.158
16.00	1.978	.621	.472	.385	.327	.286	.232	.174
18.00	2.055	.678	.517	.422	.359	.314	.254	.189
20.00	2.128	.733	.561	.458	.390	.341	.276	.205
24.00	2.269	.839	.647	.530	.451	.394	.318	.235
30.00	2.470	.989	.770	.633	.540	.473	.381	.281
36.00	2.664	1.133	.888	.733	.627	.549	.443	.325
42.00	2.855	1.271	1.002	.830	.711	.624	.503	.369

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.249	.190	.158	.137	.123	.105	.085
4.50	1.674	.299	.226	.187	.162	.144	.121	.097
5.50	1.775	.350	.264	.217	.187	.166	.138	.109
6.62	1.867	.399	.300	.246	.211	.187	.155	.121
7.62	1.949	.443	.334	.273	.233	.206	.170	.132
8.62	2.026	.487	.367	.299	.256	.225	.185	.143
9.62	2.101	.530	.399	.325	.277	.244	.200	.153
10.75	2.182	.577	.435	.354	.302	.265	.217	.165
12.75	2.321	.658	.497	.405	.344	.302	.246	.186
14.00	2.405	.707	.535	.436	.370	.324	.263	.198
16.00	2.536	.784	.595	.485	.412	.360	.292	.218
18.00	2.664	.860	.654	.533	.453	.396	.320	.238
20.00	2.792	.934	.713	.581	.493	.431	.348	.258
24.00	3.045	1.079	.827	.675	.574	.501	.404	.298
30.00	3.432	1.293	.997	.815	.693	.605	.486	.357
36.00	3.839	1.506	1.165	.955	.812	.709	.569	.415
42.00	4.280	1.722	1.336	1.096	.932	.813	.652	.475

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.245	.188	.156	.136	.122	.104	.085
4.50	1.511	.293	.223	.185	.160	.143	.120	.096
5.56	1.592	.342	.259	.214	.184	.164	.137	.108
6.62	1.666	.389	.295	.242	.208	.184	.153	.120
7.62	1.731	.431	.327	.268	.230	.203	.168	.131
8.62	1.791	.472	.358	.293	.251	.222	.183	.141
9.62	1.849	.512	.389	.318	.272	.240	.197	.152
10.75	1.912	.556	.423	.346	.296	.260	.214	.163
12.75	2.017	.631	.482	.394	.337	.296	.242	.183
14.00	2.079	.676	.517	.424	.362	.318	.259	.196
16.00	2.176	.746	.573	.470	.401	.352	.286	.215
18.00	2.269	.814	.628	.515	.440	.386	.313	.235
20.00	2.360	.880	.681	.560	.478	.419	.340	.254
24.00	2.536	1.007	.784	.646	.553	.485	.393	.292
30.00	2.792	1.189	.934	.773	.662	.581	.471	.348
36.00	3.045	1.365	1.079	.896	.769	.675	.547	.404
42.00	3.301	1.537	1.222	1.018	.875	.769	.623	.459

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.242	.186	.155	.135	.122	.104	.084
4.50	1.413	.289	.221	.183	.159	.142	.120	.096
5.56	1.484	.337	.256	.212	.183	.163	.136	.108
6.62	1.548	.382	.291	.239	.206	.183	.152	.119
7.62	1.603	.423	.322	.265	.228	.201	.167	.130
8.62	1.655	.462	.353	.290	.248	.220	.181	.140
9.62	1.705	.500	.382	.314	.269	.237	.196	.151
10.75	1.758	.542	.415	.341	.292	.257	.211	.162
12.75	1.846	.613	.471	.387	.332	.292	.239	.182
14.00	1.898	.655	.505	.416	.356	.313	.256	.194
16.00	1.978	.721	.558	.460	.394	.346	.283	.213
18.00	2.055	.784	.610	.503	.431	.379	.309	.232
20.00	2.128	.846	.660	.545	.468	.411	.335	.251
24.00	2.269	.962	.757	.628	.539	.474	.386	.288
30.00	2.470	1.127	.895	.746	.642	.566	.460	.342
36.00	2.664	1.283	1.027	.860	.742	.654	.533	.396
42.00	2.855	1.433	1.155	.971	.840	.742	.605	.449

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPF

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.290	.223	.186	.163	.146	.125	.101
4.50	1.674	.347	.265	.220	.191	.171	.144	.115
5.50	1.775	.405	.309	.255	.220	.196	.164	.130
6.62	1.867	.460	.350	.288	.248	.220	.183	.144
7.62	1.949	.511	.389	.319	.275	.243	.201	.157
8.62	2.026	.559	.426	.350	.300	.265	.219	.169
9.62	2.101	.607	.463	.380	.325	.287	.236	.182
10.75	2.182	.659	.504	.413	.354	.311	.256	.196
12.75	2.321	.749	.574	.471	.403	.354	.290	.220
14.00	2.405	.804	.617	.506	.433	.380	.311	.235
16.00	2.536	.889	.685	.562	.480	.422	.344	.259
18.00	2.664	.972	.751	.617	.527	.463	.376	.282
20.00	2.792	1.053	.816	.672	.574	.504	.409	.306
24.00	3.045	1.212	.944	.779	.666	.584	.473	.352
30.00	3.432	1.446	1.134	.937	.802	.704	.569	.421
36.00	3.839	1.680	1.322	1.095	.938	.823	.665	.490
42.00	4.280	1.917	1.514	1.255	1.076	.944	.762	.559

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DEFINITION      Q=KP*(TG-TP)

      WHERE     Q = HEAT TRANSFER TO PIPE
                    BTU/HR,FT OF PIPE

                KP= PIPE HEAT TRANSFER FACTOR
                    BTU/HR,FT OF PIPE, F

                TG= AVERAGE EARTH TEMPERATURE, F

                TP= PIPE TEMPERATURE ,   F
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THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION	THICKNESS	(INCHES)					
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.285	.220	.184	.161	.145	.124	.101
4.50	1.511	.340	.261	.217	.189	.169	.143	.115
5.56	1.592	.395	.303	.251	.217	.193	.162	.129
6.62	1.666	.447	.343	.283	.244	.217	.181	.143
7.62	1.731	.494	.379	.313	.270	.239	.199	.155
8.62	1.791	.540	.415	.342	.294	.261	.216	.168
9.62	1.849	.584	.450	.371	.319	.282	.233	.180
10.75	1.912	.632	.488	.402	.346	.305	.252	.193
12.75	2.017	.714	.553	.457	.392	.346	.284	.217
14.00	2.079	.764	.593	.490	.421	.371	.304	.231
16.00	2.176	.840	.655	.542	.466	.411	.336	.254
18.00	2.269	.914	.716	.593	.510	.449	.367	.277
20.00	2.360	.985	.775	.643	.553	.487	.398	.299
24.00	2.536	1.122	.889	.740	.638	.562	.459	.344
30.00	2.792	1.318	1.053	.881	.761	.672	.548	.409
36.00	3.045	1.507	1.212	1.019	.881	.779	.636	.473
42.00	3.301	1.691	1.369	1.154	1.000	.884	.723	.538

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.281	.218	.183	.160	.144	.123	.100
4.50	1.413	.334	.258	.215	.187	.168	.142	.114
5.50	1.484	.388	.298	.248	.215	.192	.161	.128
6.62	1.548	.438	.337	.279	.242	.215	.180	.142
7.62	1.603	.483	.373	.309	.266	.237	.197	.154
8.62	1.655	.527	.407	.337	.291	.258	.214	.166
9.62	1.705	.569	.440	.364	.314	.278	.230	.178
10.75	1.758	.614	.477	.395	.340	.301	.249	.192
12.75	1.846	.691	.540	.447	.385	.341	.281	.215
14.00	1.898	.738	.577	.479	.413	.365	.300	.229
16.00	1.978	.809	.636	.529	.456	.403	.331	.251
18.00	2.055	.877	.693	.577	.498	.440	.361	.273
20.00	2.128	.942	.748	.624	.539	.477	.391	.295
24.00	2.269	1.067	.854	.716	.619	.548	.449	.338
30.00	2.470	1.242	1.004	.846	.735	.651	.534	.401
36.00	2.664	1.407	1.147	.972	.846	.751	.617	.463
42.00	2.855	1.565	1.285	1.093	.954	.849	.698	.524

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.330	.255	.214	.187	.169	.144	.117
4.50	1.674	.393	.303	.252	.220	.197	.166	.134
5.56	1.775	.457	.351	.291	.253	.225	.189	.150
6.62	1.867	.517	.398	.329	.285	.253	.211	.166
7.62	1.949	.572	.440	.364	.314	.279	.232	.181
8.62	2.026	.626	.482	.398	.343	.304	.252	.196
9.62	2.101	.678	.523	.432	.372	.329	.272	.210
10.75	2.182	.734	.568	.469	.403	.356	.294	.226
12.75	2.321	.832	.645	.533	.458	.404	.332	.254
14.00	2.405	.890	.693	.573	.492	.434	.356	.271
16.00	2.536	.982	.767	.635	.545	.481	.394	.298
18.00	2.664	1.072	.839	.696	.598	.527	.431	.325
20.00	2.792	1.159	.911	.756	.650	.572	.468	.351
24.00	3.045	1.330	1.051	.874	.752	.663	.540	.404
30.00	3.432	1.580	1.257	1.049	.904	.797	.649	.483
36.00	3.839	1.831	1.463	1.224	1.055	.930	.757	.562
42.00	4.280	2.087	1.673	1.401	1.209	1.066	.867	.642

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.323	.251	.211	.185	.167	.143	.116
4.50	1.511	.383	.297	.248	.216	.194	.165	.133
5.56	1.592	.443	.343	.286	.248	.222	.187	.149
6.62	1.666	.501	.388	.322	.279	.249	.209	.165
7.62	1.731	.552	.428	.356	.308	.274	.228	.179
8.62	1.791	.601	.467	.388	.336	.298	.248	.193
9.62	1.849	.649	.506	.420	.363	.322	.267	.207
10.75	1.912	.701	.547	.455	.393	.348	.288	.223
12.75	2.017	.789	.619	.515	.445	.394	.325	.249
14.00	2.079	.842	.663	.552	.477	.422	.348	.266
16.00	2.176	.923	.730	.609	.526	.466	.384	.292
18.00	2.269	1.001	.796	.665	.575	.509	.419	.318
20.00	2.360	1.077	.859	.720	.623	.552	.453	.343
24.00	2.536	1.222	.982	.826	.716	.635	.522	.394
30.00	2.792	1.429	1.159	.980	.852	.756	.621	.468
36.00	3.045	1.627	1.330	1.129	.984	.874	.719	.540
42.00	3.301	1.821	1.497	1.275	1.114	.991	.816	.613

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.318	.248	.209	.184	.166	.142	.116
4.50	1.413	.377	.293	.245	.214	.192	.163	.132
5.56	1.484	.435	.338	.282	.246	.220	.185	.148
6.62	1.546	.489	.381	.318	.276	.246	.207	.163
7.62	1.603	.538	.420	.350	.304	.270	.226	.178
8.62	1.655	.585	.458	.381	.330	.294	.245	.191
9.62	1.705	.630	.494	.412	.357	.317	.264	.205
10.75	1.758	.679	.534	.445	.386	.343	.284	.220
12.75	1.846	.761	.602	.503	.436	.387	.320	.247
14.00	1.898	.810	.643	.538	.466	.414	.342	.263
16.00	1.978	.885	.706	.593	.514	.456	.377	.288
18.00	2.055	.957	.767	.645	.560	.497	.411	.313
20.00	2.128	1.026	.826	.697	.605	.538	.444	.338
24.00	2.269	1.157	.939	.796	.693	.616	.509	.386
30.00	2.470	1.340	1.100	.937	.819	.730	.604	.457
36.00	2.664	1.512	1.251	1.072	.940	.839	.696	.527
42.00	2.855	1.676	1.398	1.202	1.057	.946	.785	.595

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.367	.286	.241	.211	.191	.163	.133
4.50	1.674	.436	.338	.283	.247	.222	.188	.152
5.56	1.775	.505	.392	.326	.284	.254	.214	.170
6.62	1.867	.570	.443	.368	.319	.285	.239	.188
7.62	1.949	.630	.489	.407	.352	.313	.262	.205
8.62	2.026	.687	.534	.444	.384	.341	.284	.221
9.62	2.101	.742	.579	.481	.416	.369	.306	.238
10.75	2.182	.803	.627	.521	.450	.399	.331	.255
12.75	2.321	.906	.711	.592	.511	.452	.373	.287
14.00	2.405	.969	.762	.635	.548	.485	.400	.306
16.00	2.536	1.066	.842	.702	.607	.537	.442	.336
18.00	2.664	1.161	.921	.769	.664	.588	.483	.366
20.00	2.792	1.254	.997	.834	.721	.638	.524	.396
24.00	3.045	1.434	1.148	.963	.833	.737	.605	.455
30.00	3.432	1.699	1.369	1.152	.999	.884	.725	.543
36.00	3.839	1.963	1.590	1.342	1.164	1.031	.845	.632
42.00	4.280	2.235	1.816	1.534	1.332	1.180	.967	.721

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.359	.281	.237	.208	.188	.161	.132
4.50	1.511	.424	.331	.278	.243	.219	.186	.150
5.56	1.592	.489	.382	.320	.279	.250	.211	.169
6.62	1.666	.550	.430	.360	.313	.280	.235	.186
7.62	1.731	.605	.474	.396	.344	.307	.257	.202
8.62	1.791	.658	.517	.432	.375	.334	.279	.218
9.62	1.849	.708	.558	.466	.405	.360	.300	.234
10.75	1.912	.763	.603	.504	.438	.389	.324	.251
12.75	2.017	.856	.680	.570	.494	.439	.365	.281
14.00	2.079	.912	.726	.610	.529	.470	.390	.300
16.00	2.176	.997	.798	.672	.583	.518	.429	.329
18.00	2.269	1.079	.868	.732	.636	.566	.468	.357
20.00	2.360	1.158	.936	.791	.688	.612	.506	.386
24.00	2.536	1.310	1.066	.905	.789	.702	.581	.442
30.00	2.792	1.525	1.254	1.069	.935	.834	.691	.524
36.00	3.045	1.731	1.434	1.228	1.078	.963	.798	.605
42.00	3.301	1.933	1.611	1.385	1.218	1.089	.904	.685

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.353	.277	.234	.206	.187	.160	.131
4.50	1.413	.416	.326	.274	.241	.217	.184	.149
5.56	1.484	.478	.375	.315	.275	.247	.209	.167
6.62	1.548	.537	.422	.354	.309	.276	.233	.185
7.62	1.603	.589	.464	.389	.339	.303	.254	.201
8.62	1.655	.638	.505	.423	.368	.329	.275	.216
9.62	1.705	.686	.544	.457	.397	.354	.296	.231
10.75	1.758	.737	.587	.493	.429	.382	.319	.248
12.75	1.846	.824	.659	.555	.483	.431	.359	.278
14.00	1.898	.875	.703	.593	.516	.460	.383	.296
16.00	1.978	.953	.770	.651	.568	.506	.421	.324
18.00	2.055	1.028	.835	.708	.618	.551	.458	.352
20.00	2.128	1.099	.897	.763	.667	.595	.494	.379
24.00	2.269	1.235	1.016	.868	.761	.680	.566	.433
30.00	2.470	1.423	1.184	1.018	.896	.803	.669	.511
36.00	2.664	1.601	1.343	1.161	1.025	.921	.769	.588
42.00	2.855	1.771	1.496	1.299	1.151	1.035	.866	.663

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.528	.424	.363	.322	.293	.254	.210
4.50	1.674	.618	.496	.423	.374	.339	.291	.238
5.56	1.775	.706	.568	.483	.426	.385	.329	.266
6.62	1.867	.788	.636	.541	.477	.430	.366	.294
7.62	1.949	.862	.697	.594	.522	.470	.399	.319
8.62	2.026	.932	.756	.644	.567	.510	.432	.343
9.62	2.101	1.000	.813	.694	.610	.549	.464	.367
10.75	2.182	1.073	.876	.748	.658	.592	.499	.394
12.75	2.321	1.197	.983	.841	.741	.666	.561	.440
14.00	2.405	1.271	1.047	.898	.791	.711	.599	.469
16.00	2.536	1.386	1.147	.986	.870	.782	.658	.514
18.00	2.664	1.497	1.245	1.073	.947	.852	.716	.558
20.00	2.792	1.606	1.340	1.157	1.023	.921	.774	.602
24.00	3.045	1.817	1.527	1.323	1.172	1.056	.888	.689
30.00	3.432	2.127	1.801	1.567	1.392	1.256	1.057	.818
36.00	3.839	2.439	2.075	1.812	1.613	1.456	1.227	.948
42.00	4.280	2.762	2.358	2.063	1.838	1.661	1.400	1.080

SSHT= 92

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.511	.413	.355	.316	.288	.250	.207
4.50	1.511	.594	.480	.412	.365	.332	.286	.234
5.56	1.592	.675	.547	.469	.415	.376	.322	.262
6.62	1.666	.750	.610	.523	.462	.418	.357	.288
7.62	1.731	.816	.667	.572	.505	.456	.389	.312
8.62	1.791	.879	.721	.618	.547	.494	.420	.336
9.62	1.849	.939	.772	.664	.587	.530	.450	.358
10.75	1.912	1.003	.829	.713	.631	.570	.483	.384
12.75	2.017	1.110	.923	.797	.707	.638	.541	.428
14.00	2.079	1.174	.980	.848	.752	.679	.576	.454
16.00	2.176	1.271	1.067	.926	.823	.744	.631	.497
18.00	2.269	1.364	1.151	1.002	.892	.807	.684	.538
20.00	2.360	1.453	1.232	1.075	.958	.868	.736	.578
24.00	2.536	1.622	1.386	1.216	1.087	.986	.838	.658
30.00	2.792	1.861	1.606	1.417	1.272	1.157	.986	.774
36.00	3.045	2.090	1.817	1.611	1.451	1.323	1.130	.888
42.00	3.301	2.316	2.024	1.802	1.627	1.486	1.272	1.001

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.499	.405	.349	.311	.284	.247	.205
4.50	1.413	.578	.470	.404	.359	.327	.282	.232
5.56	1.484	.655	.534	.459	.407	.369	.317	.258
6.62	1.548	.725	.594	.511	.453	.410	.351	.284
7.62	1.603	.787	.647	.557	.494	.447	.382	.308
8.62	1.655	.845	.698	.601	.533	.483	.412	.330
9.62	1.705	.900	.746	.644	.572	.517	.441	.353
10.75	1.758	.959	.798	.691	.613	.555	.473	.377
12.75	1.846	1.056	.886	.769	.684	.620	.528	.419
14.00	1.898	1.114	.938	.816	.727	.659	.561	.445
16.00	1.978	1.201	1.017	.888	.793	.719	.613	.485
18.00	2.055	1.283	1.093	.958	.856	.778	.663	.525
20.00	2.128	1.361	1.165	1.024	.918	.834	.712	.563
24.00	2.269	1.508	1.302	1.151	1.035	.943	.807	.638
30.00	2.470	1.712	1.494	1.329	1.201	1.098	.942	.747
36.00	2.664	1.903	1.674	1.497	1.358	1.245	1.073	.852
42.00	2.855	2.086	1.846	1.659	1.510	1.387	1.199	.955

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.569	.700	.581	.507	.457	.419	.368	.308
4.50	1.674	.806	.670	.585	.525	.481	.419	.348
5.56	1.775	.908	.758	.662	.593	.542	.471	.388
6.62	1.867	1.003	.841	.734	.658	.601	.520	.427
7.62	1.949	1.086	.914	.799	.717	.654	.565	.462
8.62	2.026	1.165	.984	.862	.773	.706	.609	.495
9.62	2.101	1.240	1.052	.923	.828	.756	.652	.529
10.75	2.182	1.321	1.125	.988	.888	.810	.699	.565
12.75	2.321	1.458	1.249	1.101	.991	.905	.780	.629
14.00	2.405	1.540	1.324	1.169	1.053	.962	.829	.668
16.00	2.536	1.666	1.439	1.275	1.150	1.052	.907	.729
18.00	2.664	1.788	1.551	1.378	1.244	1.139	.983	.789
20.00	2.792	1.906	1.660	1.478	1.337	1.225	1.058	.849
24.00	3.045	2.136	1.873	1.674	1.519	1.394	1.205	.966
30.00	3.432	2.476	2.186	1.963	1.787	1.643	1.423	1.141
36.00	3.839	2.821	2.503	2.255	2.056	1.894	1.643	1.317
42.00	4.280	3.182	2.832	2.557	2.335	2.152	1.869	1.498

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.425	.670	.560	.491	.443	.408	.359	.302
4.50	1.511	.766	.643	.563	.508	.466	.408	.341
5.56	1.592	.858	.723	.634	.571	.524	.457	.379
6.62	1.666	.942	.797	.701	.631	.578	.503	.415
7.62	1.731	1.015	.863	.760	.685	.627	.545	.448
8.62	1.791	1.083	.925	.816	.736	.675	.586	.480
9.62	1.849	1.148	.985	.870	.786	.720	.625	.511
10.75	1.912	1.217	1.048	.929	.839	.770	.668	.545
12.75	2.017	1.332	1.155	1.027	.930	.854	.742	.604
14.00	2.079	1.399	1.219	1.086	.985	.905	.786	.640
16.00	2.176	1.502	1.315	1.177	1.069	.984	.856	.695
18.00	2.269	1.600	1.408	1.263	1.150	1.060	.923	.750
20.00	2.360	1.694	1.497	1.347	1.229	1.133	.988	.803
24.00	2.536	1.872	1.666	1.506	1.379	1.275	1.115	.907
30.00	2.792	2.123	1.906	1.734	1.594	1.478	1.297	1.058
36.00	3.045	2.365	2.136	1.952	1.801	1.674	1.474	1.205
42.00	3.301	2.604	2.363	2.167	2.004	1.867	1.648	1.350

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.337	.650	.546	.480	.435	.401	.353	.298
4.50	1.413	.740	.624	.549	.496	.456	.401	.335
5.56	1.484	.825	.700	.616	.557	.512	.448	.372
6.62	1.548	.903	.769	.679	.613	.563	.492	.407
7.62	1.603	.970	.830	.734	.664	.610	.532	.439
8.62	1.655	1.032	.888	.787	.712	.654	.571	.469
9.62	1.705	1.090	.942	.837	.758	.697	.608	.499
10.75	1.758	1.153	1.000	.891	.808	.743	.648	.532
12.75	1.846	1.255	1.097	.981	.892	.822	.717	.587
14.00	1.898	1.315	1.154	1.034	.942	.869	.759	.621
16.00	1.978	1.405	1.240	1.116	1.019	.941	.823	.674
18.00	2.055	1.490	1.322	1.194	1.092	1.010	.885	.724
20.00	2.128	1.571	1.400	1.268	1.162	1.077	.945	.774
24.00	2.269	1.722	1.546	1.408	1.296	1.203	1.060	.870
30.00	2.470	1.932	1.750	1.604	1.483	1.382	1.222	1.007
36.00	2.664	2.129	1.941	1.788	1.660	1.551	1.378	1.139
42.00	2.855	2.317	2.124	1.964	1.829	1.714	1.527	1.268

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.161	.120	.099	.086	.076	.064	.052
4.50	2.093	.196	.145	.118	.101	.090	.075	.059
5.56	2.218	.231	.170	.137	.117	.103	.086	.067
6.62	2.334	.266	.195	.157	.133	.117	.096	.074
7.62	2.436	.299	.218	.175	.148	.129	.106	.081
8.62	2.533	.331	.241	.192	.162	.142	.115	.088
9.62	2.626	.362	.263	.210	.177	.154	.125	.094
10.75	2.728	.397	.288	.230	.193	.168	.136	.102
12.75	2.901	.458	.332	.264	.222	.192	.154	.115
14.00	3.006	.496	.360	.286	.239	.207	.166	.123
16.00	3.170	.556	.403	.320	.267	.231	.184	.136
18.00	3.330	.614	.446	.353	.295	.255	.203	.148
20.00	3.490	.672	.488	.387	.323	.278	.221	.161
24.00	3.806	.787	.572	.454	.378	.325	.257	.186
30.00	4.290	.956	.697	.553	.460	.395	.311	.224
36.00	4.798	1.124	.822	.651	.542	.465	.366	.261
42.00	5.350	1.294	.947	.751	.624	.535	.420	.299

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.160	.120	.098	.085	.076	.064	.052
4.50	1.889	.194	.144	.117	.101	.089	.075	.059
5.56	1.990	.229	.168	.136	.116	.103	.085	.067
6.62	2.082	.263	.193	.155	.132	.116	.096	.074
7.62	2.163	.294	.215	.173	.147	.129	.105	.081
8.62	2.239	.325	.238	.191	.161	.141	.115	.087
9.62	2.312	.356	.260	.208	.175	.153	.124	.094
10.75	2.390	.389	.284	.227	.191	.166	.135	.101
12.75	2.521	.448	.327	.261	.219	.190	.153	.114
14.00	2.599	.484	.353	.282	.236	.205	.164	.122
16.00	2.720	.540	.395	.314	.263	.228	.183	.135
18.00	2.837	.595	.436	.347	.291	.251	.201	.147
20.00	2.950	.649	.476	.379	.317	.274	.218	.160
24.00	3.170	.755	.556	.443	.370	.320	.254	.184
30.00	3.490	.909	.672	.537	.449	.387	.306	.221
36.00	3.806	1.059	.787	.629	.526	.454	.358	.257
42.00	4.126	1.207	.900	.720	.603	.520	.410	.293

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .150 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.159	.119	.098	.085	.076	.064	.052
4.50	1.766	.192	.143	.117	.100	.089	.074	.059
5.56	1.855	.227	.167	.136	.116	.102	.085	.067
6.62	1.935	.260	.191	.155	.131	.116	.095	.074
7.62	2.004	.291	.214	.172	.146	.128	.105	.081
8.62	2.069	.321	.236	.189	.160	.140	.114	.087
9.62	2.131	.351	.257	.206	.174	.152	.124	.094
10.75	2.197	.384	.281	.225	.190	.165	.134	.101
12.75	2.307	.441	.323	.258	.217	.189	.152	.114
14.00	2.373	.475	.349	.279	.234	.203	.163	.122
16.00	2.473	.529	.389	.311	.261	.226	.181	.134
18.00	2.568	.582	.429	.343	.287	.249	.199	.146
20.00	2.660	.634	.468	.374	.314	.272	.217	.159
24.00	2.837	.735	.544	.436	.365	.316	.251	.183
30.00	3.088	.879	.656	.526	.441	.381	.303	.219
36.00	3.330	1.019	.764	.614	.516	.446	.353	.255
42.00	3.569	1.154	.870	.701	.589	.509	.404	.290

SSHT= 100

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.210	.158	.130	.113	.101	.085	.069
4.50	2.093	.254	.189	.155	.133	.118	.099	.079
5.56	2.218	.299	.222	.180	.154	.136	.113	.089
6.62	2.334	.343	.253	.205	.175	.154	.127	.098
7.62	2.436	.384	.283	.228	.194	.170	.139	.107
8.62	2.533	.424	.312	.251	.213	.186	.152	.116
9.62	2.626	.463	.340	.274	.231	.202	.164	.125
10.75	2.728	.507	.372	.299	.252	.220	.178	.135
12.75	2.901	.582	.428	.343	.289	.251	.203	.152
14.00	3.006	.629	.463	.370	.312	.271	.218	.162
16.00	3.170	.702	.517	.414	.348	.302	.242	.179
18.00	3.330	.774	.571	.457	.383	.332	.266	.196
20.00	3.490	.844	.624	.499	.419	.363	.289	.212
24.00	3.806	.984	.729	.583	.489	.423	.337	.245
30.00	4.290	1.189	.885	.708	.594	.513	.407	.294
36.00	4.798	1.394	1.040	.833	.698	.603	.477	.343
42.00	5.350	1.601	1.196	.959	.803	.693	.547	.392

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.207	.156	.129	.112	.100	.085	.069
4.50	1.889	.250	.187	.153	.132	.117	.098	.078
5.56	1.990	.294	.219	.178	.153	.135	.112	.088
6.62	2.082	.337	.250	.203	.173	.153	.126	.098
7.62	2.163	.376	.279	.225	.192	.169	.138	.107
8.62	2.239	.415	.307	.248	.210	.184	.151	.115
9.62	2.312	.452	.335	.270	.229	.200	.163	.124
10.75	2.390	.494	.365	.294	.249	.218	.177	.134
12.75	2.521	.565	.419	.337	.285	.248	.201	.150
14.00	2.599	.609	.452	.363	.307	.267	.215	.161
16.00	2.720	.677	.503	.405	.341	.297	.239	.177
18.00	2.837	.743	.554	.446	.376	.327	.262	.194
20.00	2.950	.808	.604	.486	.410	.356	.285	.210
24.00	3.170	.935	.702	.566	.477	.414	.331	.242
30.00	3.490	1.118	.844	.682	.575	.499	.398	.289
36.00	3.806	1.295	.984	.797	.672	.583	.465	.337
42.00	4.126	1.470	1.121	.910	.768	.667	.531	.383

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .200 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.206	.156	.129	.112	.100	.085	.068
4.50	1.766	.248	.186	.152	.131	.117	.098	.078
5.56	1.855	.291	.217	.177	.152	.135	.112	.088
6.62	1.935	.333	.248	.201	.172	.152	.125	.098
7.62	2.004	.371	.276	.224	.190	.168	.138	.106
8.62	2.069	.408	.303	.246	.209	.183	.150	.115
9.62	2.131	.445	.331	.267	.227	.199	.162	.124
10.75	2.197	.485	.360	.291	.247	.216	.176	.133
12.75	2.307	.554	.412	.333	.282	.246	.199	.150
14.00	2.373	.595	.444	.359	.303	.264	.214	.160
16.00	2.473	.660	.494	.399	.337	.294	.237	.176
18.00	2.568	.724	.543	.439	.371	.323	.259	.192
20.00	2.660	.785	.591	.478	.404	.351	.282	.208
24.00	2.837	.904	.684	.554	.468	.407	.327	.240
30.00	3.088	1.073	.819	.665	.563	.490	.392	.286
36.00	3.330	1.235	.949	.774	.656	.571	.457	.332
42.00	3.569	1.392	1.075	.879	.747	.650	.520	.378

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.256	.194	.160	.139	.125	.106	.086
4.50	2.093	.309	.232	.190	.164	.146	.123	.098
5.50	2.218	.363	.271	.221	.190	.168	.140	.110
6.62	2.334	.415	.309	.251	.215	.190	.157	.122
7.62	2.436	.463	.345	.279	.238	.210	.172	.133
8.62	2.533	.510	.379	.307	.261	.229	.188	.144
9.62	2.626	.556	.413	.334	.284	.249	.203	.155
10.75	2.728	.607	.451	.365	.309	.270	.220	.167
12.75	2.901	.695	.518	.418	.353	.309	.250	.188
14.00	3.006	.749	.558	.450	.381	.332	.268	.201
16.00	3.170	.833	.623	.502	.424	.369	.298	.221
18.00	3.330	.916	.686	.553	.467	.406	.327	.242
20.00	3.490	.998	.748	.604	.510	.443	.356	.262
24.00	3.806	1.158	.872	.704	.594	.516	.413	.302
30.00	4.290	1.394	1.054	.853	.719	.625	.498	.363
36.00	4.798	1.629	1.236	1.001	.845	.733	.584	.423
42.00	5.350	1.867	1.420	1.151	.971	.842	.670	.483

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.253	.192	.159	.138	.124	.105	.085
4.50	1.889	.304	.229	.188	.163	.145	.122	.097
5.56	1.990	.356	.267	.219	.188	.167	.139	.109
6.62	2.082	.406	.304	.248	.213	.188	.156	.121
7.62	2.163	.452	.338	.275	.235	.207	.171	.132
8.62	2.239	.497	.372	.302	.258	.227	.186	.143
9.62	2.312	.540	.405	.329	.280	.246	.201	.154
10.75	2.390	.588	.441	.358	.304	.267	.218	.165
12.75	2.521	.671	.504	.409	.347	.304	.247	.186
14.00	2.599	.721	.543	.440	.373	.326	.265	.199
16.00	2.720	.799	.603	.489	.415	.362	.293	.219
18.00	2.837	.874	.662	.538	.456	.398	.321	.239
20.00	2.950	.948	.720	.585	.496	.433	.349	.258
24.00	3.170	1.091	.833	.679	.576	.502	.404	.298
30.00	3.490	1.297	.998	.815	.692	.604	.485	.356
36.00	3.806	1.496	1.158	.949	.807	.704	.565	.413
42.00	4.126	1.691	1.315	1.081	.920	.804	.645	.470

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .250 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.250	.191	.158	.138	.123	.105	.085
4.50	1.766	.300	.227	.187	.162	.144	.121	.097
5.56	1.855	.351	.265	.217	.187	.166	.138	.109
6.62	1.935	.400	.301	.246	.211	.187	.155	.121
7.62	2.004	.445	.334	.273	.233	.206	.170	.132
8.62	2.069	.488	.367	.299	.255	.225	.185	.142
9.62	2.131	.530	.399	.325	.277	.243	.199	.153
10.75	2.197	.576	.434	.353	.301	.264	.216	.164
12.75	2.307	.654	.495	.403	.343	.300	.244	.185
14.00	2.373	.702	.532	.433	.368	.323	.262	.197
16.00	2.473	.776	.590	.481	.409	.358	.290	.217
18.00	2.568	.847	.646	.527	.448	.392	.317	.237
20.00	2.660	.916	.701	.573	.487	.426	.344	.256
24.00	2.837	1.049	.808	.662	.564	.493	.398	.294
30.00	3.088	1.237	.962	.791	.675	.591	.476	.351
36.00	3.330	1.416	1.109	.916	.783	.686	.553	.406
42.00	3.569	1.589	1.253	1.038	.889	.780	.629	.461

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.300	.229	.190	.165	.148	.126	.102
4.50	2.093	.361	.273	.225	.195	.173	.146	.117
5.56	2.218	.423	.318	.261	.225	.199	.166	.131
6.62	2.334	.482	.362	.296	.254	.225	.186	.145
7.62	2.436	.537	.403	.329	.281	.248	.205	.159
8.62	2.533	.590	.443	.361	.308	.271	.223	.171
9.62	2.626	.642	.482	.392	.334	.294	.241	.184
10.75	2.728	.699	.526	.427	.364	.319	.261	.198
12.75	2.901	.798	.601	.489	.415	.364	.296	.223
14.00	3.006	.858	.648	.526	.447	.391	.317	.238
16.00	3.170	.952	.721	.586	.497	.435	.352	.263
18.00	3.330	1.045	.793	.644	.547	.478	.386	.287
20.00	3.490	1.135	.864	.703	.596	.520	.419	.311
24.00	3.806	1.313	1.003	.817	.693	.605	.486	.358
30.00	4.290	1.574	1.209	.987	.838	.730	.586	.429
36.00	4.798	1.834	1.415	1.157	.982	.856	.686	.500
42.00	5.350	2.099	1.623	1.328	1.128	.983	.786	.571

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR-SQ.FT.F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .300 BTU/HR,SQ.FT.F/IN

DEPTH OF PIPE DPTH= [illegible].0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.296	.226	.188	.164	.147	.125	.102
4.50	1.889	.354	.269	.222	.193	.172	.145	[illegible]
5.50	1.990	.413	.313	.258	.222	.197	.165	[illegible]
6.62	2.082	.470	.356	.292	.251	.222	.184	[illegible]
7.62	2.163	.522	.395	.323	.277	.245	.203	[illegible]
8.62	2.239	.572	.433	.354	.303	.267	.220	[illegible]
9.62	2.312	.621	.471	.385	.329	.289	.238	[illegible]
10.75	2.390	.674	.512	.418	.357	.314	.257	[illegible]
12.75	2.521	.766	.583	.476	.406	.357	.291	.221
14.00	2.599	.821	.627	.512	.437	.383	.312	[illegible]
16.00	2.720	.907	.695	.568	.485	.425	.345	[illegible]
18.00	2.837	.990	.761	.623	.531	.466	.378	[illegible]
20.00	2.950	1.071	.826	.677	.578	.506	.410	[illegible]
24.00	3.170	1.227	.952	.783	.669	.586	.474	[illegible]
30.00	3.490	1.451	1.135	.937	.801	.703	.568	[illegible]
36.00	3.806	1.667	1.313	1.087	.932	.817	.661	[illegible]
42.00	4.126	1.879	1.487	1.236	1.060	.931	.753	[illegible]

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .300 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.293	.224	.187	.163	.146	.125	.101
4.50	1.766	.350	.266	.221	.191	.171	.144	.115
5.56	1.855	.407	.310	.255	.220	.196	.164	.130
6.62	1.935	.462	.351	.289	.248	.220	.183	.144
7.62	2.004	.512	.389	.319	.274	.243	.201	.156
8.62	2.069	.560	.426	.350	.300	.265	.218	.169
9.62	2.131	.607	.463	.379	.325	.286	.236	.181
10.75	2.197	.658	.502	.412	.352	.310	.255	.195
12.75	2.307	.745	.571	.468	.400	.352	.288	.219
14.00	2.373	.797	.612	.503	.430	.378	.309	.233
16.00	2.473	.878	.677	.557	.476	.418	.341	.257
18.00	2.568	.955	.740	.609	.521	.458	.373	.280
20.00	2.660	1.030	.801	.661	.566	.497	.404	.302
24.00	2.837	1.174	.920	.761	.652	.573	.466	.347
30.00	3.088	1.377	1.089	.905	.778	.684	.556	.413
36.00	3.330	1.569	1.251	1.045	.900	.793	.644	.478
42.00	3.569	1.753	1.408	1.180	1.019	.899	.731	.541

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION -
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.343	.263	.219	.191	.171	.146	.118
4.50	2.093	.410	.312	.259	.224	.200	.169	.135
5.50	2.218	.479	.364	.300	.259	.230	.192	.152
6.62	2.334	.545	.413	.339	.292	.259	.215	[illegible]
7.62	2.436	.605	.459	.376	.323	.285	.236	.184
8.62	2.533	.664	.504	.412	.353	.312	.257	.198
9.62	2.626	.721	.547	.448	.383	.338	.277	.213
10.75	2.728	.784	.596	.487	.416	.366	.300	.229
12.75	2.901	.892	.680	.556	.475	.417	.340	.258
14.00	3.006	.958	.731	.598	.510	.448	.365	.275
16.00	3.170	1.060	.812	.665	.567	.497	.404	.303
18.00	3.330	1.161	.892	.730	.623	.546	.443	.331
20.00	3.490	1.259	.970	.795	.678	.594	.481	.359
24.00	3.806	1.452	1.124	.923	.787	.689	.557	.413
30.00	4.290	1.734	1.351	1.112	.949	.831	.671	.494
36.00	4.798	2.016	1.577	1.301	1.111	.973	.784	.576
42.00	5.350	2.303	1.807	1.492	1.275	1.116	.898	.657

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.337	.259	.216	.189	.170	.145	.118
4.50	1.889	.402	.308	.255	.222	.198	.167	.134
5.56	1.990	.467	.357	.295	.255	.227	.190	.151
6.62	2.082	.530	.405	.334	.288	.255	.213	.167
7.62	2.163	.587	.448	.369	.318	.281	.233	.182
8.62	2.239	.642	.491	.404	.347	.307	.254	.196
9.62	2.312	.695	.532	.438	.376	.332	.274	.211
10.75	2.390	.753	.578	.475	.408	.359	.296	.227
12.75	2.521	.852	.657	.540	.463	.408	.334	.254
14.00	2.599	.912	.705	.580	.497	.438	.358	.272
16.00	2.720	1.005	.779	.642	.550	.484	.396	.299
18.00	2.837	1.094	.852	.703	.603	.530	.433	.325
20.00	2.950	1.181	.923	.763	.655	.576	.469	.352
24.00	3.170	1.348	1.060	.880	.756	.665	.541	.404
30.00	3.490	1.586	1.259	1.049	.903	.795	.647	.481
36.00	3.806	1.816	1.452	1.214	1.047	.923	.751	.557
42.00	4.126	2.041	1.640	1.376	1.189	1.049	.854	.633

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .350 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.333	.257	.215	.188	.169	.144	.117
4.50	1.766	.396	.304	.253	.220	.197	.166	.134
5.56	1.855	.460	.352	.292	.253	.225	.189	.150
6.62	1.935	.520	.399	.330	.285	.253	.211	.166
7.62	2.004	.575	.441	.364	.314	.278	.231	.181
8.62	2.069	.627	.482	.398	.342	.303	.251	.195
9.62	2.131	.678	.522	.431	.371	.328	.271	.209
10.75	2.197	.733	.566	.467	.402	.355	.292	.225
12.75	2.307	.826	.641	.530	.455	.402	.330	.252
14.00	2.373	.883	.687	.568	.488	.431	.353	.269
16.00	2.473	.969	.757	.628	.540	.476	.390	.295
18.00	2.568	1.052	.826	.686	.590	.520	.426	.321
20.00	2.660	1.132	.892	.742	.639	.564	.461	.347
24.00	2.837	1.284	1.020	.852	.735	.649	.530	.398
30.00	3.086	1.498	1.202	1.009	.873	.772	.632	.473
36.00	3.330	1.700	1.376	1.161	1.007	.892	.730	.546
42.00	3.569	1.894	1.544	1.308	1.137	1.009	.827	.618

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.383	.295	.247	.216	.194	.166	.135
4.50	2.093	.457	.351	.291	.253	.226	.191	.153
5.56	2.218	.532	.407	.337	.292	.260	.218	.173
6.62	2.334	.604	.462	.381	.329	.292	.243	.191
7.62	2.436	.670	.512	.422	.363	.322	.267	.208
8.62	2.533	.733	.561	.462	.397	.351	.290	.225
9.62	2.626	.795	.609	.501	.430	.380	.313	.241
10.75	2.728	.863	.662	.545	.467	.412	.339	.260
12.75	2.901	.979	.754	.620	.531	.468	.384	.292
14.00	3.006	1.049	.810	.667	.571	.503	.411	.312
16.00	3.170	1.159	.898	.740	.633	.557	.455	.343
18.00	3.330	1.266	.984	.812	.695	.611	.498	.374
20.00	3.490	1.371	1.069	.882	.756	.665	.541	.405
24.00	3.806	1.576	1.235	1.022	.876	.770	.626	.466
30.00	4.290	1.878	1.481	1.229	1.055	.927	.752	.558
36.00	4.798	2.178	1.726	1.435	1.233	1.083	.878	.649
42.00	5.350	2.485	1.974	1.644	1.413	1.242	1.006	.741

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.376	.291	.244	.213	.192	.164	.134
4.50	1.889	.447	.344	.287	.250	.224	.189	.152
5.56	1.990	.518	.399	.331	.287	.256	.215	.171
6.62	2.082	.586	.451	.374	.323	.288	.240	.189
7.62	2.163	.647	.499	.413	.356	.316	.263	.206
8.62	2.239	.706	.545	.451	.389	.345	.286	.222
9.62	2.312	.763	.591	.488	.421	.373	.308	.238
10.75	2.390	.826	.640	.530	.456	.403	.333	.256
12.75	2.521	.931	.725	.601	.517	.457	.376	.287
14.00	2.599	.995	.777	.644	.554	.490	.402	.307
16.00	2.720	1.093	.858	.712	.613	.541	.444	.337
18.00	2.837	1.188	.936	.778	.671	.592	.485	.367
20.00	2.950	1.279	1.012	.843	.727	.642	.526	.396
24.00	3.170	1.455	1.159	.969	.837	.740	.605	.455
30.00	3.490	1.706	1.371	1.152	.998	.882	.722	.541
36.00	3.806	1.946	1.576	1.330	1.154	1.022	.837	.626
42.00	4.126	2.182	1.778	1.505	1.308	1.160	.951	.710

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .400 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.371	.288	.242	.212	.191	.163	.133
4.50	1.766	.440	.340	.284	.248	.222	.188	.151
5.56	1.855	.509	.393	.327	.284	.254	.214	.170
6.62	1.935	.574	.444	.369	.319	.285	.238	.188
7.62	2.004	.632	.490	.407	.352	.313	.261	.204
8.62	2.069	.689	.535	.444	.383	.340	.283	.221
9.62	2.131	.743	.578	.480	.414	.368	.305	.236
10.75	2.197	.801	.625	.519	.448	.397	.329	.254
12.75	2.307	.900	.707	.588	.507	.449	.371	.284
14.00	2.373	.960	.755	.629	.543	.481	.397	.303
16.00	2.473	1.051	.831	.694	.600	.531	.437	.333
18.00	2.568	1.138	.904	.757	.654	.579	.477	.362
20.00	2.660	1.221	.975	.818	.708	.627	.516	.391
24.00	2.837	1.380	1.111	.936	.812	.720	.592	.447
30.00	3.088	1.603	1.304	1.105	.962	.854	.703	.530
36.00	3.330	1.814	1.488	1.266	1.106	.984	.812	.611
42.00	3.569	2.015	1.665	1.423	1.246	1.111	.918	.691

DEFINITION   Q=KP*(TG-TP)

WHERE   Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE ,   F

THERMAL CONDUCTIVITY OF EARTH   KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE   DPTH=   4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.562	.444	.377	.333	.302	.260	.213
4.50	2.093	.662	.523	.441	.388	.350	.299	.242
5.56	2.218	.761	.601	.507	.444	.399	.338	.272
6.62	2.334	.855	.676	.569	.498	.446	.377	.300
7.62	2.436	.939	.745	.627	.547	.490	.412	.326
8.62	2.533	1.019	.811	.682	.595	.532	.447	.352
9.62	2.626	1.097	.875	.737	.643	.574	.481	.377
10.75	2.728	1.182	.945	.797	.695	.620	.518	.404
12.75	2.901	1.326	1.066	.900	.785	.700	.584	.453
14.00	3.006	1.413	1.139	.963	.840	.749	.624	.483
16.00	3.170	1.547	1.253	1.061	.927	.827	.688	.530
18.00	3.330	1.677	1.364	1.158	1.012	.903	.750	.577
20.00	3.490	1.804	1.473	1.252	1.095	.977	.812	.623
24.00	3.806	2.052	1.686	1.438	1.260	1.125	.935	.714
30.00	4.290	2.415	1.999	1.712	1.503	1.344	1.117	.851
36.00	4.798	2.779	2.312	1.987	1.747	1.563	1.299	.987
42.00	5.350	3.155	2.633	2.267	1.995	1.786	1.484	1.126

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.546	.434	.370	.327	.297	.256	.211
4.50	1.889	.640	.509	.432	.380	.344	.294	.239
5.56	1.990	.732	.583	.494	.434	.391	.333	.268
6.62	2.082	.819	.654	.553	.485	.436	.370	.295
7.62	2.163	.895	.717	.607	.532	.478	.403	.321
8.62	2.239	.968	.778	.659	.577	.518	.437	.345
9.62	2.312	1.038	.837	.710	.622	.557	.469	.369
10.75	2.390	1.114	.901	.765	.670	.601	.505	.396
12.75	2.521	1.240	1.010	.859	.754	.675	.567	.442
14.00	2.599	1.316	1.075	.917	.805	.721	.604	.471
16.00	2.720	1.431	1.176	1.005	.884	.792	.664	.516
18.00	2.837	1.542	1.273	1.091	.960	.861	.722	.559
20.00	2.950	1.648	1.367	1.175	1.035	.929	.779	.603
24.00	3.170	1.851	1.547	1.336	1.181	1.061	.890	.688
30.00	3.490	2.138	1.804	1.567	1.390	1.252	1.052	.812
36.00	3.806	2.413	2.052	1.791	1.593	1.438	1.211	.935
42.00	4.126	2.682	2.294	2.010	1.793	1.621	1.368	1.056

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= .650 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.535	.428	.365	.323	.294	.254	.209
4.50	1.766	.625	.500	.425	.375	.339	.291	.237
5.56	1.855	.713	.571	.485	.427	.385	.329	.265
6.62	1.935	.795	.638	.542	.477	.429	.365	.292
7.62	2.004	.867	.699	.594	.522	.469	.398	.317
8.62	2.069	.935	.756	.643	.565	.508	.430	.341
9.62	2.131	1.000	.812	.692	.608	.546	.461	.364
1[illegible][illegible]75	2.197	1.070	.872	.744	.654	.588	.495	.390
1[illegible].75	2.307	1.186	.973	.833	.734	.659	.555	.435
1[illegible].00	2.373	1.255	1.034	.887	.781	.702	.591	.463
1[illegible].00	2.473	1.360	1.127	.969	.856	.770	.648	.506
1[illegible].00	2.568	1.459	1.216	1.049	.927	.835	.703	.548
[illegible][illegible].00	2.660	1.553	1.301	1.126	.997	.898	.757	.589
[illegible][illegible].00	2.837	1.732	1.463	1.273	1.131	1.021	.861	.670
[illegible]0.00	3.088	1.980	1.690	1.481	1.321	1.196	1.012	.788
[illegible].00	3.330	2.212	1.905	1.677	1.503	1.364	1.158	.903
[illegible].00	3.569	2.434	2.110	1.867	1.678	1.527	1.299	1.015

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.961	.760	.620	.535	.478	.437	.380	.316
4.50	2.093	.882	.720	.621	.553	.503	.435	.358
5.56	2.218	1.002	.820	.706	.628	.570	.490	.400
6.62	2.334	1.113	.914	.787	.699	.634	.544	.441
7.62	2.436	1.211	.998	.861	.764	.692	.592	.477
8.62	2.533	1.305	1.079	.931	.827	.749	.639	.513
9.62	2.626	1.394	1.157	1.000	.888	.804	.686	.549
10.75	2.728	1.491	1.242	1.075	.955	.865	.737	.588
12.75	2.901	1.655	1.387	1.204	1.071	.969	.825	.656
14.00	3.006	1.753	1.474	1.282	1.141	1.033	.879	.697
16.00	3.170	1.904	1.609	1.403	1.251	1.133	.964	.763
18.00	3.330	2.050	1.740	1.521	1.358	1.231	1.048	.827
20.00	3.490	2.192	1.868	1.637	1.463	1.328	1.130	.891
24.00	3.806	2.469	2.118	1.863	1.669	1.517	1.292	1.018
30.00	4.290	2.676	2.486	2.197	1.974	1.797	1.533	1.205
36.00	4.798	3.287	2.855	2.532	2.279	2.078	1.774	1.394
42.00	5.350	3.715	3.238	2.877	2.593	2.366	2.022	1.587

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.781	.731	.601	.521	.467	.427	.373	.311
4.50	1.889	.844	.694	.601	.537	.490	.425	.351
5.56	1.990	.952	.787	.681	.608	.554	.478	.392
6.62	2.082	1.052	.873	.756	.675	.614	.529	.431
7.62	2.163	1.140	.949	.824	.735	.668	.574	.466
8.62	2.239	1.222	1.022	.888	.793	.721	.619	.500
9.62	2.312	1.300	1.092	.951	.849	.772	.662	.533
10.75	2.390	1.384	1.167	1.018	.910	.827	.709	.570
12.75	2.521	1.524	1.293	1.133	1.014	.923	.791	.634
14.00	2.599	1.606	1.369	1.201	1.077	.980	.840	.672
16.00	2.720	1.732	1.484	1.307	1.174	1.070	.918	.733
18.00	2.837	1.851	1.595	1.409	1.267	1.156	.993	.792
20.00	2.950	1.966	1.701	1.507	1.358	1.240	1.066	.850
24.00	3.170	2.183	1.904	1.695	1.533	1.403	1.208	.964
30.00	3.490	2.491	2.192	1.964	1.783	1.637	1.414	1.130
36.00	3.806	2.787	2.469	2.222	2.025	1.863	1.615	1.292
42.00	4.126	3.077	2.741	2.476	2.262	2.086	1.812	1.453

SSHT= 120

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

THERMAL CONDUCTIVITY OF INSULATION
KI= 1.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP

PIPE SIZE	INSULATION THICKNESS (INCHES)							
OD(INCHES)	.000	1.000	1.500	2.000	2.500	3.000	4.000	6.000
3.50	1.672	.712	.588	.511	.459	.421	.368	.308
4.50	1.766	.819	.677	.588	.527	.482	.419	.347
5.56	1.855	.920	.765	.665	.595	.543	.470	.386
6.62	1.935	1.013	.846	.736	.658	.600	.519	.424
7.62	2.004	1.094	.917	.800	.715	.652	.563	.458
8.62	2.069	1.170	.985	.860	.770	.702	.605	.491
9.62	2.131	1.241	1.049	.919	.823	.750	.646	.523
10.75	2.197	1.317	1.119	.981	.880	.803	.691	.558
12.75	2.307	1.443	1.235	1.087	.977	.892	.768	.619
14.00	2.375	1.516	1.303	1.150	1.036	.946	.815	.656
16.00	2.475	1.628	1.407	1.247	1.125	1.029	.887	.714
18.00	2.568	1.733	1.506	1.339	1.210	1.109	.957	.770
20.00	2.666	1.832	1.600	1.427	1.293	1.186	1.025	.824
24.00	2.837	2.020	1.778	1.595	1.450	1.333	1.156	.931
30.00	3.088	2.279	2.026	1.829	1.671	1.542	1.343	1.084
36.00	3.330	2.522	2.259	2.050	1.881	1.740	1.521	1.231
42.00	3.569	2.755	2.482	2.262	2.082	1.931	1.694	1.375

SSHTP

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	.565						
3	.074	.622						
4	.074	.670	4	1.070	.683			
6	.105	.748	6	1.320	.763			
8	.105	.818	8	1.520	.832			
10	.136	.879	10	1.920	.897			
12	.167	.936	12	2.180	.956			
14	.167	.993	14	2.480	1.014			
16	.198	1.046	16	2.720	1.070	16	1.780	1.111
18	.229	1.099	18	3.300	1.128	18	2.000	1.170
20	.260	1.150	20	3.640	1.183	20	2.125	1.227
22	.260	1.203						
24	.291	1.255	24	4.320	1.295	24	2.375	1.342
30	.354	1.413				30	2.750	1.520
36	.398	1.580	36	6.460	1.664	36	3.125	1.713
						42	3.500	1.929
						48	3.875	2.179
						54	4.075	2.470
						60	5.375	2.941

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	.519						
3	.074	.568						
4	.074	.607	4	1.070	.618			
6	.105	.670	6	1.320	.682			
8	.105	.725	8	1.520	.737			
10	.136	.773	10	1.920	.787			
12	.167	.817	12	2.180	.832			
14	.167	.860	14	2.480	.875			
16	.198	.899	16	2.720	.916	16	1.780	.946
18	.229	.937	18	3.300	.957	18	2.000	.988
20	.260	.974	20	3.640	.995	20	2.125	1.028
22	.260	1.011						
24	.291	1.047	24	4.320	1.071	24	2.375	1.105
30	.354	1.152				30	2.750	1.219
36	.398	1.256	36	6.460	1.295	36	3.125	1.333
						42	3.500	1.450
						48	3.875	1.573
						54	4.075	1.698
						60	5.375	1.862

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 5.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	.491						
3	.074	.534						
4	.074	.569	4	1.070	.579			
6	.105	.624	6	1.320	.635			
8	.105	.672	8	1.520	.682			
10	.136	.713	10	1.920	.724			
12	.167	.750	12	2.180	.762			
14	.167	.785	14	2.480	.798			
16	.198	.816	16	2.720	.832	16	1.780	.856
18	.229	.849	18	3.300	.865	18	2.000	.891
20	.260	.879	20	3.640	.896	20	2.125	.922
22	.260	.909						
24	.291	.938	24	4.320	.956	24	2.375	.984
30	.354	1.020				30	2.750	1.072
36	.398	1.100	36	6.460	1.127	36	3.125	1.158
						42	3.500	1.243
						48	3.875	1.329
						54	4.075	1.413
						60	5.375	1.518

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	.834						
3	.074	.923						
4	.074	.996	4	1.070	.975			
6	.105	1.111	6	1.320	1.092			
8	.105	1.217	8	1.520	1.193			
10	.136	1.307	10	1.920	1.280			
12	.167	1.391	12	2.180	1.365			
14	.167	1.476	14	2.480	1.444			
16	.198	1.554	16	2.720	1.523	16	1.780	1.637
18	.229	1.631	18	3.300	1.594	18	2.000	1.724
20	.260	1.706	20	3.640	1.668	20	2.125	1.807
22	.260	1.786						
24	.291	1.861	24	4.320	1.817	24	2.375	1.975
30	.354	2.093				30	2.750	2.235
36	.398	2.339	36	6.460	2.292	36	3.125	2.515
						42	3.500	2.826
						48	3.875	3.186
						54	4.075	3.605
						60	5.375	4.247

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	.768						
3	.074	.843						
4	.074	.903	4	1.070	.886			
6	.105	.997	6	1.320	.981			
8	.105	1.080	8	1.520	1.062			
10	.136	1.151	10	1.920	1.130			
12	.167	1.215	12	2.180	1.195			
14	.167	1.280	14	2.480	1.255			
16	.198	1.338	16	2.720	1.313	16	1.780	1.397
18	.229	1.393	18	3.300	1.364	18	2.000	1.459
20	.260	1.447	20	3.640	1.417	20	2.125	1.517
22	.260	1.503						
24	.291	1.555	24	4.320	1.520	24	2.375	1.631
30	.354	1.710				30	2.750	1.799
36	.398	1.864	36	6.460	1.817	36	3.125	1.966
						42	3.500	2.137
						48	3.875	2.316
						54	4.075	2.500
						60	5.375	2.727

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS= 7.500 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	.727						
3	.074	.794						
4	.074	.847	4	1.070	.832			
6	.105	.929	6	1.320	.915			
8	.105	1.001	8	1.520	.985			
10	.136	1.061	10	1.920	1.043			
12	.167	1.116	12	2.180	1.098			
14	.167	1.170	14	2.480	1.148			
16	.198	1.218	16	2.720	1.197	16	1.780	1.267
18	.229	1.263	18	3.300	1.239	18	2.000	1.317
20	.260	1.308	20	3.640	1.282	20	2.125	1.364
22	.260	1.353						
24	.291	1.394	24	4.320	1.365	24	2.375	1.455
30	.354	1.516				30	2.750	1.585
36	.398	1.635	36	6.460	1.595	36	3.125	1.711
						42	3.500	1.836
						48	3.875	1.962
						54	4.075	2.087
						60	5.375	2.233

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.096						
3	.074	1.217						
4	.074	1.316	4	1.070	1.241			
6	.105	1.468	6	1.320	1.392			
8	.105	1.609	8	1.520	1.523			
10	.136	1.727	10	1.920	1.628			
12	.167	1.837	12	2.180	1.734			
14	.167	1.951	14	2.480	1.833			
16	.198	2.053	16	2.720	1.931	16	1.780	2.145
18	.229	2.152	18	3.300	2.009	18	2.000	2.257
20	.260	2.250	20	3.640	2.099	20	2.125	2.366
22	.260	2.356						
24	.291	2.453	24	4.320	2.276	24	2.375	2.584
30	.354	2.756				30	2.750	2.922
36	.398	3.079	36	6.460	2.826	36	3.125	3.283
						42	3.500	3.683
						48	3.875	4.143
						54	4.075	4.681
						60	5.375	5.460

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.010						
3	.074	1.112						
4	.074	1.194	4	1.070	1.132			
6	.105	1.316	6	1.320	1.256			
8	.105	1.430	8	1.520	1.362			
10	.136	1.522	10	1.920	1.445			
12	.167	1.607	12	2.180	1.527			
14	.167	1.693	14	2.480	1.602			
16	.198	1.769	16	2.720	1.676	16	1.780	1.836
18	.229	1.841	18	3.300	1.733	18	2.000	1.916
20	.260	1.912	20	3.640	1.798	20	2.125	1.992
22	.260	1.966						
24	.291	2.054	24	4.320	1.923	24	2.375	2.142
30	.354	2.257				30	2.750	2.361
36	.398	2.460	36	6.460	2.276	36	3.125	2.579
						42	3.500	2.801
						48	3.875	3.032
						54	4.075	3.272
						60	5.375	3.551

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=10.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	.957						
3	.074	1.048						
4	.074	1.120	4	1.070	1.065			
6	.105	1.229	6	1.320	1.175			
8	.105	1.326	8	1.520	1.267			
10	.136	1.405	10	1.920	1.338			
12	.167	1.476	12	2.180	1.408			
14	.167	1.549	14	2.480	1.472			
16	.198	1.611	16	2.720	1.534	16	1.780	1.666
18	.229	1.671	18	3.300	1.581	18	2.000	1.732
20	.260	1.729	20	3.640	1.634	20	2.125	1.794
22	.260	1.789						
24	.291	1.843	24	4.320	1.736	24	2.375	1.913
30	.354	2.004				30	2.750	2.084
36	.398	2.161	36	6.460	2.013	36	3.125	2.249
						42	3.500	2.412
						48	3.875	2.576
						54	4.075	2.740
						60	5.375	2.920

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.299						
3	.074	1.447						
4	.074	1.567	4	1.070	1.436			
6	.105	1.748	6	1.320	1.613			
8	.105	1.919	8	1.520	1.767			
10	.136	2.057	10	1.920	1.885			
12	.167	2.187	12	2.180	2.006			
14	.167	2.325	14	2.480	2.118			
16	.198	2.444	16	2.720	2.230	16	1.780	2.539
18	.229	2.561	18	3.300	2.310	18	2.000	2.669
20	.260	2.676	20	3.640	2.409	20	2.125	2.798
22	.260	2.804						
24	.291	2.917	24	4.320	2.604	24	2.375	3.056
30	.354	3.275				30	2.750	3.452
36	.398	3.657	36	6.460	3.199	36	3.125	3.875
						42	3.500	4.342
						48	3.875	4.875
						54	4.075	5.502
						60	5.375	6.370

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.199						
3	.074	1.324						
4	.074	1.423	4	1.070	1.314			
6	.105	1.570	6	1.320	1.461			
8	.105	1.707	8	1.520	1.586			
10	.136	1.815	10	1.920	1.679			
12	.167	1.915	12	2.180	1.774			
14	.167	2.020	14	2.480	1.860			
16	.198	2.108	16	2.720	1.945	16	1.780	2.177
18	.229	2.194	18	3.300	2.005	18	2.000	2.271
20	.260	2.277	20	3.640	2.077	20	2.125	2.362
22	.260	2.367						
24	.291	2.446	24	4.320	2.216	24	2.375	2.539
30	.354	2.686				30	2.750	2.797
36	.398	2.928	36	6.460	2.605	36	3.125	3.054
						42	3.500	3.316
						48	3.875	3.586
						54	4.075	3.870
						60	5.375	4.183

SSHTP= 12

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=12.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=~~2.5~~ 1.8			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.136						
3	.074	1.248						
4	.074	1.336	4	1.070	1.239			
6	.105	1.465	6	1.320	1.369			
8	.105	1.583	8	1.520	1.478			
10	.136	1.676	10	1.920	1.559			
12	.167	1.760	12	2.180	1.640			
14	.167	1.848	14	2.480	1.713			
16	.198	1.922	16	2.720	1.785	16	1.780	1.979
18	.229	1.992	18	3.300	1.834	18	2.000	2.055
20	.260	2.060	20	3.640	1.894	20	2.125	2.129
22	.260	2.134						
24	.291	2.197	24	4.320	2.008	24	2.375	2.271
30	.354	2.388				30	2.750	2.473
36	.398	2.574	36	6.460	2.316	36	3.125	2.668
						42	3.500	2.861
						48	3.875	3.054
						54	4.075	3.248
						60	5.375	3.451

KS = 1.8

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE

BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR

BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 4.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.596						
3	.074	1.785						
4	.074	1.938	4	1.070	1.704			
6	.105	2.160	6	1.320	1.919			
8	.105	2.376	8	1.520	2.105			
10	.136	2.545	10	1.920	2.237			
12	.167	2.703	12	2.180	2.380			
14	.167	2.876	14	2.480	2.507			
16	.198	3.021	16	2.720	2.638	16	1.780	3.111
18	.229	3.163	18	3.300	2.718	18	2.000	3.267
20	.260	3.302	20	3.640	2.828	20	2.125	3.424
22	.260	3.461						
24	.291	3.599	24	4.320	3.044	24	2.375	3.738
30	.354	4.035				30	2.750	4.217
36	.398	4.502	36	6.460	3.685	36	3.125	4.727
						42	3.500	5.286
						48	3.875	5.922
						54	4.075	6.673
						60	5.375	7.643

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 6.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.474						
3	.074	1.635						
4	.074	1.762	4	1.070	1.566			
6	.105	1.943	6	1.320	1.745			
8	.105	2.116	8	1.520	1.898			
10	.136	2.248	10	1.920	2.004			
12	.167	2.370	12	2.180	2.117			
14	.167	2.502	14	2.480	2.217			
16	.198	2.610	16	2.720	2.317	16	1.780	2.675
18	.229	2.714	18	3.300	2.377	18	2.000	2.788
20	.260	2.815	20	3.640	2.459	20	2.125	2.900
22	.260	2.928						
24	.291	3.024	24	4.320	2.615	24	2.375	3.117
30	.354	3.318				30	2.750	3.432
36	.398	3.616	36	6.460	3.045	36	3.125	3.745
						42	3.500	4.062
						48	3.875	4.389
						54	4.075	4.734
						60	5.375	5.090

DEFINITION Q=KP*(TG-TP)

WHERE Q = HEAT TRANSFER TO PIPE
BTU/HR,FT OF PIPE

KP= PIPE HEAT TRANSFER FACTOR
BTU/HR,FT OF PIPE, F

TG= AVERAGE EARTH TEMPERATURE, F

TP= PIPE TEMPERATURE , F

THERMAL CONDUCTIVITY OF EARTH KS=15.000 BTU/HR,SQ.FT,F/IN

DEPTH OF PIPE DPTH= 8.0FT.

KI= THERMAL CONDUCTIVITY OF PIPE WALL, BTU/HR,SQ.FT,F/IN

HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PIPES, KP

FIBERGLASS PIPES KI=2.5			CEMENT ASBESTOS PIPES, KI=5.5			REINFORCED CONCRETE PIPES, KI=12.0		
PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP	PIPE SIZE ID(IN)	WALL THICKNESS (IN)	KP
2	.074	1.399						
3	.074	1.542						
4	.074	1.655	4	1.070	1.481			
6	.105	1.814	6	1.320	1.640			
8	.105	1.963	8	1.520	1.774			
10	.136	2.077	10	1.920	1.866			
12	.167	2.180	12	2.180	1.964			
14	.167	2.291	14	2.480	2.049			
16	.198	2.381	16	2.720	2.134	16	1.780	2.435
18	.229	2.467	18	3.300	2.184	18	2.000	2.528
20	.260	2.550	20	3.640	2.253	20	2.125	2.619
22	.260	2.642						
24	.291	2.719	24	4.320	2.383	24	2.375	2.793
30	.354	2.953				30	2.750	3.041
36	.398	3.183	36	6.460	2.727	36	3.125	3.280
						42	3.500	3.514
						48	3.875	3.749
						54	4.075	3.988
						60	5.375	4.219

Table TG-1 through TG-11 Average Earth Temperature at Various Stations in the United States for Selected Values of Thermal Diffusivities

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .005

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	62.	62.	69.	69.	65.
DECATUR, ALABAMA	55.	55.	63.	64.	59.
PALMER AAES, ALASKA	33.	32.	40.	40.	36.
TEMPE, ARIZONA	64.	65.	71.	72.	68.
TUCSON, ARIZONA	70.	70.	76.	78.	73.
BRAWLEY, CALIFORNIA	73.	74.	81.	82.	77.
DAVIS, CALIFORMIA	63.	62.	70.	71.	67.
FT. COLLINS, COLO.	46.	46.	55.	55.	51.
STORRS, CONN.	48.	47.	56.	57.	52.
GAINESVILLE, FLA.	68.	70.	76.	76.	73.
ATHENS, GEORGIA	62.	62.	70.	71.	66.
MOSCOW, IDAHO	44.	43.	50.	51.	47.
LEMONT, ILLINOIS	48.	47.	57.	58.	52.
URBANA, ILLINOIS	49.	48.	58.	59.	53.
WEST LAFAYETTE, IND	50.	49.	59.	60.	54.
AMES, IOWA	47.	46.	58.	59.	52.
BURLINGTON, IOWA	50.	50.	62.	63.	56.
CASTANA, IOWA	45.	44.	57.	58.	51.
COUNCIL BLUFFS, IOWA	50.	49.	60.	60.	55.
SARATOGA, IOWA	44.	42.	55.	55.	49.
SPENCER, IOWA	44.	44.	55.	55.	50.
GARDEN CITY, KANSAS	51.	53.	63.	64.	58.
MANHATTAN, KANSAS	51.	51.	61.	62.	56.
MOUND VALLEY, KANSAS	55.	55.	65.	66.	60.
LEXINGTON, KENTUCKY	54.	53.	62.	63.	58.
UPPER MARLBORO, MD.	51.	51.	60.	61.	56.
EAST LANSING, MICH.	47.	45.	54.	55.	50.
FAIRMONT, MINNESOTA	45.	45.	55.	55.	50.
FARIBAULT, MINNESOTA	43.	41.	52.	52.	47.
ST. PAUL, MINNESOTA	45.	42.	54.	55.	49.
WASECA, MINNESOTA	44.	47.	56.	54.	50.
STATE UNIV., MISS.	62.	63.	71.	72.	67.
FAUCETT, MISSOURI	50.	48.	58.	59.	54.
KANSAS CITY, MO.	51.	50.	59.	60.	55.
SIKESTON, MISSOURI	55.	55.	65.	66.	60.
SPICKARD, MISSOURI	52.	50.	58.	60.	55.
BOZEMAN, MONTANA	41.	39.	47.	47.	43.
HUNTLEY, MONTANA	46.	45.	55.	55.	50.
LINCOLN, NEBRASKA	47.	47.	57.	58.	53.
NEW BRUNSWICK, N.J.	50.	49.	57.	59.	54.
ITHACA, NEW YORK	45.	44.	52.	53.	49.
COLUMBUS, OHIO	49.	48.	57.	58.	53.
COSHOCTON, OHIO	48.	47.	55.	57.	52.
WOOSTER, OHIO	48.	47.	56.	57.	52.
BARNSDALL, OKLAHOMA	59.	58.	67.	68.	63.
LAKE HEFNER, OKLA.	59.	59.	68.	69.	64.
PAWHUSKA, OKLAHOMA	57.	56.	65.	66.	61.
OTTAWA, ONTARIO	43.	41.	51.	51.	47.
CORVALLIS, OREGON	52.	52.	59.	59.	55.
HOOD RIVER, OREGON	48.	49.	55.	56.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .005

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	53.	53.	59.	60.	56.
PENDLETON, OREGON	49.	50.	59.	59.	54.
STATE COLLEGE, PA.	48.	47.	56.	57.	52.
KINGSTON, R. I.	47.	44.	53.	54.	50.
CALHOUN, S.CAROLINA	58.	59.	67.	68.	63.
MADISON, S. DAKOTA	43.	41.	52.	52.	47.
JACKSON, TENNESSEE	55.	56.	64.	63.	59.
TEMPLE, TEXAS	67.	66.	75.	75.	71.
SALT LAKE CITY,UTAH	46.	46.	54.	54.	50.
BURLINGTON, VERMONT	44.	42.	52.	52.	48.
PULLMAN, WASHINGTON	45.	46.	53.	52.	50.
SEATTLE, WASHINGTON	50.	50.	55.	55.	53.
AFTON, WYOMING	45.	44.	51.	52.	48.

Table TG-2

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .010

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	60.	61.	71.	70.	65.
DECATUR, ALABAMA	52.	54.	65.	65.	59.
PALMER AAES, ALASKA	31.	31.	42.	41.	36.
TEMPE, ARIZONA	62.	64.	73.	74.	68.
TUCSON, ARIZONA	68.	69.	77.	79.	73.
BRAWLEY, CALIFORNIA	70.	73.	83.	84.	77.
DAVIS, CALIFORMIA	61.	61.	72.	72.	67.
FT. COLLINS, COLO.	44.	45.	58.	56.	51.
STORRS, CONN.	46.	45.	58.	58.	52.
GAINESVILLE, FLA.	65.	70.	77.	77.	73.
ATHENS, GEORGIA	59.	61.	72.	72.	66.
MOSCOW, IDAHO	43.	42.	52.	52.	47.
LEMONT, ILLINOIS	46.	45.	59.	59.	52.
URBANA, ILLINOIS	46.	47.	61.	60.	53.
WEST LAFAYETTE, IND	47.	47.	62.	61.	54.
AMES, IOWA	44.	45.	62.	60.	52.
BURLINGTON, IOWA	47.	49.	66.	65.	56.
CASTANA, IOWA	42.	42.	61.	59.	51.
COUNCIL BLUFFS,IOWA	47.	47.	62.	62.	55.
SARATOGA, IOWA	41.	40.	59.	57.	49.
SPENCER, IOWA	42.	42.	58.	57.	50.
GARDEN CITY, KANSAS	48.	51.	66.	66.	58.
MANHATTAN, KANSAS	48.	50.	64.	64.	56.
MOUND VALLEY,KANSAS	52.	54.	68.	68.	60.
LEXINGTON, KENTUCKY	51.	52.	65.	64.	58.
UPPER MARLBORO, MD.	48.	49.	63.	63.	56.
EAST LANSING, MICH.	45.	43.	57.	57.	50.
FAIRMONT, MINNESOTA	42.	43.	58.	57.	50.
FARIBAULT,MINNESOTA	40.	40.	55.	53.	47.
ST. PAUL, MINNESOTA	42.	40.	57.	56.	49.
WASECA, MINNESOTA	41.	46.	59.	54.	50.
STATE UNIV., MISS.	60.	62.	73.	73.	67.
FAUCETT, MISSOURI	47.	47.	61.	61.	54.
KANSAS CITY, MO.	48.	49.	62.	61.	55.
SIKESTON, MISSOURI	52.	54.	67.	67.	60.
SPICKARD, MISSOURI	50.	49.	60.	62.	55.
BOZEMAN, MONTANA	39.	37.	50.	48.	43.
HUNTLEY, MONTANA	44.	44.	58.	57.	50.
LINCOLN, NEBRASKA	45.	45.	60.	60.	53.
NEW BRUNSWICK, N.J.	48.	48.	60.	60.	54.
ITHACA, NEW YORK	44.	43.	54.	54.	49.
COLUMBUS, OHIO	47.	47.	59.	60.	53.
COSHOCTON, OHIO	46.	46.	58.	58.	52.
WOOSTER, OHIO	46.	46.	58.	58.	52.
BARNSDALL, OKLAHOMA	56.	57.	69.	69.	63.
LAKE HEFNER, OKLA.	56.	57.	70.	71.	64.
PAWHUSKA, OKLAHOMA	54.	55.	68.	68.	61.
OTTAWA, ONTARIO	42.	39.	54.	52.	47.
CORVALLIS, OREGON	50.	51.	61.	60.	55.
HOOD RIVER, OREGON	46.	48.	57.	57.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .010

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	51.	52.	61.	61.	56.
PENDLETON, OREGON	46.	49.	61.	60.	54.
STATE COLLEGE, PA.	46.	45.	59.	58.	52.
KINGSTON, R. I.	45.	43.	55.	56.	50.
CALHOUN, S.CAROLINA	56.	58.	70.	69.	63.
MADISON, S. DAKOTA	40.	40.	54.	54.	47.
JACKSON, TENNESSEE	53.	55.	66.	64.	59.
TEMPLE, TEXAS	64.	65.	77.	77.	71.
SALT LAKE CITY, UTAH	44.	45.	56.	55.	50.
BURLINGTON, VERMONT	42.	40.	54.	53.	48.
PULLMAN, WASHINGTON	43.	46.	55.	52.	50.
SEATTLE, WASHINGTON	48.	50.	56.	56.	53.
AFTON, WYOMING	43.	43.	53.	53.	48.

Table TG-3

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .015

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	58.	61.	72.	70.	65.
DECATUR, ALABAMA	51.	53.	67.	65.	59.
PALMER AAES, ALASKA	30.	31.	43.	41.	36.
TEMPE, ARIZONA	60.	63.	75.	74.	68.
TUCSON, ARIZONA	67.	69.	79.	80.	73.
BRAWLEY, CALIFORNIA	68.	73.	85.	84.	77.
DAVIS, CALIFORMIA	59.	61.	74.	73.	67.
FT. COLLINS, COLO.	42.	45.	59.	57.	51.
STORRS, CONN.	45.	45.	60.	58.	52.
GAINESVILLE, FLA.	63.	71.	78.	78.	73.
ATHENS, GEORGIA	57.	61.	74.	73.	66.
MOSCOW, IDAHO	41.	42.	53.	52.	47.
LEMONT, ILLINOIS	44.	45.	61.	60.	52.
URBANA, ILLINOIS	44.	47.	63.	61.	53.
WEST LAFAYETTE, IND	45.	47.	64.	62.	54.
AMES, IOWA	42.	44.	64.	61.	52.
BURLINGTON, IOWA	45.	48.	68.	65.	56.
CASTANA, IOWA	39.	42.	63.	60.	51.
COUNCIL BLUFFS, IOWA	45.	47.	64.	63.	55.
SARATOGA, IOWA	39.	40.	61.	58.	49.
SPENCER, IOWA	39.	42.	60.	57.	50.
GARDEN CITY, KANSAS	45.	51.	68.	66.	58.
MANHATTAN, KANSAS	46.	49.	66.	64.	56.
MOUND VALLEY, KANSAS	50.	54.	69.	68.	60.
LEXINGTON, KENTUCKY	49.	52.	67.	65.	58.
UPPER MARLBORO, MD.	46.	49.	64.	64.	56.
EAST LANSING, MICH.	43.	42.	59.	57.	50.
FAIRMONT, MINNESOTA	40.	43.	60.	57.	50.
FARIBAULT, MINNESOTA	39.	39.	57.	54.	47.
ST. PAUL, MINNESOTA	40.	39.	59.	57.	49.
WASECA, MINNESOTA	39.	46.	61.	54.	50.
STATE UNIV., MISS.	58.	62.	74.	74.	67.
FAUCETT, MISSOURI	46.	46.	63.	61.	54.
KANSAS CITY, MO.	46.	48.	63.	61.	55.
SIKESTON, MISSOURI	50.	54.	69.	68.	60.
SPICKARD, MISSOURI	49.	48.	61.	63.	55.
BOZEMAN, MONTANA	38.	37.	51.	49.	43.
HUNTLEY, MONTANA	42.	43.	60.	57.	50.
LINCOLN, NEBRASKA	43.	44.	62.	61.	53.
NEW BRUNSWICK, N.J.	46.	47.	61.	61.	54.
ITHACA, NEW YORK	42.	42.	56.	54.	49.
COLUMBUS, OHIO	45.	47.	61.	60.	53.
COSHOCTON, OHIO	44.	45.	59.	59.	52.
WOOSTER, OHIO	44.	45.	60.	59.	52.
BARNSDALL, OKLAHOMA	55.	56.	70.	70.	63.
LAKE HEFNER, OKLA.	55.	57.	72.	72.	64.
PAWHUSKA, OKLAHOMA	53.	54.	70.	68.	61.
OTTAWA, ONTARIO	40.	38.	55.	52.	47.
CORVALLIS, OREGON	48.	51.	62.	60.	55.
HOOD RIVER, OREGON	45.	48.	58.	57.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .015

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	50.	52.	62.	61.	56.
PENDLETON, OREGON	43.	49.	63.	61.	54.
STATE COLLEGE, PA.	44.	45.	61.	59.	52.
KINGSTON, R. I.	43.	42.	56.	56.	50.
CALHOUN, S.CAROLINA	54.	58.	71.	70.	63.
MADISON, S. DAKOTA	39.	39.	56.	54.	47.
JACKSON, TENNESSEE	52.	55.	67.	64.	59.
TEMPLE, TEXAS	63.	65.	79.	77.	71.
SALT LAKE CITY, UTAH	42.	45.	58.	56.	50.
BURLINGTON, VERMONT	41.	39.	56.	54.	48.
PULLMAN, WASHINGTON	42.	45.	56.	52.	50.
SEATTLE, WASHINGTON	47.	49.	57.	56.	53.
AFTON, WYOMING	42.	42.	54.	53.	48.

Table TG-4

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .020

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	57.	61.	73.	70.	65.
DECATUR, ALABAMA	50.	53.	68.	65.	59.
PALMER AAES, ALASKA	29.	30.	44.	41.	36.
TEMPE, ARIZONA	59.	63.	76.	74.	68.
TUCSON, ARIZONA	65.	69.	79.	80.	73.
BRAWLEY, CALIFORNIA	67.	73.	86.	84.	77.
DAVIS, CALIFORMIA	58.	60.	75.	73.	67.
FT. COLLINS, COLO.	41.	44.	61.	57.	51.
STORRS, CONN.	44.	44.	61.	58.	52.
GAINESVILLE, FLA.	62.	71.	79.	78.	73.
ATHENS, GEORGIA	56.	60.	75.	73.	66.
MOSCOW, IDAHO	41.	42.	54.	53.	47.
LEMONT, ILLINOIS	43.	44.	62.	60.	52.
URBANA, ILLINOIS	43.	47.	64.	61.	53.
WEST LAFAYETTE, IND	44.	47.	65.	62.	54.
AMES, IOWA	40.	44.	65.	61.	52.
BURLINGTON, IOWA	43.	48.	69.	66.	56.
CASTANA, IOWA	37.	41.	65.	60.	51.
COUNCIL BLUFFS, IOWA	43.	47.	66.	63.	55.
SARATOGA, IOWA	38.	39.	63.	58.	49.
SPENCER, IOWA	38.	42.	61.	58.	50.
GARDEN CITY, KANSAS	43.	51.	69.	66.	58.
MANHATTAN, KANSAS	45.	49.	67.	65.	56.
MOUND VALLEY, KANSAS	49.	54.	71.	69.	60.
LEXINGTON, KENTUCKY	48.	51.	68.	65.	58.
UPPER MARLBORO, MD.	45.	49.	65.	64.	56.
EAST LANSING, MICH.	42.	42.	60.	57.	50.
FAIRMONT, MINNESOTA	39.	43.	62.	57.	50.
FARIBAULT, MINNESOTA	37.	38.	58.	54.	47.
ST. PAUL, MINNESOTA	39.	38.	61.	57.	49.
WASECA, MINNESOTA	37.	47.	63.	54.	50.
STATE UNIV., MISS.	57.	62.	75.	74.	67.
FAUCETT, MISSOURI	44.	46.	64.	61.	54.
KANSAS CITY, MO.	45.	48.	65.	62.	55.
SIKESTON, MISSOURI	49.	54.	71.	68.	60.
SPICKARD, MISSOURI	48.	48.	62.	63.	55.
BOZEMAN, MONTANA	37.	36.	52.	49.	43.
HUNTLEY, MONTANA	41.	43.	61.	57.	50.
LINCOLN, NEBRASKA	41.	44.	64.	61.	53.
NEW BRUNSWICK, N.J.	45.	47.	62.	61.	54.
ITHACA, NEW YORK	41.	42.	57.	54.	49.
COLUMBUS, OHIO	44.	46.	62.	61.	53.
COSHOCTON, OHIO	43.	45.	60.	59.	52.
WOOSTER, OHIO	43.	45.	61.	59.	52.
BARNSDALL, OKLAHOMA	54.	56.	72.	70.	63.
LAKE HEFNER, OKLA.	53.	56.	73.	72.	64.
PAWHUSKA, OKLAHOMA	51.	54.	71.	68.	61.
OTTAWA, ONTARIO	39.	38.	57.	52.	47.
CORVALLIS, OREGON	47.	51.	63.	61.	55.
HOOD RIVER, OREGON	44.	48.	59.	57.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .020

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	49.	52.	63.	61.	56.
PENDLETON, OREGON	42.	49.	64.	61.	54.
STATE COLLEGE, PA.	43.	44.	62.	59.	52.
KINGSTON, R. I.	42.	42.	58.	57.	50.
CALHOUN, S.CAROLINA	53.	57.	72.	70.	63.
MADISON, S. DAKOTA	37.	38.	58.	55.	47.
JACKSON, TENNESSEE	51.	55.	69.	64.	59.
TEMPLE, TEXAS	62.	65.	80.	77.	71.
SALT LAKE CITY,UTAH	41.	45.	59.	56.	50.
BURLINGTON, VERMONT	40.	39.	58.	54.	48.
PULLMAN, WASHINGTON	41.	45.	57.	52.	50.
SEATTLE, WASHINGTON	46.	49.	58.	56.	53.
AFTON, WYOMING	41.	42.	55.	53.	48.

Table TG-5

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .025

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	57.	61.	74.	70.	65.
DECATUR, ALABAMA	49.	53.	69.	66.	59.
PALMER AAES, ALASKA	29.	30.	45.	41.	36.
TEMPE, ARIZONA	58.	63.	77.	74.	68.
TUCSON, ARIZONA	65.	69.	80.	80.	73.
BRAWLEY, CALIFORNIA	66.	73.	87.	85.	77.
DAVIS, CALIFORMIA	57.	60.	76.	73.	67.
FT. COLLINS, COLO.	40.	44.	62.	57.	51.
STORRS, CONN.	43.	44.	62.	59.	52.
GAINESVILLE, FLA.	61.	71.	79.	78.	73.
ATHENS, GEORGIA	55.	60.	75.	73.	66.
MOSCOW, IDAHO	40.	42.	55.	53.	47.
LEMONT, ILLINOIS	42.	44.	64.	60.	52.
URBANA, ILLINOIS	42.	47.	65.	61.	53.
WEST LAFAYETTE, IND	43.	47.	66.	62.	54.
AMES, IOWA	39.	44.	67.	61.	52.
BURLINGTON, IOWA	42.	48.	71.	66.	56.
CASTANA, IOWA	36.	41.	66.	61.	51.
COUNCIL BLUFFS,IOWA	42.	47.	67.	63.	55.
SARATOGA, IOWA	37.	39.	64.	58.	49.
SPENCER, IOWA	37.	41.	62.	58.	50.
GARDEN CITY, KANSAS	42.	51.	71.	67.	58.
MANHATTAN, KANSAS	44.	49.	68.	65.	56.
MOUND VALLEY,KANSAS	47.	54.	72.	69.	60.
LEXINGTON, KENTUCKY	47.	51.	69.	65.	58.
UPPER MARLBORO, MD.	44.	49.	66.	64.	56.
EAST LANSING, MICH.	41.	41.	61.	58.	50.
FAIRMONT, MINNESOTA	38.	43.	63.	57.	50.
FARIBAULT,MINNESOTA	36.	38.	59.	54.	47.
ST. PAUL, MINNESOTA	38.	38.	62.	57.	49.
WASECA, MINNESOTA	36.	47.	64.	54.	50.
STATE UNIV., MISS.	56.	62.	76.	74.	67.
FAUCETT, MISSOURI	43.	45.	65.	61.	54.
KANSAS CITY, MO.	44.	48.	65.	62.	55.
SIKESTON, MISSOURI	48.	54.	72.	68.	60.
SPICKARD, MISSOURI	47.	48.	63.	64.	55.
BOZEMAN, MONTANA	36.	36.	53.	49.	43.
HUNTLEY, MONTANA	40.	43.	63.	57.	50.
LINCOLN, NEBRASKA	40.	44.	65.	61.	53.
NEW BRUNSWICK, N.J.	44.	47.	63.	61.	54.
ITHACA, NEW YORK	41.	41.	58.	54.	49.
COLUMBUS, OHIO	43.	46.	63.	61.	53.
COSHOCTON, OHIO	42.	45.	61.	59.	52.
WOOSTER, OHIO	42.	45.	62.	59.	52.
BARNSDALL, OKLAHOMA	53.	56.	73.	70.	63.
LAKE HEFNER, OKLA.	52.	56.	74.	72.	64.
PAWHUSKA, OKLAHOMA	50.	54.	72.	68.	61.
OTTAWA, ONTARIO	39.	37.	58.	52.	47.
CORVALLIS, OREGON	47.	50.	64.	60.	55.
HOOD RIVER, OREGON	43.	48.	59.	57.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .025

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	48.	52.	64.	61.	56.
PENDLETON, OREGON	41.	49.	65.	61.	54.
STATE COLLEGE, PA.	42.	44.	63.	59.	52.
KINGSTON, R. I.	41.	41.	58.	57.	50.
CALHOUN, S.CAROLINA	52.	57.	73.	70.	63.
MADISON, S. DAKOTA	36.	38.	59.	55.	47.
JACKSON, TENNESSEE	50.	55.	69.	64.	59.
TEMPLE, TEXAS	61.	65.	81.	77.	71.
SALT LAKE CITY,UTAH	40.	45.	60.	56.	50.
BURLINGTON, VERMONT	39.	38.	59.	54.	48.
PULLMAN, WASHINGTON	40.	45.	58.	52.	50.
SEATTLE, WASHINGTON	46.	50.	59.	56.	53.
AFTON, WYOMING	41.	42.	56.	53.	48.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .030

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	56.	61.	75.	70.	65.
DECATUR, ALABAMA	48.	53.	70.	66.	59.
PALMER AAES, ALASKA	28.	30.	46.	41.	36.
TEMPE, ARIZONA	57.	64.	77.	74.	68.
TUCSON, ARIZONA	64.	69.	80.	80.	73.
BRAWLEY, CALIFORNIA	65.	73.	88.	85.	77.
DAVIS, CALIFORMIA	56.	60.	76.	73.	67.
FT. COLLINS, COLO.	39.	44.	63.	57.	51.
STORRS, CONN.	42.	44.	63.	59.	52.
GAINESVILLE, FLA.	60.	71.	80.	78.	73.
ATHENS, GEORGIA	54.	61.	76.	73.	66.
MOSCOW, IDAHO	39.	42.	55.	53.	47.
LEMONT, ILLINOIS	41.	44.	64.	60.	52.
URBANA, ILLINOIS	41.	47.	66.	61.	53.
WEST LAFAYETTE, IND	42.	47.	67.	62.	54.
AMES, IOWA	38.	44.	68.	61.	52.
BURLINGTON, IOWA	41.	48.	72.	66.	56.
CASTANA, IOWA	35.	41.	67.	61.	51.
COUNCIL BLUFFS, IOWA	41.	47.	68.	63.	55.
SARATOGA, IOWA	36.	39.	65.	58.	49.
SPENCER, IOWA	36.	41.	63.	58.	50.
GARDEN CITY, KANSAS	41.	52.	72.	67.	58.
MANHATTAN, KANSAS	43.	49.	69.	65.	56.
MOUND VALLEY, KANSAS	46.	54.	73.	69.	60.
LEXINGTON, KENTUCKY	46.	51.	70.	65.	58.
UPPER MARLBORO, MD.	43.	49.	67.	64.	56.
EAST LANSING, MICH.	41.	41.	62.	58.	50.
FAIRMONT, MINNESOTA	37.	43.	64.	57.	50.
FARIBAULT, MINNESOTA	36.	38.	60.	54.	47.
ST. PAUL, MINNESOTA	37.	38.	63.	57.	49.
WASECA, MINNESOTA	34.	48.	65.	54.	50.
STATE UNIV., MISS.	55.	62.	77.	74.	67.
FAUCETT, MISSOURI	43.	45.	66.	61.	54.
KANSAS CITY, MO.	43.	48.	66.	62.	55.
SIKESTON, MISSOURI	47.	54.	73.	68.	60.
SPICKARD, MISSOURI	46.	48.	64.	64.	55.
BOZEMAN, MONTANA	36.	36.	54.	48.	43.
HUNTLEY, MONTANA	39.	43.	63.	57.	50.
LINCOLN, NEBRASKA	39.	44.	66.	61.	53.
NEW BRUNSWICK, N.J.	43.	47.	64.	61.	54.
ITHACA, NEW YORK	40.	41.	59.	54.	49.
COLUMBUS, OHIO	42.	46.	64.	61.	53.
COSHOCTON, OHIO	41.	45.	62.	59.	52.
WOOSTER, OHIO	42.	45.	63.	59.	52.
BARNSDALL, OKLAHOMA	52.	56.	73.	70.	63.
LAKE HEFNER, OKLA.	51.	56.	75.	73.	64.
PAWHUSKA, OKLAHOMA	50.	54.	73.	68.	61.
OTTAWA, ONTARIO	38.	37.	59.	52.	47.
CORVALLIS, OREGON	46.	50.	65.	60.	55.
HOOD RIVER, OREGON	43.	48.	60.	57.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F. TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .030

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	48.	52.	64.	61.	56.
PENDLETON, OREGON	40.	49.	66.	61.	54.
STATE COLLEGE, PA.	41.	44.	64.	59.	52.
KINGSTON, R. I.	41.	41.	59.	57.	50.
CALHOUN, S.CAROLINA	51.	58.	74.	70.	63.
MADISON, S. DAKOTA	36.	38.	60.	55.	47.
JACKSON, TENNESSEE	50.	55.	70.	64.	59.
TEMPLE, TEXAS	60.	65.	82.	77.	71.
SALT LAKE CITY,UTAH	39.	45.	61.	56.	50.
BURLINGTON, VERMONT	38.	38.	59.	54.	48.
PULLMAN, WASHINGTON	39.	45.	58.	51.	50.
SEATTLE, WASHINGTON	45.	50.	59.	56.	53.
AFTON, WYOMING	40.	42.	57.	53.	48.

Table TG-7

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .035

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	55.	61.	75.	70.	65.
DECATUR, ALABAMA	48.	53.	70.	66.	59.
PALMER AAES, ALASKA	28.	30.	47.	41.	36.
TEMPE, ARIZONA	57.	64.	78.	74.	68.
TUCSON, ARIZONA	63.	69.	81.	80.	73.
BRAWLEY, CALIFORNIA	65.	73.	88.	85.	77.
DAVIS, CALIFORMIA	56.	60.	77.	73.	67.
FT. COLLINS, COLO.	38.	45.	63.	57.	51.
STORRS, CONN.	42.	44.	64.	59.	52.
GAINESVILLE, FLA.	59.	72.	80.	79.	73.
ATHENS, GEORGIA	54.	61.	77.	73.	66.
MOSCOW, IDAHO	39.	42.	56.	53.	47.
LEMONT, ILLINOIS	40.	44.	65.	60.	52.
URBANA, ILLINOIS	40.	47.	67.	61.	53.
WEST LAFAYETTE, IND	41.	47.	68.	62.	54.
AMES, IOWA	37.	44.	69.	61.	52.
BURLINGTON, IOWA	40.	48.	73.	66.	56.
CASTANA, IOWA	34.	41.	68.	61.	51.
COUNCIL BLUFFS, IOWA	40.	47.	69.	63.	55.
SARATOGA, IOWA	35.	39.	66.	58.	49.
SPENCER, IOWA	35.	41.	64.	58.	50.
GARDEN CITY, KANSAS	40.	52.	72.	67.	58.
MANHATTAN, KANSAS	42.	49.	70.	65.	56.
MOUND VALLEY, KANSAS	46.	54.	73.	69.	60.
LEXINGTON, KENTUCKY	46.	51.	70.	65.	58.
UPPER MARLBORO, MD.	43.	49.	68.	64.	56.
EAST LANSING, MICH.	40.	41.	62.	58.	50.
FAIRMONT, MINNESOTA	36.	43.	65.	57.	50.
FARIBAULT, MINNESOTA	35.	38.	61.	54.	47.
ST. PAUL, MINNESOTA	36.	38.	64.	57.	49.
WASECA, MINNESOTA	34.	48.	66.	54.	50.
STATE UNIV., MISS.	54.	62.	77.	74.	67.
FAUCETT, MISSOURI	42.	45.	67.	61.	54.
KANSAS CITY, MO.	43.	48.	67.	61.	55.
SIKESTON, MISSOURI	46.	54.	73.	68.	60.
SPICKARD, MISSOURI	46.	48.	64.	64.	55.
BOZEMAN, MONTANA	35.	36.	55.	48.	43.
HUNTLEY, MONTANA	39.	43.	64.	57.	50.
LINCOLN, NEBRASKA	38.	44.	67.	62.	53.
NEW BRUNSWICK, N.J.	43.	47.	65.	61.	54.
ITHACA, NEW YORK	40.	41.	59.	54.	49.
COLUMBUS, OHIO	42.	46.	64.	61.	53.
COSHOCTON, OHIO	41.	45.	63.	59.	52.
WOOSTER, OHIO	41.	45.	64.	59.	52.
BARNSDALL, OKLAHOMA	52.	56.	74.	70.	63.
LAKE HEFNER, OKLA.	51.	56.	76.	73.	64.
PAWHUSKA, OKLAHOMA	49.	54.	73.	68.	61.
OTTAWA, ONTARIO	38.	37.	59.	52.	47.
CORVALLIS, OREGON	46.	50.	65.	60.	55.
HOOD RIVER, OREGON	42.	48.	60.	58.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .035

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	47.	52.	65.	61.	56.
PENDLETON, OREGON	39.	50.	66.	61.	54.
STATE COLLEGE, PA.	41.	44.	64.	59.	52.
KINGSTON, R. I.	40.	41.	60.	57.	50.
CALHOUN, S.CAROLINA	51.	58.	75.	70.	63.
MADISON, S. DAKOTA	35.	38.	61.	55.	47.
JACKSON, TENNESSEE	49.	55.	71.	64.	59.
TEMPLE, TEXAS	60.	65.	82.	77.	71.
SALT LAKE CITY,UTAH	39.	45.	61.	56.	50.
BURLINGTON, VERMONT	38.	38.	60.	54.	48.
PULLMAN, WASHINGTON	39.	45.	59.	51.	50.
SEATTLE, WASHINGTON	45.	50.	60.	56.	53.
AFTON, WYOMING	40.	42.	57.	53.	48.

Table TG-8

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .040

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	55.	61.	76.	70.	65.
DECATUR, ALABAMA	47.	53.	71.	65.	59.
PALMER AAES, ALASKA	27.	30.	47.	41.	36.
TEMPE, ARIZONA	56.	64.	78.	74.	68.
TUCSON, ARIZONA	63.	69.	81.	80.	73.
BRAWLEY, CALIFORNIA	64.	73.	89.	84.	77.
DAVIS, CALIFORMIA	55.	60.	78.	73.	67.
FT. COLLINS, COLO.	38.	45.	64.	57.	51.
STORRS, CONN.	41.	44.	64.	59.	52.
GAINESVILLE, FLA.	59.	72.	80.	79.	73.
ATHENS, GEORGIA	53.	61.	77.	73.	66.
MOSCOW, IDAHO	39.	42.	56.	53.	47.
LEMONT, ILLINOIS	40.	44.	66.	60.	52.
URBANA, ILLINOIS	40.	47.	67.	61.	53.
WEST LAFAYETTE, IND	41.	47.	68.	62.	54.
AMES, IOWA	36.	44.	69.	61.	52.
BURLINGTON, IOWA	39.	48.	73.	66.	56.
CASTANA, IOWA	33.	41.	69.	61.	51.
COUNCIL BLUFFS,IOWA	40.	47.	69.	63.	55.
SARATOGA, IOWA	34.	39.	66.	58.	49.
SPENCER, IOWA	34.	42.	65.	58.	50.
GARDEN CITY, KANSAS	39.	52.	73.	67.	58.
MANHATTAN, KANSAS	41.	49.	71.	65.	56.
MOUND VALLEY,KANSAS	45.	54.	74.	69.	60.
LEXINGTON, KENTUCKY	45.	51.	71.	65.	58.
UPPER MARLBORO, MD.	42.	49.	68.	64.	56.
EAST LANSING, MICH.	40.	41.	63.	57.	50.
FAIRMONT, MINNESOTA	36.	43.	66.	57.	50.
FARIBAULT,MINNESOTA	34.	38.	61.	54.	47.
ST. PAUL, MINNESOTA	36.	38.	64.	57.	49.
WASECA, MINNESOTA	33.	48.	66.	53.	50.
STATE UNIV., MISS.	54.	62.	78.	74.	67.
FAUCETT, MISSOURI	41.	45.	67.	61.	54.
KANSAS CITY, MO.	42.	48.	67.	61.	55.
SIKESTON, MISSOURI	46.	54.	74.	68.	60.
SPICKARD, MISSOURI	45.	48.	65.	64.	55.
BOZEMAN, MONTANA	35.	35.	56.	48.	43.
HUNTLEY, MONTANA	38.	43.	65.	57.	50.
LINCOLN, NEBRASKA	37.	44.	67.	62.	53.
NEW BRUNSWICK, N.J.	42.	47.	65.	61.	54.
ITHACA, NEW YORK	39.	41.	60.	54.	49.
COLUMBUS, OHIO	41.	46.	65.	61.	53.
COSHOCTON, OHIO	40.	45.	63.	60.	52.
WOOSTER, OHIO	41.	45.	64.	59.	52.
BARNSDALL, OKLAHOMA	51.	56.	74.	70.	63.
LAKE HEFNER, OKLA.	50.	56.	76.	73.	64.
PAWHUSKA, OKLAHOMA	49.	54.	74.	68.	61.
OTTAWA, ONTARIO	37.	37.	60.	52.	47.
CORVALLIS, OREGON	45.	50.	66.	60.	55.
HOOD RIVER, OREGON	42.	49.	61.	58.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .040

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	47.	52.	65.	61.	56.
PENDLETON, OREGON	39.	50.	67.	61.	54.
STATE COLLEGE, PA.	40.	44.	65.	59.	52.
KINGSTON, R. I.	40.	41.	60.	57.	50.
CALHOUN, S.CAROLINA	50.	58.	75.	70.	63.
MADISON, S. DAKOTA	34.	38.	61.	55.	47.
JACKSON, TENNESSEE	49.	55.	71.	64.	59.
TEMPLE, TEXAS	59.	65.	83.	77.	71.
SALT LAKE CITY,UTAH	38.	45.	62.	56.	50.
BURLINGTON, VERMONT	37.	38.	61.	54.	48.
PULLMAN, WASHINGTON	38.	45.	59.	51.	50.
SEATTLE, WASHINGTON	44.	50.	60.	56.	53.
AFTON, WYOMING	39.	42.	58.	53.	48.

Table TG-9

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .045

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	55.	61.	76.	70.	65.
DECATUR, ALABAMA	47.	53.	71.	65.	59.
PALMER AAES, ALASKA	27.	30.	48.	41.	36.
TEMPE, ARIZONA	56.	64.	79.	74.	68.
TUCSON, ARIZONA	63.	69.	81.	81.	73.
BRAWLEY, CALIFORNIA	64.	73.	89.	84.	77.
DAVIS, CALIFORMIA	55.	60.	78.	73.	67.
FT. COLLINS, COLO.	37.	45.	64.	56.	51.
STORRS, CONN.	41.	44.	65.	59.	52.
GAINESVILLE, FLA.	58.	72.	81.	79.	73.
ATHENS, GEORGIA	53.	61.	77.	73.	66.
MOSCOW, IDAHO	38.	42.	57.	53.	47.
LEMONT, ILLINOIS	39.	44.	66.	60.	52.
URBANA, ILLINOIS	39.	47.	68.	61.	53.
WEST LAFAYETTE, IND	40.	47.	69.	62.	54.
AMES, IOWA	36.	44.	70.	61.	52.
BURLINGTON, IOWA	39.	48.	74.	66.	56.
CASTANA, IOWA	33.	42.	70.	61.	51.
COUNCIL BLUFFS,IOWA	39.	47.	70.	63.	55.
SARATOGA, IOWA	34.	39.	67.	58.	49.
SPENCER, IOWA	34.	42.	65.	58.	50.
GARDEN CITY, KANSAS	39.	52.	74.	67.	58.
MANHATTAN, KANSAS	41.	49.	71.	65.	56.
MOUND VALLEY,KANSAS	44.	54.	74.	69.	60.
LEXINGTON, KENTUCKY	45.	51.	71.	65.	58.
UPPER MARLBORO, MD.	41.	49.	68.	64.	56.
EAST LANSING, MICH.	39.	41.	63.	57.	50.
FAIRMONT, MINNESOTA	35.	43.	66.	57.	50.
FARIBAULT,MINNESOTA	34.	38.	62.	54.	47.
ST. PAUL, MINNESOTA	35.	38.	65.	57.	49.
WASECA, MINNESOTA	32.	49.	67.	53.	50.
STATE UNIV., MISS.	53.	62.	78.	74.	67.
FAUCETT, MISSOURI	41.	45.	68.	61.	54.
KANSAS CITY, MO.	42.	48.	68.	61.	55.
SIKESTON, MISSOURI	45.	54.	74.	68.	60.
SPICKARD, MISSOURI	45.	48.	65.	64.	55.
BOZEMAN, MONTANA	35.	35.	56.	48.	43.
HUNTLEY, MONTANA	38.	43.	65.	57.	50.
LINCOLN, NEBRASKA	37.	44.	68.	62.	53.
NEW BRUNSWICK, N.J.	42.	47.	66.	62.	54.
ITHACA, NEW YORK	39.	41.	60.	54.	49.
COLUMBUS, OHIO	41.	46.	65.	61.	53.
COSHOCTON, OHIO	40.	45.	64.	60.	52.
WOOSTER, OHIO	40.	45.	64.	59.	52.
BARNSDALL, OKLAHOMA	51.	56.	75.	70.	63.
LAKE HEFNER, OKLA.	50.	56.	77.	73.	64.
PAWHUSKA, OKLAHOMA	48.	54.	74.	68.	61.
OTTAWA, ONTARIO	37.	37.	60.	51.	47.
CORVALLIS, OREGON	45.	50.	66.	60.	55.
HOOD RIVER, OREGON	41.	49.	61.	58.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .045

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	46.	52.	66.	61.	56.
PENDLETON, OREGON	38.	50.	67.	60.	54.
STATE COLLEGE, PA.	40.	44.	66.	59.	52.
KINGSTON, R. I.	39.	41.	61.	57.	50.
CALHOUN, S.CAROLINA	50.	58.	76.	70.	63.
MADISON, S. DAKOTA	34.	38.	62.	55.	47.
JACKSON, TENNESSEE	48.	55.	72.	64.	59.
TEMPLE, TEXAS	59.	65.	83.	77.	71.
SALT LAKE CITY,UTAH	38.	45.	62.	56.	50.
BURLINGTON, VERMONT	37.	38.	61.	54.	48.
PULLMAN, WASHINGTON	38.	45.	60.	50.	50.
SEATTLE, WASHINGTON	44.	50.	60.	56.	53.
AFTON, WYOMING	39.	42.	58.	53.	48.

Table TG-10

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .050

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	54.	61.	76.	70.	65.
DECATUR, ALABAMA	46.	53.	71.	65.	59.
PALMER AAES, ALASKA	27.	30.	48.	41.	36.
TEMPE, ARIZONA	56.	64.	79.	74.	68.
TUCSON, ARIZONA	62.	69.	82.	81.	73.
BRAWLEY, CALIFORNIA	63.	73.	90.	84.	77.
DAVIS, CALIFORMIA	55.	60.	78.	73.	67.
FT. COLLINS, COLO.	37.	45.	65.	56.	51.
STORRS, CONN.	40.	44.	65.	59.	52.
GAINESVILLE, FLA.	58.	72.	81.	79.	73.
ATHENS, GEORGIA	52.	61.	78.	73.	66.
MOSCOW, IDAHO	38.	42.	57.	53.	47.
LEMONT, ILLINOIS	39.	44.	67.	60.	52.
URBANA, ILLINOIS	39.	47.	68.	60.	53.
WEST LAFAYETTE, IND	40.	47.	69.	62.	54.
AMES, IOWA	35.	44.	70.	61.	52.
BURLINGTON, IOWA	38.	48.	74.	66.	56.
CASTANA, IOWA	32.	42.	70.	61.	51.
COUNCIL BLUFFS,IOWA	39.	47.	70.	63.	55.
SARATOGA, IOWA	33.	39.	68.	58.	49.
SPENCER, IOWA	33.	42.	66.	58.	50.
GARDEN CITY, KANSAS	38.	52.	74.	67.	58.
MANHATTAN, KANSAS	40.	49.	72.	65.	56.
MOUND VALLEY,KANSAS	44.	55.	75.	69.	60.
LEXINGTON, KENTUCKY	44.	51.	72.	65.	58.
UPPER MARLBORO, MD.	41.	49.	69.	64.	56.
EAST LANSING, MICH.	39.	41.	64.	57.	50.
FAIRMONT, MINNESOTA	35.	43.	67.	57.	50.
FARIBAULT,MINNESOTA	34.	38.	62.	54.	47.
ST. PAUL, MINNESOTA	35.	38.	65.	57.	49.
WASECA, MINNESOTA	31.	49.	67.	53.	50.
STATE UNIV., MISS.	53.	62.	78.	74.	67.
FAUCETT, MISSOURI	41.	45.	68.	61.	54.
KANSAS CITY, MO.	41.	48.	68.	61.	55.
SIKESTON, MISSOURI	45.	54.	75.	68.	60.
SPICKARD, MISSOURI	44.	48.	65.	64.	55.
BOZEMAN, MONTANA	34.	35.	57.	48.	43.
HUNTLEY, MONTANA	37.	43.	66.	57.	50.
LINCOLN, NEBRASKA	36.	44.	68.	62.	53.
NEW BRUNSWICK, N.J.	41.	47.	66.	62.	54.
ITHACA, NEW YORK	39.	41.	61.	54.	49.
COLUMBUS, OHIO	40.	47.	65.	61.	53.
COSHOCTON, OHIO	40.	45.	64.	60.	52.
WOOSTER, OHIO	40.	45.	65.	59.	52.
BARNSDALL, OKLAHOMA	50.	56.	75.	70.	63.
LAKE HEFNER, OKLA.	49.	57.	77.	73.	64.
PAWHUSKA, OKLAHOMA	48.	54.	75.	68.	61.
OTTAWA, ONTARIO	37.	37.	61.	51.	47.
CORVALLIS, OREGON	45.	51.	67.	60.	55.
HOOD RIVER, OREGON	41.	49.	61.	57.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .050

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	46.	52.	66.	61.	56.
PENDLETON, OREGON	38.	50.	68.	60.	54.
STATE COLLEGE, PA.	40.	44.	66.	59.	52.
KINGSTON, R. I.	39.	41.	61.	57.	50.
CALHOUN, S.CAROLINA	49.	58.	76.	69.	63.
MADISON, S. DAKOTA	33.	38.	62.	55.	47.
JACKSON, TENNESSEE	48.	55.	72.	64.	59.
TEMPLE, TEXAS	58.	65.	84.	77.	71.
SALT LAKE CITY,UTAH	37.	45.	62.	55.	50.
BURLINGTON, VERMONT	37.	38.	62.	54.	48.
PULLMAN, WASHINGTON	37.	45.	60.	50.	50.
SEATTLE, WASHINGTON	44.	50.	60.	56.	53.
AFTON, WYOMING	39.	42.	59.	53.	48.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .055

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
AUBURN, ALABAMA	54.	61.	77.	70.	65.
DECATUR, ALABAMA	46.	53.	72.	65.	59.
PALMER AAES, ALASKA	27.	30.	49.	41.	36.
TEMPE, ARIZONA	55.	64.	79.	74.	68.
TUCSON, ARIZONA	62.	69.	82.	81.	73.
BRAWLEY, CALIFORNIA	63.	73.	90.	84.	77.
DAVIS, CALIFORMIA	54.	60.	79.	73.	67.
FT. COLLINS, COLO.	37.	45.	65.	56.	51.
STORRS, CONN.	40.	44.	65.	58.	52.
GAINESVILLE, FLA.	58.	73.	81.	79.	73.
ATHENS, GEORGIA	52.	61.	78.	73.	66.
MOSCOW, IDAHO	38.	42.	57.	53.	47.
LEMONT, ILLINOIS	39.	44.	67.	60.	52.
URBANA, ILLINOIS	38.	47.	68.	60.	53.
WEST LAFAYETTE, IND	39.	47.	69.	62.	54.
AMES, IOWA	35.	44.	71.	61.	52.
BURLINGTON, IOWA	38.	49.	75.	66.	56.
CASTANA, IOWA	32.	42.	71.	61.	51.
COUNCIL BLUFFS,IOWA	38.	47.	71.	63.	55.
SARATOGA, IOWA	33.	39.	68.	58.	49.
SPENCER, IOWA	33.	42.	66.	58.	50.
GARDEN CITY, KANSAS	38.	53.	75.	66.	58.
MANHATTAN, KANSAS	40.	49.	72.	65.	56.
MOUND VALLEY,KANSAS	44.	55.	75.	69.	60.
LEXINGTON, KENTUCKY	44.	51.	72.	65.	58.
UPPER MARLBORO, MD.	41.	49.	69.	64.	56.
EAST LANSING, MICH.	39.	41.	64.	57.	50.
FAIRMONT, MINNESOTA	34.	43.	67.	57.	50.
FARIBAULT,MINNESOTA	33.	38.	63.	54.	47.
ST. PAUL, MINNESOTA	34.	38.	66.	57.	49.
WASECA, MINNESOTA	31.	49.	68.	53.	50.
STATE UNIV., MISS.	52.	63.	79.	74.	67.
FAUCETT, MISSOURI	40.	45.	69.	61.	54.
KANSAS CITY, MO.	41.	48.	68.	61.	55.
SIKESTON, MISSOURI	44.	54.	75.	68.	60.
SPICKARD, MISSOURI	44.	48.	66.	64.	55.
BOZEMAN, MONTANA	34.	35.	57.	48.	43.
HUNTLEY, MONTANA	37.	43.	66.	57.	50.
LINCOLN, NEBRASKA	36.	44.	69.	61.	53.
NEW BRUNSWICK, N.J.	41.	47.	66.	62.	54.
ITHACA, NEW YORK	38.	41.	61.	54.	49.
COLUMBUS, OHIO	40.	47.	66.	61.	53.
COSHOCTON, OHIO	39.	45.	64.	60.	52.
WOOSTER, OHIO	39.	45.	65.	59.	52.
BARNSDALL, OKLAHOMA	50.	56.	76.	70.	63.
LAKE HEFNER, OKLA.	49.	57.	77.	73.	64.
PAWHUSKA, OKLAHOMA	48.	54.	75.	68.	61.
OTTAWA, ONTARIO	36.	37.	61.	51.	47.
CORVALLIS, OREGON	44.	51.	67.	60.	55.
HOOD RIVER, OREGON	41.	49.	62.	57.	52.

AVERAGE EARTH TEMPERATURE IN DEG. F, TG

THERMAL DIFFUSIVITY IN FT**2/HR ALPHA= .055

STATION STATES	WINTER	SPRING	SUMMER	FALL	YEAR
MEDFORD, OREGON	46.	52.	66.	61.	56.
PENDLETON, OREGON	37.	50.	68.	60.	54.
STATE COLLEGE, PA.	39.	44.	66.	59.	52.
KINGSTON, R. I.	39.	41.	62.	57.	50.
CALHOUN, S.CAROLINA	49.	58.	76.	69.	63.
MADISON, S. DAKOTA	33.	38.	63.	55.	47.
JACKSON, TENNESSEE	48.	55.	72.	64.	59.
TEMPLE, TEXAS	58.	65.	84.	77.	71.
SALT LAKE CITY,UTAH	37.	45.	63.	55.	50.
BURLINGTON, VERMONT	36.	38.	62.	54.	48.
PULLMAN, WASHINGTON	37.	45.	60.	50.	50.
SEATTLE, WASHINGTON	43.	50.	61.	56.	53.
AFTON, WYOMING	39.	42.	59.	53.	48.

Computer Programs

Appendix A - Computer Programs

```
@C RUN KUSUDA,24100,10,125
@N ASG A=898
@IT FOR  PIPE,PIPE
      COMMON /AA/ XX(60),YY(60),TT(60,60),TITLE(12)
      DIMENSION  T(60,60 ),X(60),Y(60),IX(60),A(4),Z(4),Q(36),TOG(60),
     1TA(4),TB(4),TGA(4),TGB(4),YTEMP(20),XTEMP(20)
C     TS    = DAILY AVERAGE EARTH TEMPERATURE
C     TOP   = PIPE SURFACE TEMPERATURE, F
C     R     = PIPE RADIUS, FT
C     DAY   = DAYS ELAPSED SINCE JAN 1
C     TA    = FOURIER COSINE COEFFICIENTS FOR DIURNAL CYCLE
C     TB    = FOURIER SINE COEFFICIENTS FOR DIURNAL CYCLE
C     TGA   = FOURIER COSINE COEFFICIENTS FOR ANNUAL CYCLE
C     TGB   = FOURIER SINE COEFFICIENTS FOR ANNUAL CYCLE
C     TGO   = ANNUAL AVERAGE EARTH TEMPERATURE
C     AMIN  = MINIMUM SPACE DIFFERENCE
C     DIF   = THERMAL DIFFUSIVITY ,FT**2/HR
C     CON   = THERMAL CONDUCTIVITY(BTU/HR,FT,F
C     NT    = MAX TIME ITERATION
C      NCMAX    NUMBER OF PIPE SECTIONS
C     NFST = STARTING NUMBER FOR TIME ITERATION
C     NSKIP= NUMBER OF TAPE BLOCKS TO BE SKIPPED
  112 FORMAT(10F10.3)
    1 FORMAT(10I7)
  999 FORMAT(12A6)
      READ(5,999)(TITLE(K),K=1,12)
      READ(5,1)I2,J1,J4,NT,NCMAX,NFST,NSKIP
      WRITE(6,1)I2,J1,J4,NT,NCMAX,NFST,NSKIP
      I1=NCMAX/2+1
      NCHF=NCMAX/2
      J2=J1+NCHF
      J3=J1+NCMAX
      PI=4.*ATAN(1.)
      ANGLE=PI/NCMAX
    2 FORMAT(10F7.0)
   37 READ(5,2) AMIN, DIF,CON,TS,TOP,R,DAY
      IF(DIF) 36,36,35
   35 WRITE(6,3) AMIN,DIF,CON,TS,TOP,R,DAY
    3 FORMAT(F7.2,F7.3,F7.2,4F7.1)
      READ(5,2)(TA(I),I=1,4)
      WRITE(6,112)(TA(I),I=1,4)
      READ(5,2)(TB(I),I=1,4)
      WRITE(6,112)(TB(I),I=1,4)
      READ(5,2)(TGA(I),I=1,4),TGO
      WRITE(6,112)(TGA(I),I=1,4),TGO
      READ(5,2)(TGB(I),I=1,4)
      WRITE(6,112)(TGB(I),I=1,4)
      DT=AMIN*AMIN/DIF/4
      DO 4  I=1,NCMAX
      ANG=ANGLE*I
      XTEMP(I)=R*SIN(ANG)
    4 YTEMP(I)=R*(1.-COS(ANG))
      X(1)=0
      I1N=I1+1
      READ(5,2)(X(I),I=I1N,I2)
      READ(5,2)(Y(J),J=1,J1)
      J1N=J1+1
      J3N=J3+1
      DO 27  I=2,I1
   27 X(I)=XTEMP(I-1)
      DO 28  J=J1N,J3
   28 Y(J)=YTEMP(J-J1)+Y(J1)
```

```
      READ(5,2)(Y(J),J=J3N,J4)
      WRITE(6,25) (X(I), I=1,I2)
      WRITE(6,25) (Y(I), I=1,J4)
      WRITE(6,40)DT
   40 FORMAT(1F7.5)
      WRITE(6,26) I1,I2
      WRITE(6,26)J1,J2,J3,J4
   25 FORMAT(20F6.1)
   26 FORMAT(20I6)
      DO    6    J=1,J1
    6 IX(J)=1
      DO    7    I=1,NCHF
      IX(J1+I)=I+1
    7 IX(J2+I)=I1-1
      DO    8    J=J3N,J4
    8 IX(J)=1
      CALL  TG( Y,DIF,TGA,TGB,TGO,TOG,DAY,J4)
      WRITE(6,111)
      WRITE(6,21)(TOG(J),J=1,J4)
  111 FORMAT(50H UNDISTURBED EARTH TEMPERATURE                         )
      DO 9 I=1,I2
      DO 9 J=1,J4
    9 T(I,J)=TOG(J)
      DO 39  J=J1,J3
      IS=IX(J)
      DO 39   I=1,IS
   39 T(I,J)=TOP
      ALPHA=DIF*DT*2.
      XD=2.*R
      XN=Y(J2)
      P=XN/XD
      XQ1=2.*(TOP-TS)
      XQ2=8.*P*P
      XQ3=4.*P*SQRT(4.*P*P-1)
      XQ=XQ1/LOG(XQ2+XQ3)*2*PI*CON
      WRITE(6,30) XQ
   30 FORMAT(10H0    XQ    =F10.5)
      NPLOT=0
      IF(NFST.EQ.1) GO TO 110
      IF(NSKIP.EQ.0) GO TO 109
      DO 113 KS=1,NSKIP
  113 READ(7)
  109 READ(7)(X(I),I=1,I2),(Y(J),J=1,J4),((T(I,J),I=1,I2),J=1,J4),N,NPLO
     1T
C     TIME ITERATION BEGINS
  110 DO 100 N=NFST,NT
      CALL  TEMP(TO,N,TA,TB,TS,DT)
C     SURFACE TEMPERATURE DETERMINATION
      DO   10    I=1,I2
   10 T(I,1)=TO
C     DEPTH TEMPERATURE CALCULATIONS
      DO   20    J=2,J4
      IS=IX(J)
      DO 13    I=1,I2
   70 IF(I.EQ.1.AND.J.LT.J1) GO TO 15
      IF(I.EQ.1.AND.J.GT.J3) GO TO 15
      IF(I.LE.IS.AND.J.GE.J1.AND.J.LE.J3) GO TO 13
      GO TO 12
   15 A(1)=X(2)-X(1)
      A(2)=A(1)
      A(3)=Y(J)-Y(J-1)
      A(4)=Y(J+1)-Y(J)
```

```
      IF(J.EQ.J4) A(4)=A(3)
      Z(1)=T(2,J)
      Z(2)=Z(1)
      Z(3)=T(1,J-1)
      Z(4)=T(1,J+1)
      IF(J.EQ.J4) Z(4)=Z(3)
      T(1,J)=TP(Z,A,ALPHA,T(1,J))
      GO TO 13
   12 A(1)=X(I)-X(I-1)
      A(2)=X(I+1)-X(I)
      IF(I.EQ.I2) A(2)=A(1)
      A(3)=Y(J)-Y(J-1)
      A(4)=Y(J+1)-Y(J)
      IF(J.EQ.J4) A(4)=A(3)
      Z(1)=T(I-1,J)
      Z(2)=T(I+1,J)
      IF(I.EQ.I2) Z(2)=Z(1)
      Z(3)=T(I,J-1)
      Z(4)=T(I,J+1)
      IF(J.EQ.J4) Z(4)=Z(3)
      T(I,J)=TP(Z,A,ALPHA,T(I,J))
   13 CONTINUE
   20 CONTINUE
   21 FORMAT(20F6.1)
      ID=2.*I2-1
      I21=I2-1
      XX(I2)=X(I2)
      DO 106 J=1,J4
  106 YY(J)=-Y(J)
      DO 101 J=1,J4
      TT(1,J)=T(I2,J)
  101 TT(I2,J)=T(1,J)
      DO 102 K=1,I21
      K1=I2-K+1
      K2=K+I2
      XX(K)=X(I2)-X(K1)
      XX(K2)=X(K+1)+X(I2)
      DO 102 J=1,J4
      TT(K,J)=T(K1,J)
  102 TT(K2,J)=T(K+1,J)
  105 FORMAT(20F6.1)
      ZN=FLOAT(N)
      NTEST=INT(ZN/100.)-1
      IF(NTEST.EQ.NPLOT) GO TO 107
      GO TO 100
  107 NPLOT=NPLOT+1
      NC=NCMAX+1
      DO  22  I=1,NC
      ICIR=I+J1-1
      IS=IX(ICIR)
      ANG=ANGLE*(I-1)
      ANGP=PI-ANG
      QX=CON*(T(IS,ICIR)-T(IS+1,ICIR))/(X(IS+1)-X(IS))
      QX=QX*(Y(ICIR+1)-Y(ICIR-1))/2.
      IF(I.GT.I1) GO TO 38
      DLY=Y(ICIR)-Y(ICIR-1)
      DTEMP=T(IS,ICIR)-T(IS,ICIR-1)
      QY=CON*DTEMP /DLY
      QY=QY*(X(IS+1)-X(IS-1))/2.
      Q(I)=QX*SIN(ANG)+QY*COS(ANG)
      GO TO 22
   38 DLY=Y(ICIR+1)-Y(ICIR)
```

```
      DTEMP=T(IS,ICIR)-T(IS,ICIR+1)
      QY=CON*DTEMP/DLY
      QY=QY*(X(IS+1)-X(IS-1))/2.
      Q(I)=QX*SIN(ANGP)+QY*COS(ANGP)
   22 CONTINUE
   29 FORMAT(12F10.2)
      SUM=0.
      DO 23 I=1, NC
   23 SUM=SUM+Q(I)
      QSUM=SUM/NC*2.*PI*R
      QSUMP=SUM*2.
      CALL MAP(ID,J4)
      WRITE(6,24) QSUM,QSUMP
   24 FORMAT(10H0     Q    =2F10.5)
      WRITE(6,26)N
  100 CONTINUE
                     WRITE(7)(X(I),I=1,I2),(Y(J),J=1,J4),((T(I,J),I=1,I2),J
     1=1,J4),N,NPLOT
      WRITE(6,112)(T(1,J),J=1,J4)
      WRITE(6,112)(T(I2,J),J=1,J4)
      WRITE(6,112)(Q(I),I=1,NC)
   36 STOP
      END
WIT FOR XTP,XTP
      FUNCTION  TP(Z,A,ALPHA,T)
      DIMENSION Z(1),A(1)
      Y1=(Z(1)*A(2)+Z(2)*A(1)-T*(A(1)+A(2)))/A(1)/A(2)/(A(1)+A(2))
      Y2=(Z(3)*A(4)+Z(4)*A(3)-T*(A(3)+A(4)))/A(4)/A(3)/(A(3)+A(4))
      TP=T+ALPHA*(Y1+Y2)
      RETURN
      END
WIT FOR TGT,TGT
      SUBROUTINE  TG(Y,DIF,A,B,AO,TOG,DAY,J4)
      DIMENSION  Y(1),A(1),B(1),TOG(1)
      PI=4.*ATAN(1.)
      BETA=SQRT(PI/DIF/8760 )
      W=2*PI/365.*DAY
      DO   2      J=1, J4
      SUM=AO
      Z=BETA*Y(J)
      4F   1        2,1,4
    1 SUM=SUM+EXP(-Z*SQRT(K))*(A(K)*COS(K*W-Z*SQRT(K))+B(K)*SIN(K*W-Z*SQ
     1RT(K)))
    2 TOG(J)=SUM
      RETURN
      END
WIT FOR TM,TM
      SUBROUTINE  TEMP(TO,N,A,B,AO,DT)
      DIMENSION  A(1),B(1)
      P=24.
      M=N-1
      TIME=M/P*2.*3.141592 *DT
      SUM=AO
      DO 2 I=1,4
    2 SUM=SUM+A(I)*COS(I*TIME)+B(I)*SIN(I*TIME)
      TO    =SUM
      RETURN
      END
WIT FOR MP,MP
      SUBROUTINE MAP(MX,MY)
      COMMON/AA/ X(60),Y(60),Z(60,60),TITLE(12)
      DIMENSION          IZ(121,51),KB(11)/
```

```
     11H0,1H ,1H2,1H ,1H4,1H ,1H6,1H ,1H8,1H ,1H*/
      DIMENSION ZL(11)/40.,45.,50.,55.,60.,65.,70.,75.,80.,85.,90./
      DX=ABS(X(MX)-X(1))/120.
      DY=ABS(Y(MY)-Y(1))/50.
      DO 17 I=1,121
      XPX=(I-1)*DX
      DO 1 IX=2,MX
      XP=X(IX)
      IF(XPX-XP)3,2,1
    1 CONTINUE
    2 ZX=0
      GO TO 4
    3 ZX=(X(IX)-XPX)/(XPX-X(IX-1))
    4 DO 17 J=1,51
      IF(J.GT.1) GO TO 31
      TX=Z(IX,1)
      GO TO 32
   31 YPY=(J-1)*DY
      DO 11  JY=2,MY
      YP=-Y(JY)
      IF(YPY-YP)13,12,11
   11 CONTINUE
   12 ZY=0
      GO TO 14
   13 ZY=(-Y(JY)-YPY)/(YPY+Y(JY-1))
   14 T1=(Z(IX-1,JY-1)*ZX+Z(IX,JY-1))/(1.+ZX)
      T2=(Z(IX-1,JY)*ZX+Z(IX,JY))/(1.+ZX)
      TX=(T1*ZY+T2)/(1.+ZY)
   32 DO 15 K=1,11
      IF(TX-ZL(K)) 16,16,15
   15 CONTINUE
   16 IZ(I,J)=KB(K)
   17 CONTINUE
   18 FORMAT(3X,121A1)
   19 FORMAT(12F10.3)
   20 FORMAT(120H0                                                                              GR
     1OUND SURFACE                                                                               )
   30 FORMAT(124H    ------------------------------------------------------------------------
     1-----------------------------------------------------------------------------------------
     2---)
   21 FORMAT(1H1,12A6)
      WRITE(6,21)(TITLE(K),K=1,6)
      WRITE(6,20)
      WRITE(6,30)
      DO 23 J=1,51
   23 WRITE(6,18)(IZ(I,J),I=1,121)
      RETURN
      END
@IT FOR MAX,MAX
      SUBROUTINE SAIDAI(MX,MY,ZMAX)
      COMMON/AA/XX(60),YY(60),Z(60,60),TITLE(12)
      ZMAX=Z(1,1)
      DO 1  I=1,MX
      DO 1 J=1,MY
      IF(ZMAX-Z(I,J)) 2,1,1
    2 ZMAX=Z(I,J)
    1 CONTINUE
      RETURN
      END
@IT FOR MIN,MIN
      SUBROUTINE SAISHO(MX,MY,ZMIN)
      COMMON/AA/XX(60),YY(60),Z(60,60),TITLE(12)
```

```
      ZMIN=Z(1,1)
      DO 1 I=1,MX
      DO 1 J=1,MY
      IF(ZMIN-Z(I,J)) 1,1,2
    2 ZMIN=Z(I,J)
    1 CONTINUE
      RETURN
      END
@N XQT PIPE
 EARTH TEMPERATURE PROFILES
    14      5      19    8000     8    4001
   0.05  0.024   0.75   86.3    40.     1.    180.


                               86.3

    1.1    1.5    2.0    3.0    4.0    5.0    6.0    8.0   16.0
    0.0    0.5    1.5    1.9    2.0
    4.1    4.5    5.0    6.0    8.0   16.0

@ FIN
@ FIN
@ FIN
@ FIN
@ FIN
@ FIN
```

```
@ RUN KUSUDA,24100,1,30
@ TPR
@ MSG PLEASE USE A GOOD LEGIBLE RIBBON ON UN-LINED PAPER
@ MSG PLEASE USE LOW SPEED PRINTER
@ MSG PLEASE PRINT TPR TWICE AND SAVE THE TPR TAPE
@ MSG AND INDICATE THE TPR TAPE NUMBER ON THE RUN
@IT FOR GSA,GSA
      DIMENSION  DO(20),TU(10),PKS(10),PKI(10),DPTH(10),PK(10)
  107 FORMAT(60H1                                                          S
     1SHT=14)
  101 FORMAT(50H0              DEFINITION       Q=KP*(TG-TP)         )
  102 FORMAT(55H0                    WHERE      Q = HEAT TRANSFER TO PIPE    )
  103 FORMAT(55H0                                   BTU/HR,FT OF PIPE        )
  104 FORMAT(60H0                               KP= PIPE HEAT TRANSFER FACTOR
     1     )
 1103 FORMAT(55H0                                   BTU/HR,FT OF PIPE, F     )
  105 FORMAT(60H0                               TG= AVERAGE EARTH TEMPERATURE
     1, F                                                                    )
  106 FORMAT(55H0                               TP= PIPE TEMPERATURE ,   F   )
  108 FORMAT(41H0         THERMAL CONDUCTIVITY OF EARTH  KS=F6.3  ,20H   BTU
     1/HR,SQ.FT,F/IN                                                         )
  114 FORMAT(41H                                           KI=F6.3  ,20H   BTU
     1/HR,SQ.FT,F/IN                                                         )
  109 FORMAT(41H0         DEPTH OF PIPE                      DPTH=F6.1  ,3HFT.)
  110 FORMAT(10H0            )
  111 FORMAT(55H  PIPE SIZE          INSULATION    THICKNESS   (INCHES)      )
  112 FORMAT(11H OD(INCHES),8F7.3)
  113 FORMAT(55H0         THERMAL CONDUCTIVITY OF INSULATION                 )
  115 FORMAT(1X,F10.2,8F7.3)
  100 FORMAT('           HEAT TRANSFER FACTORS OF UNDERGROUND PIPES, KP')
 1104 FORMAT('--------------------------------------------------------------
     1---------')
 1105 FORMAT(43H0         THERMAL CONDUCTIVITY OF INSULATION   )
 1106 FORMAT('0       KI= THERMAL CONDUCTIVITY OF PIPE WALL,   BTU/HR,SQ.F
     1T,F/IN')
 1107 FORMAT('0       HEAT TRANSFER FACTORS OF NONMETALLIC UNDERGROUND PI
     1PES, KP')
 1111 FORMAT(' FIBERGLASS PIPE, KI=2.5      CEMENT AND CONCRETE PIPES,KI=
     16.0')
 1112 FORMAT(3(' PIPE    WALL             '))
 1113 FORMAT(3(' SIZE  THICKNESS          '))
 1114 FORMAT(3(' ID(IN)   (IN)            '))
 1121 FORMAT(1X,I2,2F8.3)
 1122 FORMAT(1H+,22X,I2,2F8.3)
 1123 FORMAT(1H+,44X,I2,2F8.3)
    1 FORMAT(10I7)
    2 FORMAT(10F7.0)
    3 FORMAT(26I3)
    4 FORMAT(9F7.0)
      PI=4.*ATAN(1.)
      READ(5,1) ID,ITU,IKS,IKI,IDPTH,NPAGE
      READ(5,2)(DO(I),I=1,ID)
      READ(5,2)(TU(I),I=1,ITU)
      READ (5,2)( PKS(I),I=1,IKS   )
      READ (5,2)( PKI(I),I=1,IKI   )
      READ (5,2)(DPTH(I),I=1,IDPTH)
      DO  116      N1=1, IKS
      DO  116      N2=1, IKI
      IF(PKS(N1)-PKI(N2)) 116,116,130
  130 DO  131      N3=1, IDPTH
      NPAGE=NPAGE+1
      WRITE(6,107) NPAGE
```

```
      WRITE(6,101)
      WRITE(6,102)
      WRITE(6,103)
      WRITE(6,104)
      WRITE(6,1103)
      WRITE(6,105)
      WRITE(6,106)
      WRITE(6,108) PKS(N1)
      WRITE(6,1105)
      WRITE(6,114) PKI(N2)
      WRITE(6,109) DPTH(N3)
      WRITE(6,110)
      WRITE(6,100)
      WRITE(6,1104)
      WRITE(6,111)
      WRITE(6,1104)
      WRITE(6,112 )(TU(I),I=1,ITU)
      WRITE(6,1104)
      DO 117 N4=3,ID
      A1=DO(N4)*0.5
      DO  118      N5=1,ITU
      IF(TU(N5))128,128,119
  119 A2=A1+TU(N5)
      R1=PKS(N1)/PKI(N2)*LOG(A2/A1)
      GO TO 120
  128 R1=0
      A2=A1
  120 D=DPTH(N3)*12.
      R=(D+SQRT(D*D-A2*A2))/A2
      R2=LOG(R)
      U=(R2+R1)/PKS(N1)
  118 PK(N5)=2.*PI/U/12.
  117 WRITE(6,115) DO(N4),(PK(N5),N5=1,ITU)
  131 CONTINUE
  116 CONTINUE
      STOP
      END
@S XQT GSA
     19        3       1        3       1       1
 1.315 2.375  3.5     4.5      5.563  6.625  7.625  8.625  9.625  10.750
 12.75 14.00  16.0    18.     20.    24.    30.    36.    42.
     0. 0.1305  0.150
5.
1.1     1.6     2.0
6.
@ FIN
```

```
@B RUN BARBER,82001,3,70
@ ASG B
@W ASG D=5594
@ XQT CUR
 ERS
 INF AXLI
 INF PLOT3D
@IT FOR PIPLOT,PIPLOT
      COMMON S,MX,MY,DX,XO,DY
C     DIMENSIONS FOR THE X,Y, AND Z ARRAYS MUST BE EXACT.  Z(I,J) IS THE VALUE
C   OF THE COORDINATE GIVEN BY X(I) AND Y(J).
      DIMENSION X(101),Y(61),Z(101,61),BUFXYZ(10000),SPEC3D(21),S(28)
    1 FORMAT(10F7.0)
    2 FORMAT(10I7)
C     ZMAX AND ZMIN ARE THE MAXIMUM AND MINIMUM VALUES OF THE Z ARRAY.  THEY
C   MUST BE EXACT.  XLENGT AND YLENGT ARE THE DESIRED DIMENSIONS OF THE X AND Y
C   AXES IN INCHES.
      READ(5,1) ZMAX,ZMIN,XLENGT,YLENGT
      READ(5,1) DX,DY,DT,XO
C     MX AND MY ARE THE EXACT NUMBER OF COORDINATES IN THE X AND Y ARRAYS.
      READ(5,2) MX, MY
      CALL GSA3D(X,Y,Z)
C     READ AND PRINT DATA FOR THE X, Y, AND Z ARRAYS FROM TAPE.  N AND NPLT HAV
C   NOTHING TO DO WITH THIS PROGRAM.
  203 FORMAT(20F6.1)
      WRITE(6,204)
      WRITE(6,203)(X(IX),IX=1,MX)
      WRITE(6,205)
      WRITE(6,203)(Y(IY),IY=1,MY)
  201 FORMAT(20F6.0)
      WRITE(6,206)
      DO 202 IX=1,MX
  202 WRITE(6,201)(Z(IX,IY),IY=1,MY)
  204 FORMAT(' X ARRAY')
  205 FORMAT(' Y ARRAY')
  206 FORMAT(' Z ARRAY')
      DO 3 J=1,MY
    3 Y(J)=-Y(J)
C     IN ORDER TO GET A BETTER VIEW OF THIS PARTICULAR PLOT, IT WAS NECESSARY T
C   NEGATE ALL THE Z VALUES IN ORDER TO GET AN INVERTED IMAGE, I. E. THE PEAK
C   GOES UP INSTEAD OF DOWN.  ZMAX AND ZMIN SHOULD BE ADJUSTED ACCORDINGLY.
      DO 4 J=1,MY
      DO 4 I=1,MX
    4 Z(I,J)=-Z(I,J)
C     THE ARRAY SPEC3D(1-21) IS USED FOR THE 3-D PLOTTING.
C     X DISTANCE IN INCHES OF THE LOWER LEFT CORNER OF THE PLOT FROM THE REFER-
C   ENCE POINT, WHICH IS AT THE LOWER LEFT CORNER OF THE PAPER.
      SPEC3D(1)=0.
C     SAME AS ABOVE FOR THE Y DISTANCE.
      SPEC3D(2)=0.
C     SPEC3D(3-6) ARE DETERMINED BY THE PLOTTER.
C      NGTH OF THE PLOT IN THE X DIRECTION (INCHES)
       EC3D(7)=XLENGT
C     LENGTH OF THE PLOT IN THE Y DIRECTION (INCHES)
      SPEC3D(8)=YLENGT
C     NUMBER OF VALUES IN THE X ARRAY.
      SPEC3D(9)=MX
C     NUMBER OF VALUES IN THE Y ARRAY.
      SPEC3D(10)=MY
C     WRITING TOOL. (NORMALLY 1)
      SPEC3D(11)=1.
C     TAPE UNIT FOR THE PRINTER PLOT. CORRESPONDS TO THE  @ ASG B  CONTROL CARD.
```

```
      SPEC3D(12)=8.
C     SPEC3D(13-18) SPECIFY THE MAXIMUM AND MINIMUM VALUES IN THE THREE ARRAYS.
C   SINCE THE X AND Y ARRAYS MUST BE INCREASING, THEIR MAXIMUM AND MINIMUM VALUF
C   ARE GIVEN BY THE LAST AND FIRST COORDINATES OF EACH ARRAY RESPECTIVELY.
C     MAXIMUM VALUE OF THE X ARRAY.
      SPEC3D(13)=X(MX)
C     MINIMUM VALUE OF THE X ARRAY.
      SPEC3D(14)=X(1)
C     MAXIMUM VALUE OF THE Y ARRAY.
      SPEC3D(15)=Y(MY)
C     MINIMUM VALUE OF THE Y ARRAY.
      SPEC3D(16)=Y(1)
C     MAXIMUM VALUE OF THE Z ARRAY.
      SPEC3D(17)=ZMAX
C     MINIMUM VALUE OF THE Z ARRAY.
      SPEC3D(18)=ZMIN
C     SPEC3D(19-21) GIVE THE X, Y, AND Z COORDINATES OF THE DESIRED VIEWING
C   POINT, RESPECTIVELY.  THE BEST DISTANCE IS 5 - 10 DIAMETERS AWAY FROM THE
C   PLOT.  HERE IT IS 6 DIAMETERS IN BACK OF IT IN THE X AND Y DIRECTIONSAND AN
C   ARBITRARY POINT (330) IS GIVEN FOR THE Z COORDINATE.
      SPEC3D(19)=ABS(X(MX)-X(1))*(-6.)
      SPEC3D(20)=ABS(Y(MY)-Y(1))*(-6.)
      SPEC3D(21)=330.
C     LENGTH GIVES THE PLOTTER ROOM TO PLOT THE POINTS IN.  IT IS ALWAYS SET TO
C   A VERY HIGH NUMBER.
      LENGTH=10000
      CALL CAMERA(2,S)
      CALL PLOT3D(X,Y,Z,BUFXYZ,LENGTH,SPEC3D)
C     CALL GDSEND(SPEC3D) AFTER THE LAST FRAME.
      CALL GDSEND(SPEC3D)
      STOP
      END
WIT FOR GSA3D,GSA3D
      SUBROUTINE GSA3D(X,Y,T)
      COMMON S,MX,MY,DX,XO,DY
C  THIS ROUTINE PERMITS THE PLOTTING OF THE MULTIPLE PIPE HEAT
C     HEAT CONDUCTION ISOTHERMS
      REAL X(101),Y(61),T(101,61),TLEVEL(20),A(5),D(5),R(5),TP(5),Q(5),KS,
     1S,S(28)
      PI=4.*ATAN(1.)
      S(1)=1.
      S(2)=1.
      S(3)=100.
      S(4)=-20.
      S(5)=0.
      S(6)=-20.
      S(7)=10.
      S(8)=8.
      S(9)=1.
      S(10)=1.
      S(11)=1.
      S(12)=8.
      LEN=10000
      S(17)=0.25
      S(18)=0.25
      S(19)=0.
      S(20)=0.
      S(21)=1.0
      S(24)=0.5
      S(26)=0.0
      S(28)=0.0
      S(25)=0.1
```

```
100 CALL MULT(A,D,R,Q,TP,L,KS,TG)
    IF(L.EQ.0) GO TO 300
    DO 10   IX=1,MX
    X(IX)=(IX-1)*DX-XO
    DO 10   IY=1,MY
    Y(IY)=(IY-1)*DY*(-1.)
    T(IX,IY)=TG
    DO 20   K=1,L
    Z1=(X(IX)-A(K))*(X(IX)-A(K))
    Z2=(Y(IY)+D(K))*(Y(IY)+D(K))
    Z3=(Y(IY)-D(K))*(Y(IY)-D(K))
    Z=R(K)*R(K)
    ZZ=Z1+Z2
    IF(ZZ-Z) 11,11,12
 12 T(IX,IY)=T(IX,IY)+Q(K)*LOG((Z1+Z3)/ (Z1+Z2))/4./PI/KS
 20 CONTINUE
    GO TO 10
 11 T(IX,IY)=TP(K)
 10 CONTINUE
    WRITE(6,200)
200 FORMAT(2H1    )
    GO TO 100
300 RETURN
    END
@IT FOR MULT,MULT
    SUBROUTINE MULT(A,D,R,Q,TP,M,KS,TG)
C   THIS PROGRAM CALCULATES HEAT TRANSFER FROM MULTIPLE UNDERGROUND PIPE
C   M = NUMBER OF PIPES, M IS LESS THAN OR EQUAL TO FIVE
C   IN= IF ANY ONE OF THESE PIPES IS INSULATED IN=1, OTHERWISE IN=0
C   A(K) = HORIZONTAL DISTANCE OF KTH PIPE FROM TH E REFERENCE LINE, IN
C   A(K) = IF TH E FIRST PIPE IS IN THE REFERENCE POSITION A(2)=0.
C          A(K) IS THEN THE DISTANCE BETWEEN THE FIRST AND KTH PIPES
C   D(K) = DEPTH OF THE GEOMETRICAL CENTER OF THE KTH PIPE, INCHES
C   R(K) = EXTERNAL RADIUS OF THE KTH PIPE. IF INSULATED R(K) SHOULD
C          BE THE EXTERNAL RADIUS OF THE INSU ATION, INCHES
C   KI(K)= THERMAL CONDUCTIVITY OF THE PIPE INSULATION  BTU/HR,FT**2/F/IN
C   TP(K)= EXTERNAL SURFACE TEMPERATURE OF THE KTH PIPE F
C   TPF(K)= INTERNAL FLUIDE TEMPERATURE OF THE KTH PIPE F
C   TH(K)= THICKNESS OF THE PIPE INSULATION, INCHES
C   Q(K) = HEAT TRANSFER TO AND FROM THE KTH PIPE  BTU/HR,FT
C   TG   = UNDISTURBED AVERAGE EARTH TEMPERATURE, F
C   KS=  THERMAL CONDUCTIVITY OF SOIL  BTU/HR,FT**2,F/IN
    REAL A(5),R(5),B(5),KI(5),TP(5),TPF(5),Q(5),TH(5),KS,PHI(5,5),C(5)
   1,QP(5),D(5),PHS(5,5),RES(5),TQ(5)
    PI=4.*ATAN(1.)
C   QP(K)=HEAT TRANSFER TO AND FROM THE KTH PIPE WHEN THERE ARE NO
C   NEIGHBORING PIPES
  1 FORMAT(10F7.0)
 11 FORMAT(10F10.3)
  2 FORMAT(10I7)
 12 FORMAT(10I10)
 19 READ(5,2) M,IN
    IF(M.EQ.0) GO TO 25
 23 WRITE(6,12) M,IN
    READ (5,1) (A(I),I=1,M)
    READ (5,1) (D(I),I=1,M)
    READ (5,1) (R(I),I=1,M)
    WRITE(6,11)(A(I),I=1,M)
    WRITE(6,11)(D(I),I=1,M)
    WRITE(6,11)(R(I),I=1,M)
    READ(5,1) KS,TG
    WRITE(6,11) KS,TG
```

```
      KS=KS/12.
      DO 21  L=1,M
      A(L)=A(L)/12.
      R(L)=R(L)/12.
   21 D(L)=D(L)/12.
      DO 3 K=1,M
      DO 3 I=1,M
      IF(I.EQ.K) GO TO 4
      AIK=(A(K)-A(I))/R(K)
      DIK=(D(K)-D(I))/R(K)
      EIK=(D(K)+D(I))/R(K)
      PHI(I,K)=LOG((AIK*AIK+EIK*EIK)/(AIK*AIK+DIK*DIK))/4./PI/KS
      GO TO 3
    4 PHI(K,K)=LOG(2.*D(K)/R(K))/2./PI/KS
      RES(K)=PHI(K,K)
    3 CONTINUE
      DO 26  I=1,M
   26 WRITE(6,11)(PHI(I,K),K=1,M)
      IF(IN.EQ.0) GO TO 15
      READ (5,1) (TPF(I),I=1,M)
      WRITE(6,11)(TPF(I),I=1,M)
      READ (5,1)  (TH(I),I=1,M)
      WRITE(6,11) (TH(I),I=1,M)
      READ (5,1)  (KI(I),I=1,M)
      WRITE(6,11) (KI(I),I=1,M)
      DO 22  L=1,M
      KI(L)=KI(L)/12.
   22 TH(L)=TH(L)/12.
C     IF THE KTH PIPE IS NOT INSULATED WHEN IN=1, KI(K)=KS
      DO 5 K=1,M
      X=             LOG(R(K)/(R(K)-TH(K)))/KI(K)
    5 C(K)=1./X*2.*PI
      WRITE(6,11)(C(K),K=1,M)
      DO 7 K=1,M
      B(K)=TG
      DO 7 I=1,M
    7 B(K)=B(K)+C(I)*PHI(I,K)*TPF(I)
      DO 24 K=1,M
      DO 8 I=1,M
      IF(I.EQ.K) GO TO 9
      PHS(I,K)=C(I)*PHI(I,K)
      GO TO 8
    9 PHS(K,K)=(1.+C(K)*PHI(K,K))
    8 CONTINUE
   24 CONTINUE
      CALL TRANS(PHS,PHI,M)
      CALL SOLVE(PHI,B,TP,M)
      WRITE(6,11)(TP(I),I=1,M)
      DO 10  K=1,M
   10 Q(K)=C(K)*(TPF(K)-TP(K))
      GO TO 17
   15 READ(5,1)(TP(I),I=1,M)
      WRITE(6,11)(TP(I),I=1,M)
      DO 16  K=1,M
   16 TQ(K)=TP(K)-TG
      CALL TRANS(PHI,PHS,M)
      CALL SOLVE(PHS,TQ,Q,M)
   17 WRITE(6,11)(Q(I),I=1,M)
      DO 18 K=1,M
      RESX=0.
      IF(IN.NE.0) RESX=1./C(K)
      RES(K)=RES(K)+RESX
```

```
      IF(IN.NE.0) QP(K)=(TPF(K)-TG)/RES(K)
      IF(IN.EQ.0) QP(K)=TQ(K)/RES(K)
   18 CONTINUE
      WRITE(6,11)(QP(I),I=1,M)
   25 RETURN
      END
@IT FOR TRANS,TRANS
      SUBROUTINE TRANS(A,TA,N)
      DIMENSION A(5,5),TA(5,5)
      DO 1  I=1,N
      DO 1 J=1,N
    1 TA(I,J)=A(J,I)
      RETURN
      END
@N XQT PIPLOT
-42.   -66.   7.5    7.5
.5     .5     5.     10.
   101     61
     2
    0.   120.
   72.    72.
   12.    12.
   5.0    66.
   42.    57.


@ XQT CUR
 ERS
 INF PRINTR
@ XQT PRINTR
@ XQT CUR
 ERS
 INF SC4020
@ XQT SC4020
@ EOF
@ FIN
@ FIN
@ FIN
```

```
QB RUN KUSUDA,24100,1,75
ЫT FOR VENT,VENT
C     THIS ROUTINE CALCULATES THE AIR TEMPERATURE WITHIN THE VENTED UNDRRGROUND
C          CONDUIT.
C     TG     = EARTH TEMPERATURE, F
C     TO      = OUTDOOR AIR TEMPERATURE, F
C     TA      = CONDUIT AIR TEMPERATURE, F
C     D       = DEPTH OF THE CONDUIT, FT
C     NS      = NUMBER OF PIPES IN THE CONDUIT
C     ZKS     = THERMAL CONDUCTIVITY OF SOIL, BTU/HR, FT**2, F/IN
C     DCON    = DIAMETER OF THE CONDUIT (INSIDE), IN.
C     ZKCON   = THERMAL CONDUCTIVITY OF THE CONDUIT WALL, BTU/HR, FT**2, F/IN
C     THCON   = THICKNESS OF THE CONDUIT WALL, IN.
C     ZL      = LENGTH OF THE CONDUIT BETWEEN THE TWO CONSECUTIVE VENT HOLES
C     CFM     = VENTILATION AIR FLOW CFM
C     NS      = NUMBER OF PIPES IN THE CONDUIT
C     TS(J),J=1,NS      TEMPERATURE WITHIN THE PIPES IN THE CONDUIT, F
C     DS(J),J=1,NS      OUTSIDE DIAMETER OF THE PIPES IN THE CONDUIT, IN
C     THS(J),J=1,NS     INSULATION THICKNESS AROUND THE PIPE IN THE CONDUIT, IN
C     ZK(J),J=1,NS      THERMAL CONDUCTIVITY OF THE PIPE INSULATION
C                       BTU/HR, FT**2, F/IN
      DIMENSION VS(10),TS(10),DS(10),THS(10),       ZK(10)
      PI=4.*ATAN(1.)
    1 FORMAT(10F7.0)
    2 FORMAT(10I7)
C     NVENT  = MECHANICAL VENTILATION
      READ(5,2) NS,NVENT
      WRITE(6,50) NS,NVENT
   50 FORMAT(4H0NS=I10,7H NVENT=I10)
      DO 3 J=1,NS
      READ(5,1) DS(J),THS(J),ZK(J),TS(J)
    3 WRITE(6,53) J,DS(J),J,THS(J),J,ZK(J),J,TS(J)
   53 FORMAT('0DS('I2,')='F10.3,',  THS('I2,')='F10.3 ,',  ZK('I2,')='F1
     10.3,',  TS('I2,')='F10.3)
      READ(5,1) ZL,D,TG,TO,ZKS,DCON,ZKCON,THCON,CFM
   51 FORMAT(120H0    ZL         D          TG         TD         ZKS
     1DCON       ZKCON      THCON      CFM                                  )
      WRITE(6,51)
      WRITE(6,52) ZL,D,TG,TO,ZKS,DCON,ZKCON,THCON,CFM
   52 FORMAT(10F10.2)
      DO 54 J=1,NS
      DS(J)=DS(J)/12.
      THS(J)=THS(J)/12.
   54 ZK(J)=ZK(J)/12.
      ZKS=ZKS/12.
      ZKCON=ZKCON/12.
      DCON=DCON/12.
      THCON=THCON/12.
      RA=1.
      DO 5 J=1,NS
      IF(THS(J)) 6,6,7
    7 R1=DS(J)*0.5
      R2=R1+THS(J)
      R=RA+R2*LOG(R2/R1)/ZK(J)
      GO TO 5
    6 R=RA
    5 VS(J)=1./R
      SUMC=DCON
      SUM=DCON*DCON
      DO 8 J=1,NS
      SUMC=SUMC+DS(J)
    8 SUM=SUM-DS(J)*DS(J)
```

```
      AC=PI*SUM/4.
      PC=PI*SUMC
      DC=4.*AC/PC
      RC1=DCON/2.
      RC2=RC1+THCON
      RC=RA/RC1+LOG(RC2/RC1)/ZKCON+LOG(D/RC2+SQRT(D*D/RC2/RC2+1))/ZKS
      ZKK=2.*PI/RC
      SUM=ZKK
      SUMT=ZKK*TG
      DO 13 J=1,NS
      Q=PI*(DS(J)+2.*THS(J))*VS(J)
      SUM=SUM+Q
   13 SUMT=SUMT+Q*TS(J)
      SUM1=SUM
      SUMT1=SUMT
      CK=2.
      IF(NVENT) 16,33,16
   33 IF(CFM) 15,15,16
   16 SUMT=SUMT+1.08*CFM*TO/ZL
      SUM=SUM+1.08*CFM/ZL
      TA=SUMT/SUM
      GO TO 23
   15 TA1=TO
      JT=1
      SUMT=SUMT1
      SUM=SUM1
   19 RHO=0.075*535./(460.+TA1)
      VIS=VISCO(TA1)
      B1=64.*VIS/DC/4005./4005./0.075*RHO*60./DC*ZL
      B2=CK*RHO/0.075/4005./4005.
      B3=0.52*14.7*D*(1./(460.+TO)-1./(460.+TA1))
      B=B1/B2
      C=B3/B2
      V=0.5*(-B+SQRT(B*B+4.*C))
      WRITE(6,32) V ,CK
   32 FORMAT('0AIR VELOCITY WITHIN THE CONDUIT IS'F10.3,'CK='F10.5)
      G=RHO*V*AC*60.
      SUMT=SUMT+G*0.24*TO/ZL
      SUM=SUM+G*0.24/ZL
      TA=SUMT/SUM
      GO TO (17,18), JT
   17 DT1=TA1-TA
      TA1=TA1+1.
      JT=2
      GO TO 19
   18 DT2=TA1-TA
      IF(DT1*DT2) 22,20,21
   21 DT1=DT2
      TA1=TA1+1.
      JT=2
      GO TO 19
   22 AB=ABS(DT2/DT1)
      TA=(TA1+1.+TA1*AB)/(1.+AB)
      GO TO 23
   20 IF(DT1) 24,25,24
   25 TA=TA1
      GO TO 23
   24 TA=TA1+1.
   23 WRITE(6,31) TA
   31 FORMAT('0CONDUIT AIR TEMPERATURE IS'F10.3)
      IF(TA-200.) 34,34,35
   34 IF(CK-50.) 36,36,35
```

```
   36 CK=CK+1
      GO TO 15
   35 STOP
      END
@IT FOR VIS,VIS
      FUNCTION VISCO(T)
      RHO80=0.0735
      VIS80=1.241E-5
      RHO=RHO80*540./(T+460.)
      TT=(T-32.)/1.8+273.16
      B=110.4
      VIS=VIS80*((TT/300.)**1.5)*410.1/(110.4+TT)
      VISCO=VIS/RHO
      RETURN
      END
@N XQT VENT
      2
8.625  3.      0.35   250.
3.5                   210.
100.   6.      75.    75.    5.0    20.    0.5    1.0
@ FIN
@ FIN
@ FIN
```

Appendix B

Transient Heat Conduction From Multiple Pipe Systems

More general treatment of heat transfer including the transient effect for the multiple underground pipe system will be given in this section.

According to Carslaw and Jaeger[10/], the general expression of earth temperature around a pipe in appropriate unit is

$$T_p - T_G = \frac{Q}{4\pi k_s} \left\{ E_1\left(\frac{r^2}{4\alpha t}\right) - E_1\left(\frac{r'^2}{4\alpha t}\right) \right\} \quad \text{(A-1)}$$

where Q : strength (or the heat transfer per unit length of the pipe) of the heat source or sink

k_s : thermal conductivity of earth around the pipe

$r^2 = (x - x_k)^2 + (y + y_k)^2$

$r'^2 = (x - x_k)^2 + (y - y_k)^2$

α : thermal diffusivity of the earth

t : time elapsed since the activation of the underground pipe

E_1 in the above expression is an exponential integral representing the following relationship

$$E_1\left(\frac{r^2}{4\alpha t}\right) = \int_{\frac{r^2}{4\alpha t}}^{\infty} \frac{e^{-u}}{u}\, du \quad \text{(A-2)}$$

where u is a dummy integration variable. When the value of $\frac{r^2}{4\alpha t}$

is relatively small or when the value of t is large

$$-E_1\left(\frac{r^2}{4\alpha t}\right) = \gamma + \ln\left(\frac{r^2}{4\alpha t}\right) - \left(\frac{r^2}{4\alpha t}\right) + \frac{1}{4}\left(\frac{r^2}{4\alpha t}\right)^2 - \cdots \tag{A-3}$$

where γ = 0.5772, the Euler constant.

As seen from this expression as the value of t further increases

$$-E_1\left(\frac{r^2}{4\alpha t}\right) \longrightarrow \ln\left(\frac{r^2}{4\alpha t}\right) \tag{A-4}$$

Substituting (A-4) into equation (A-1), it is evident that

$$T_p - T_G = \frac{Q}{4\pi k_s} \ln\left(\frac{r'}{r}\right)^2 \tag{A-5}$$

which is the steady state heat transfer equation used in the main text of this report.

As in the case of the steady state heat transfer situation, the superposition principle can be used to calculate the earth temperature influenced by the multitude of the underground pipes as follows:

$$T_p - T_G = \sum_{k=1}^{M} \frac{Q_k}{4\pi k_s} \left\{ E_1\left(\frac{r_k^2}{4\alpha t}\right) - E_1\left(\frac{r_k'^2}{4\alpha t}\right) \right\} \tag{A-6}$$

where Q_k is the strength of the k-th pipe and r_k and r_k' are distance parameters similar to those shown in (A-1).

Using equation (A-6) the average temperature around the j-th pipe of the m pipe system may be approximated by the following equation:

$$\overline{(T_P - T_G)}_j = \frac{1}{2\pi}\int_0^{2\pi}(T_P - T_G)\,d\varphi$$

$$= \sum_{k=1}^{M} \frac{Q_k}{4\pi k_s}\left\{\frac{1}{\pi}\int_0^{\pi} E_1\left(\frac{r_{jk}^2}{4\alpha t}\right)d\varphi_j - \frac{1}{\pi}\int_0^{\pi} E_1\left(\frac{r_{jk}'^2}{4\alpha t}\right)d\varphi_j'\right\} \quad \text{(A-7)}$$

where r_{jk}, r'_{jk}, φ_j and φ'_j are defined graphically in Figure 1-B.

By denoting the terms in the bracket of the above equation by P_{jk} and assuming that the average pipe wall temperature being equal to the known pipe temperature $T_{p,j}$ for j-th pipe, the heat transfer from each of the m pipes, Q_1, Q_2, Q_3 ... Q_j ... and Q_M can be obtained by solving the following simultaneous equations:

$$\frac{1}{4\pi k_s}\begin{vmatrix} P_{11} & P_{12} & \cdots & P_{1M} \\ P_{21} & & & \\ \vdots & & & \\ P_{M1} & & \cdots & P_{MM} \end{vmatrix} \cdot \begin{vmatrix} Q_1 \\ Q_2 \\ \vdots \\ Q_M \end{vmatrix} = \begin{vmatrix} T_{P1} - T_G \\ T_{P2} - T_G \\ \vdots \\ T_{PM} - T_G \end{vmatrix} \quad \text{(A-8)}$$

These determinant relationships are exactly the same as those shown in the steady heat transfer solutions given in the main text. The only differences are that

1. $\frac{r^2}{4\alpha t}$ in lieu of r where r represents length parameters such as pipe radius, depth and distance
2. function E_1 in lieu of ln or natural logarithmic function is used for the transient heat transfer solutions

For the case of two pipes separated by distance of l, with their diameters, depths, and temperatures being the same, the heat transfer from one of the pipes can be obtained as

$$Q = \frac{4\pi k_s (T_P - T_G)}{\{E_1(A) - EINT(A,D) + EINT(A,L) - EINT(A,L')\}} \quad (A-9)$$

where EINT is the integral of function E_1 in the following form

$$EINT(A,D) = \frac{1}{\pi}\int_0^{\pi} E_1(A^2 + D^2 - 2AD\cos\varphi)\,d\varphi \quad (A-10)$$

where A, D, L, and L' are all dimensionless quantities such as

$A = \frac{a}{2\sqrt{\alpha t}}$ and a is the pipe radius

$D = \frac{2d}{2\sqrt{\alpha t}}$ and d is the pipe depth

$$L = \frac{\ell}{2\sqrt{\alpha t}}$$ and l is the pipe center distance

$$L' = \frac{\sqrt{\ell^2 + 4d^2}}{2\sqrt{\alpha t}}$$

The steady state heat transfer equation for the two pipe system corresponding to the case above will be then

$$Q = \frac{4\pi k_s (T_p - T_q)}{\ln\left(\frac{2d}{a}\right)\sqrt{\frac{\ell^2 + 4d^2}{\ell^2}}} \qquad \text{(A-11)}$$

Figure 2B shows the result of sample calculations that utilize the formulas developed above. The problem analyzed is for

a = 1 ft

d = 6 ft

l = 4 ft

k_s = 10 Btu in/hr, ft^2, F

α = 0.025 ft^2/hr

Plotted in this figure are transient as well as steady heat transfer from a pipe, Q in Btu/hr, ft, F, for a double pipe (dotted curve) and single pipe (solid curve) systems. These curves show that the heat transfer will be extremely high immediately after the pipes are activated but it rapidly decreases to a relatively stable value at around 300 hours. Then even after 900 hours the heat transfer values are still 20 and 30 percent higher than the steady state values (for the double and single pipe systems respectively). Secondly, the heat transfer of a single pipe of the double pipe system is almost identical during the first 100 hour period as that of the single pipe system. It, however, becomes eventually lower than the single pipe to approximately 85 percent of the single pipe heat transfer. This is expected because the average temperature of the soil surrounding the double pipe chilled water system, for example, will be lower than that surrounding the single pipe system. This effect of temperature disturbance caused by the existence of the adjacent pipe, however, does not become apparent, at least in this example, during the first 100 hours. It is also evident from Figure B2 that it takes more than a month after the activation of an underground heat distribution system before theoretical steady state heat transfer condition is reached.

In order to permit similar type analyses for many other piping systems, the computer program used for this particular calculation is attached at the end of this section.

Computer Program for Heat Transfer from Double Pipe System

(Transient Case)

```
      REAL K,L,L1,LP
    1 FORMAT(10F7.3)
    2 FORMAT(4F20.3)
    4 FORMAT(10H0INFINITY=3F20.3)
    5 FORMAT(10H1        TIME3F20.3)
      PI=4.*ATAN(1.)
      READ (5,1) A,D,L,ALPHA,K,TG,TP
      WRITE(6,1) A,D,L,ALPHA,K,TG,TP
      Z=4.*PI*K*(TP-TG)/12.
      WRITE(6,5)
      DO 3 J=1,1000,10
      TIME=FLOAT(J)
      X=SQRT(ALPHA*4.*TIME)
      A1=(A/12.)/X
      D1=(2.*D/12.)/X
      L1=L/12./X
      LP=SQRT(L*L+4.*D*D)/ 12./X
      AA=A1*A1
      Y1=EIF(AA)-EINT(A1,D1)
      Y2=EINT(A1,L1)-EINT(A1,LP)
      Z1=Z/Y1
      Z2=Z/Y2
      Z3=Z/(Y1+Y2)
    3 WRITE(6,2) TIME,Z1,Z2,Z3
      Y1=LOG(2.*D/A)*2.
      Y3=SQRT(L*L+4.*D*D)
      Y2=LOG(Y3/L)
      Z1=Z/Y1
      Z2=Z/Y2
      Z3=Z/(Y1+Y2)
      WRITE(6,4) Z1,Z2,Z3
      STOP
      END
```

$$EINT(A,B) = \frac{1}{\pi}\int_0^{\pi} E_1(A^2+B^2-2A.B.\cos\varphi)\,d\varphi$$

```
      FUNCTION EINT(A,B)
      DIMENSION Y(101)
      PI=4.*ATAN(1.)
      DP=PI/100.
      DO 1 J=1,101
      Z=(J-1)*DP
      X=A*A+B*B-2.*A*B*COS(Z)
    1 Y(J)=E1F(X)
      P1=Y(1)+Y(101)
      P2=0.
      DO 2 K=2,100,2
    2 P2=P2+Y(K)
      P3=0.
      DO 3 K=3,99,2
    3 P3=P3+Y(K)
      EINT=DP*(P1+4.*P2+2.*P3)/3./PI
      RETURN
      END
```

$$E_1(x) = \int_x^{\infty} \frac{e^{-u}}{u}\, du$$

```
      FUNCTION EIF(X)
      DIMENSION  A(6)/-.57721566,.99999193,-.24991055,.05519968,-.009760
     104,.00107857/,B(2)/2.334733,.250621/,C(2)/3.330657,1.681534/,D(2)/
     24.03640,1.15198/,E(2)/5.03637,4.19160/
      IF(X-1.) 1,1,2
    1 SUM=A(1)-LOG(X)
      DO 3 J=2,6
    3 SUM=SUM+A(J)*X**(J-1)
      GO TO 10
    2 IF(X-10.) 4,4,5
    4 P1=(X*X+B(1)*X+B(2))/(X*X+C(1)*X+C(2))
      IF(X-20.) 11,12,12
   12 SUM=0.
      GO TO 10
   11 SUM=P1/X/EXP(X)
      GO TO 10
    5 DO 6 K=1,2
      B(K)=D(K)
    6 C(K)=E(K)
      GO TO 4
   10 EIF=SUM
      RETURN
      END
```

t Time (hr)	Single Pipe System Q	Double Pipe System Q
1.000	2519137.344	2519137.344
11.000	40.888	40.887
21.000	17.757	17.742
31.000	12.264	12.234
41.000	9.846	9.754
51.000	8.453	8.316
61.000	7.542	7.362
71.000	6.894	6.674
81.000	6.407	6.149
91.000	6.025	5.733
101.000	5.716	5.394
111.000	5.460	5.111
121.000	5.244	4.870
131.000	5.058	4.661
141.000	4.897	4.479
151.000	4.754	4.319
161.000	4.628	4.175
171.000	4.515	4.047
181.000	4.413	3.931
191.000	4.320	3.825
201.000	4.235	3.729
211.000	4.158	3.640
221.000	4.086	3.559
231.000	4.020	3.484
241.000	3.958	3.414
251.000	3.901	3.349
261.000	3.847	3.288
271.000	3.797	3.231
281.000	3.750	3.178
291.000	3.705	3.127
301.000	3.663	3.080
311.000	3.624	3.035
321.000	3.586	2.993
331.000	3.551	2.953
341.000	3.517	2.914
351.000	3.484	2.878
361.000	3.454	2.844
371.000	3.424	2.811
381.000	3.396	2.780
391.000	3.369	2.750
401.000	3.344	2.721
411.000	3.319	2.694
421.000	3.295	2.667
431.000	3.272	2.642
441.000	3.251	2.618
451.000	3.230	2.595
461.000	3.209	2.573
471.000	3.190	2.551
481.000	3.171	2.530
491.000	3.153	2.511
501.000	3.135	2.491
511.000	3.118	2.473
521.000	3.102	2.455
531.000	3.086	2.438
541.000	3.070	2.421
551.000	3.056	2.405

561.000	3.041	2.389
571.000	3.027	2.374
581.000	3.014	2.359
591.000	3.000	2.345
601.000	2.988	2.331
611.000	2.975	2.318
621.000	2.963	2.305
631.000	2.951	2.292
641.000	2.940	2.280
651.000	2.929	2.268
661.000	2.918	2.256
671.000	2.907	2.245
681.000	2.897	2.234
691.000	2.887	2.223
701.000	2.877	2.213
711.000	2.868	2.203
721.000	2.858	2.193
731.000	2.849	2.183
741.000	2.841	2.174
751.000	2.832	2.165
761.000	2.823	2.156
771.000	2.815	2.147
781.000	2.807	2.139
791.000	2.799	2.130
801.000	2.792	2.122
811.000	2.784	2.114
821.000	2.777	2.107
831.000	2.769	2.099
841.000	2.762	2.092
851.000	2.756	2.084
861.000	2.749	2.077
871.000	2.742	2.070
881.000	2.736	2.064
891.000	2.729	2.057
901.000	2.723	2.051
911.000	2.717	2.044
921.000	2.711	2.038
931.000	2.705	2.032
941.000	2.699	2.026
951.000	2.694	2.020
961.000	2.688	2.014
971.000	2.683	2.009
981.000	2.678	2.003
991.000	2.672	1.998
steady state solution	2.107	1.711
	single pipe system	double pipe system

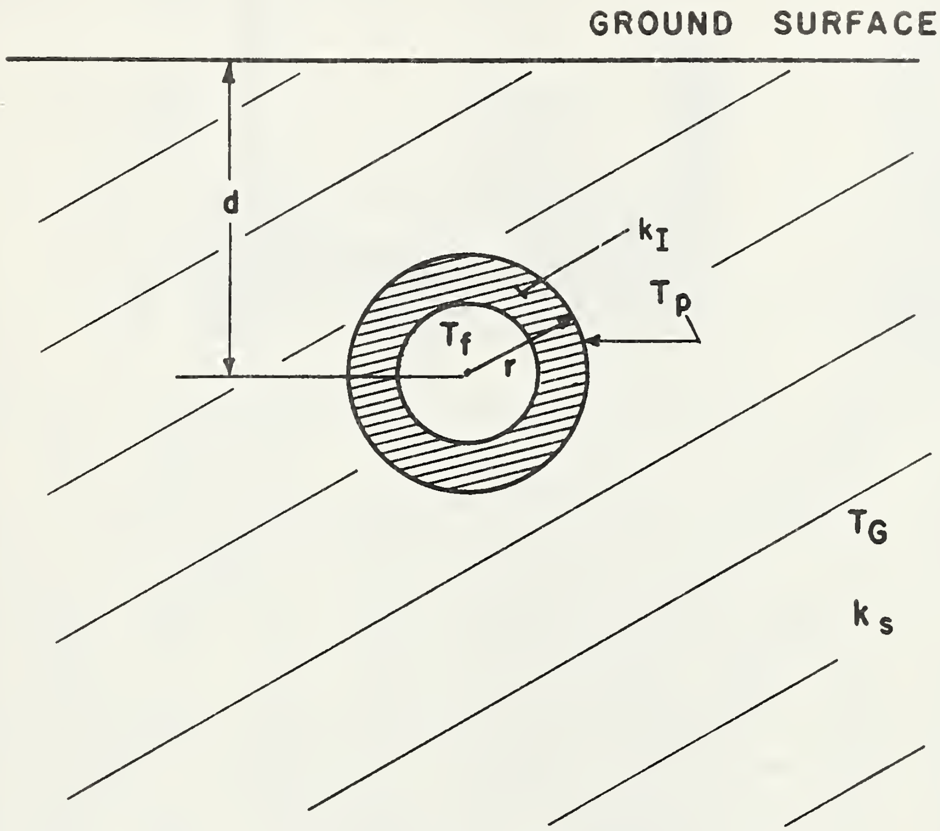
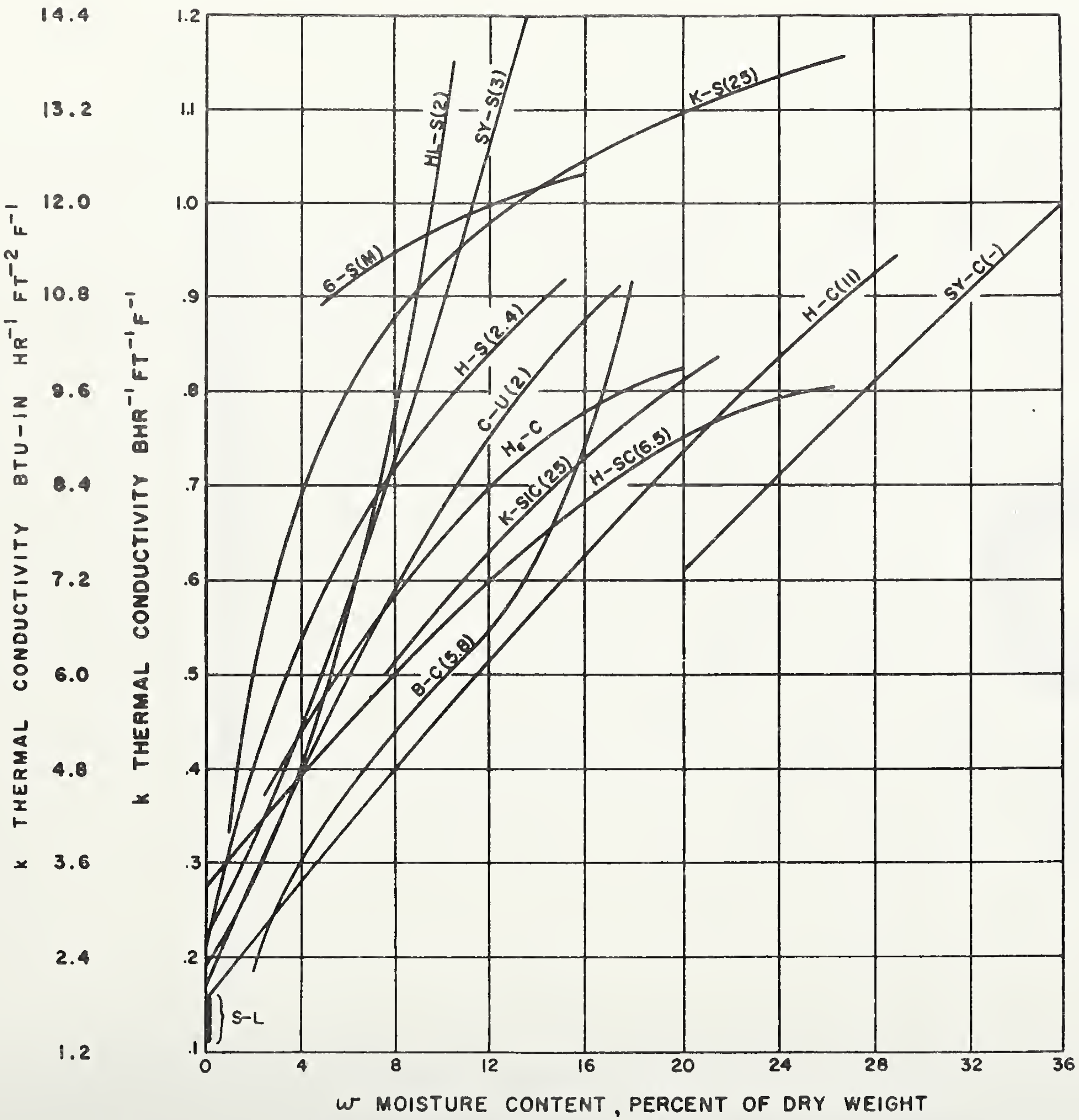


FIG. 1 SINGLE PIPE SYSTEM (NOMENCLATURE)



SUMMARY OF THERMAL CONDUCTIVITY AS A FUNCTION OF MOISTURE CONTENT FOR VARIOUS SOILS AS MEASURED BY SEVERAL INVESTIGATORS (TAKEN FROM J.D.BOTTORF, PURDUE) UNIVERSITY THESIS, 1951

EXPLANATION OF SYMBOLS

FIRST SYMBOL, INVESTIGATOR

B - BOTTORF
C - COOGAN (9)
G - GEMANT (10)
H - HADLEY (7)
H_e - HARSEM (1)
HL - HOOPER & LEPPER (8)
K - KERSTEN (2)
SY - SMITH & YAMAUCHI (6)

SECOND SYMBOL, SOIL TYPE

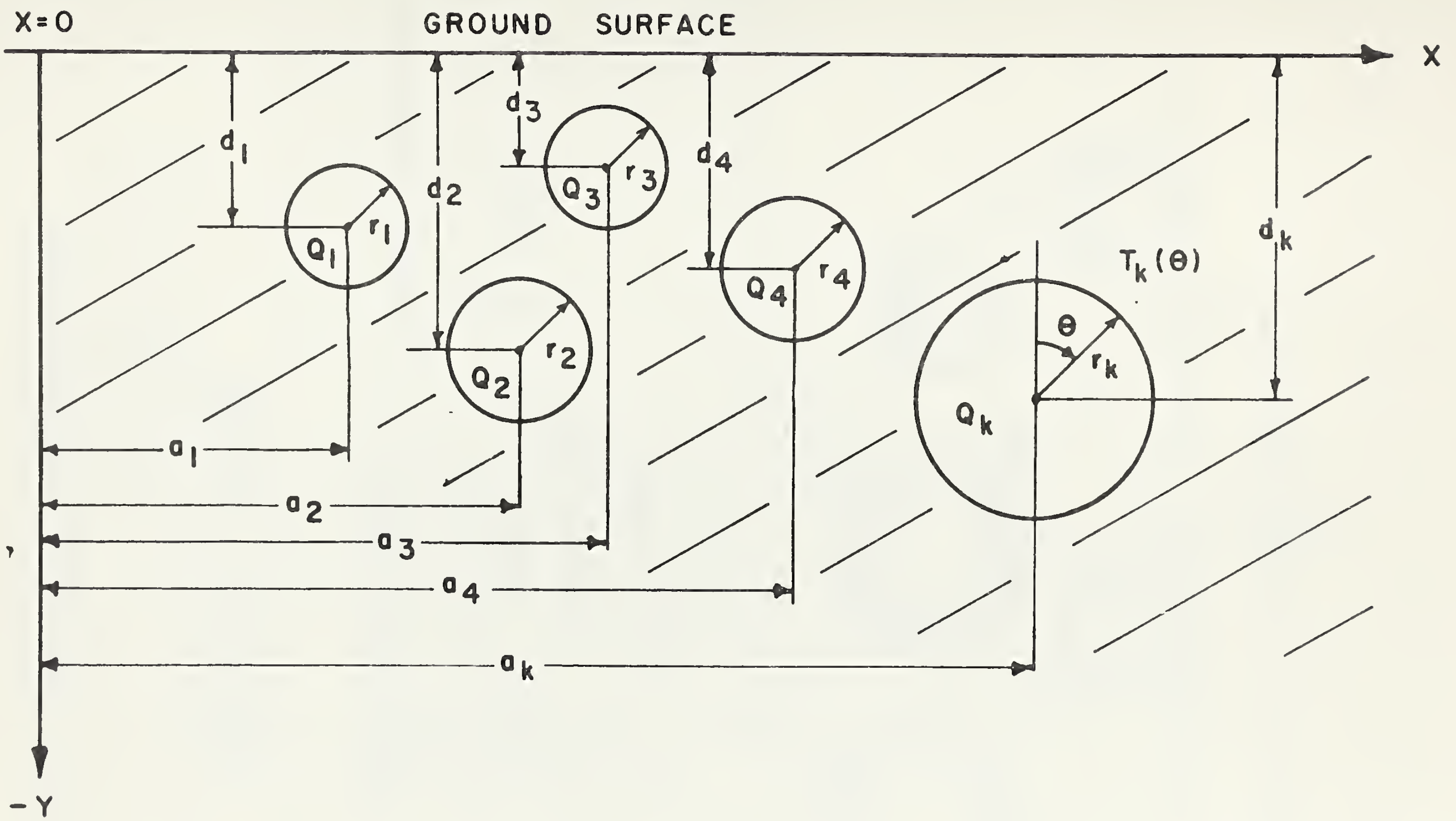
S - SAND
SC - SAND CLAY
SIC - SILTY CLAY
C - CLAY
SL - SANDY LOAM
L - LOAM
U - UNSPECIFIED

THIRD SYMBOL

NUMBERS REPRESENT AVERAGE PERCENT DEVIATION OF DATA FROM THE MEAN CURVE SHOWN

"M" INDICATES CALCULATED VALUES BASED UPON A MODEL

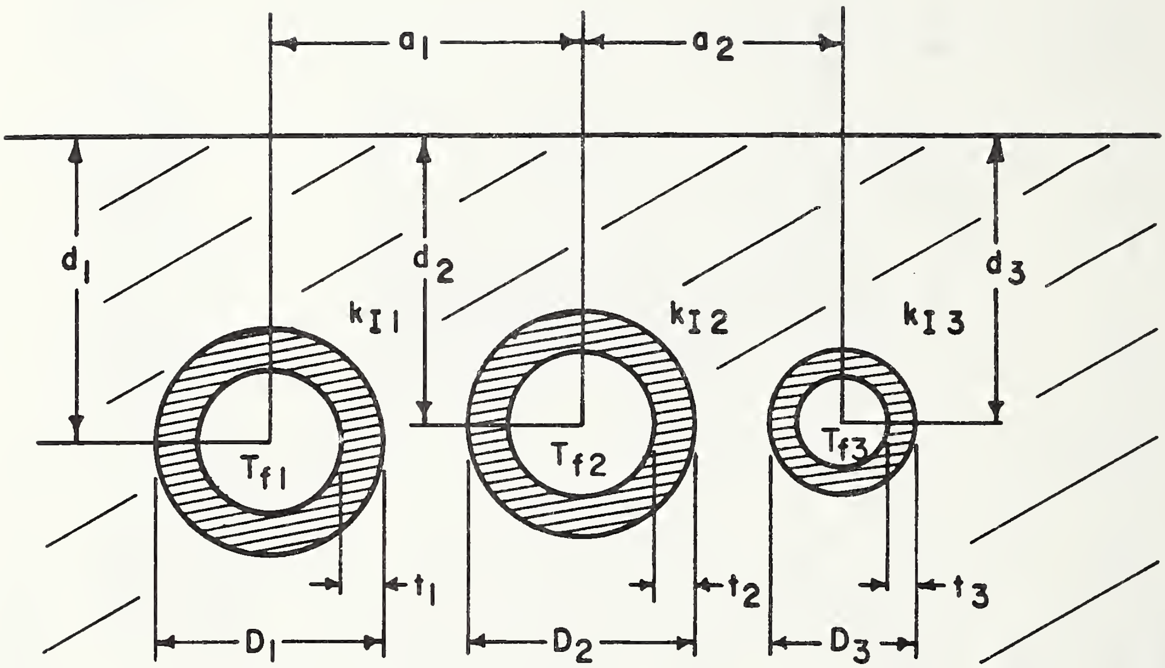
FIG. 2 THERMAL CONDUCTIVITY VERSUS MOISTURE CONTENT FOR SEVERAL SOILS



UNDISTURBED AVERAGE EARTH TEMPERATURE, T_G

UNDISTURBED AVERAGE THERMAL CONDUCTIVITY, k_s

FIG. 3 MULTIPLE PIPE SYSTEM (BARE PIPES)



T_f = PIPE TEMPERATURE

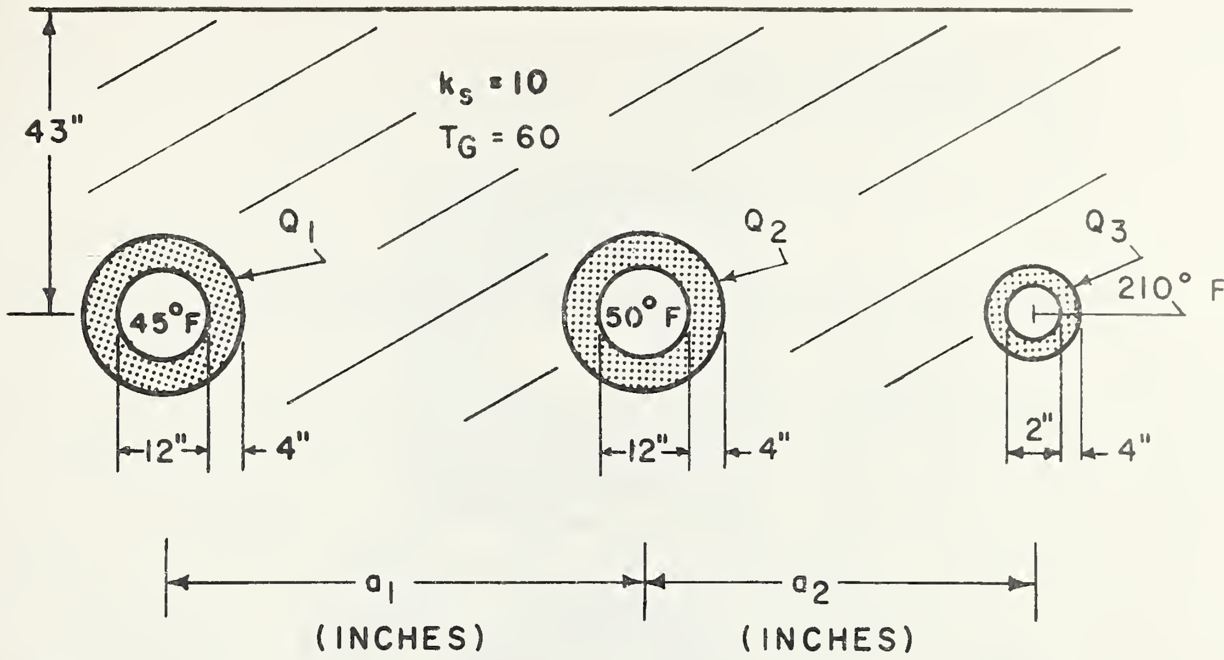
T_G = EARTH TEMPERATURE, °F

k_s = THERMAL CONDUCTIVITY OF EARTH BTU/HR, FT^2, °F/IN

k_I = THERMAL CONDUCTIVITY OF PIPE INSULATION BTU/HR, FT^2, °F/IN

THREE-PIPE SYSTEM

FIG. 4 MULTIPLE PIPE SYSTEM (INSULATED PIPES)



CASE	a_1	a_2	Q_1	Q_2	Q_3
1	60	50	-17.89 (16)	-20.30 (72)	81.24 (2)
2	55	45	-18.15 (12)	-21.46 (98)	81.57 (3)
3	50	40	-18.48 (14)	-22.82 (111)	82.00 (3)
4	45	35	-18.89 (16)	-24.46 (126)	82.55 (4)
5	∞	∞	-16.23	-10.82	79.40

FIG. 5 SAMPLE CALCULATION FOR MULTIPLE PIPE SYSTEM (INSULATED PIPE SYSTEM)

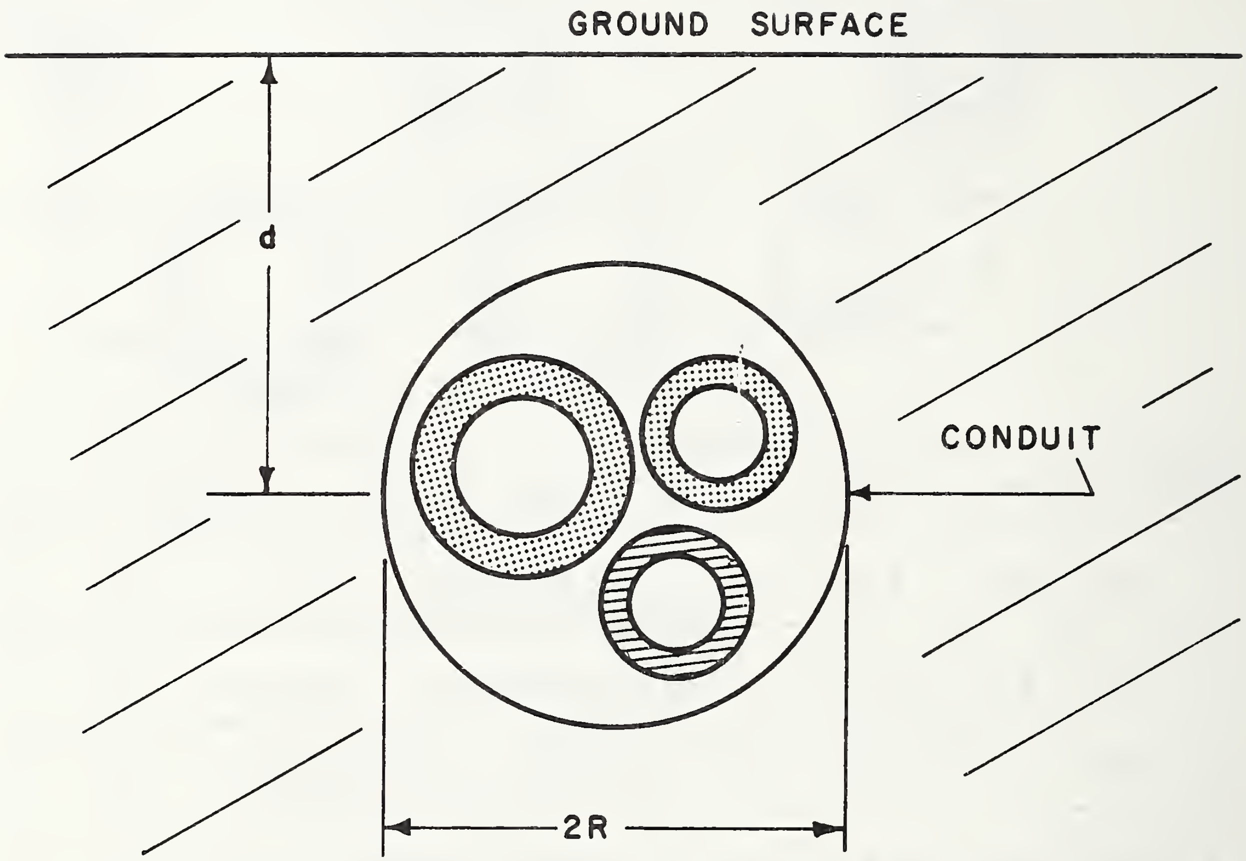


FIG. 6 PIPES IN A CONDUIT

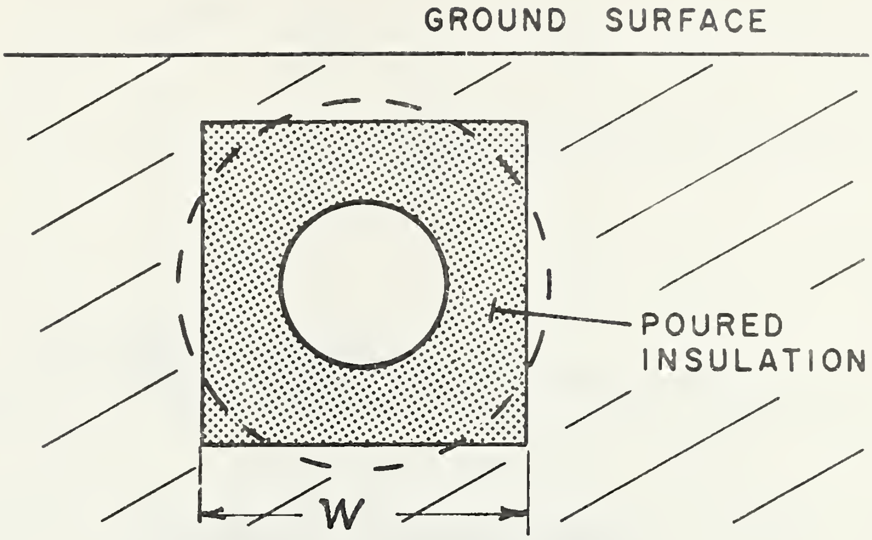


FIG. 7 PIPE IN AN INSULATED TRENCH

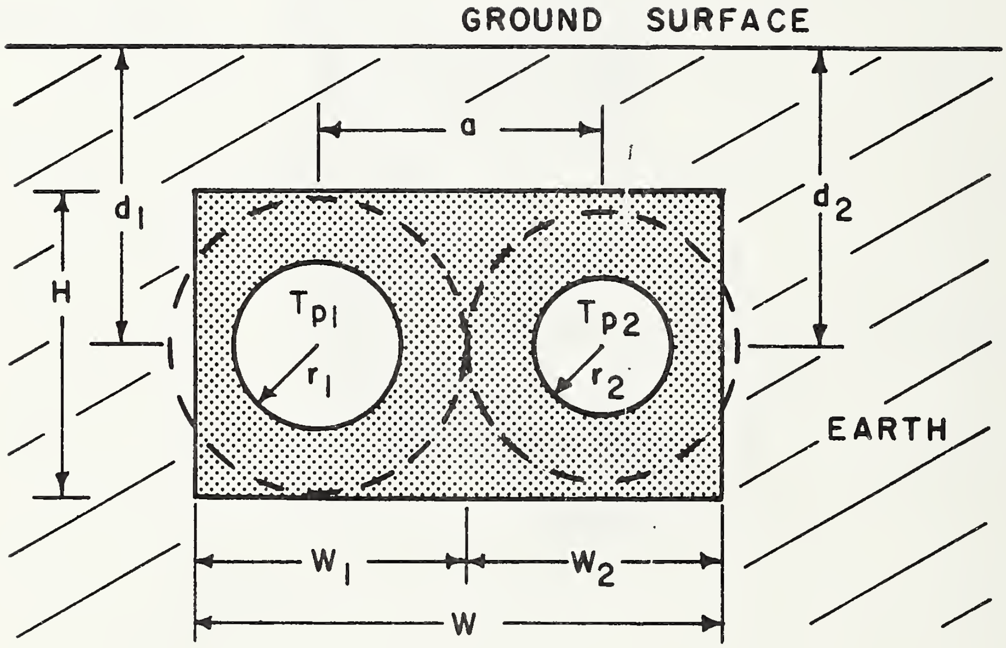


Fig. 8 PIPES IN AN INSULATED TRENCH

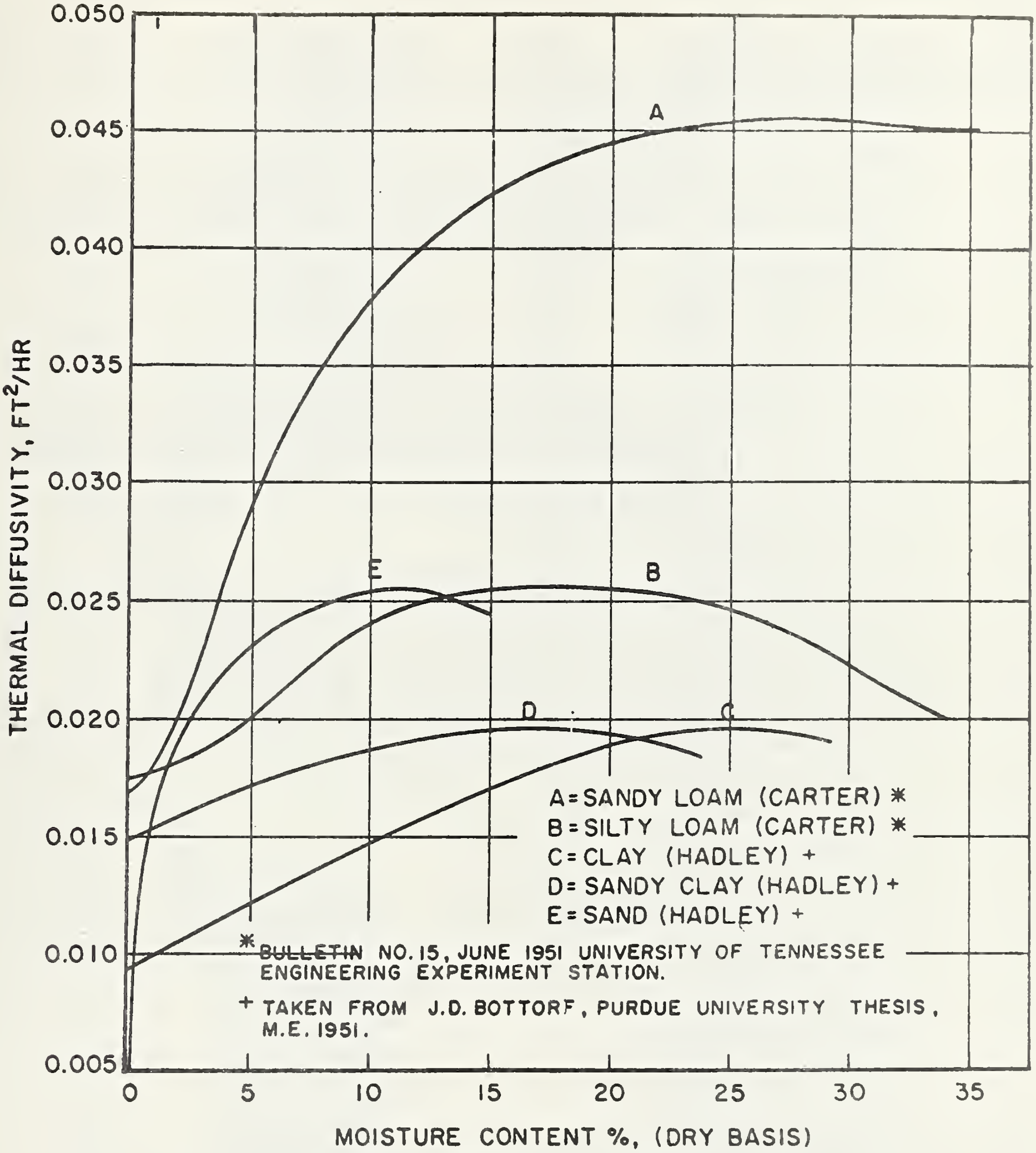


Fig. 9 THERMAL DIFFUSIVITY VERSUS MOISTURE CONTENT FOR SEVERAL SOILS

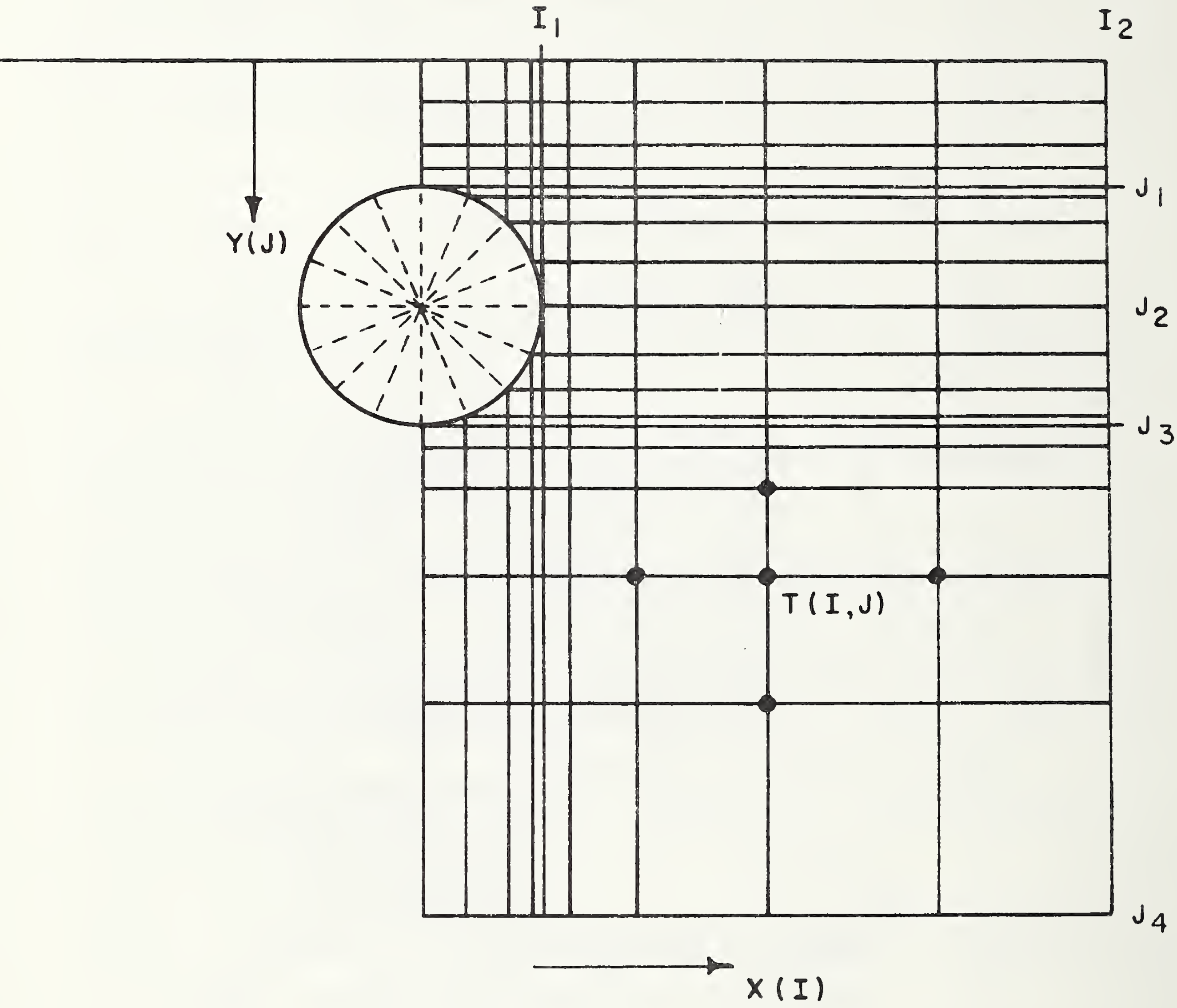
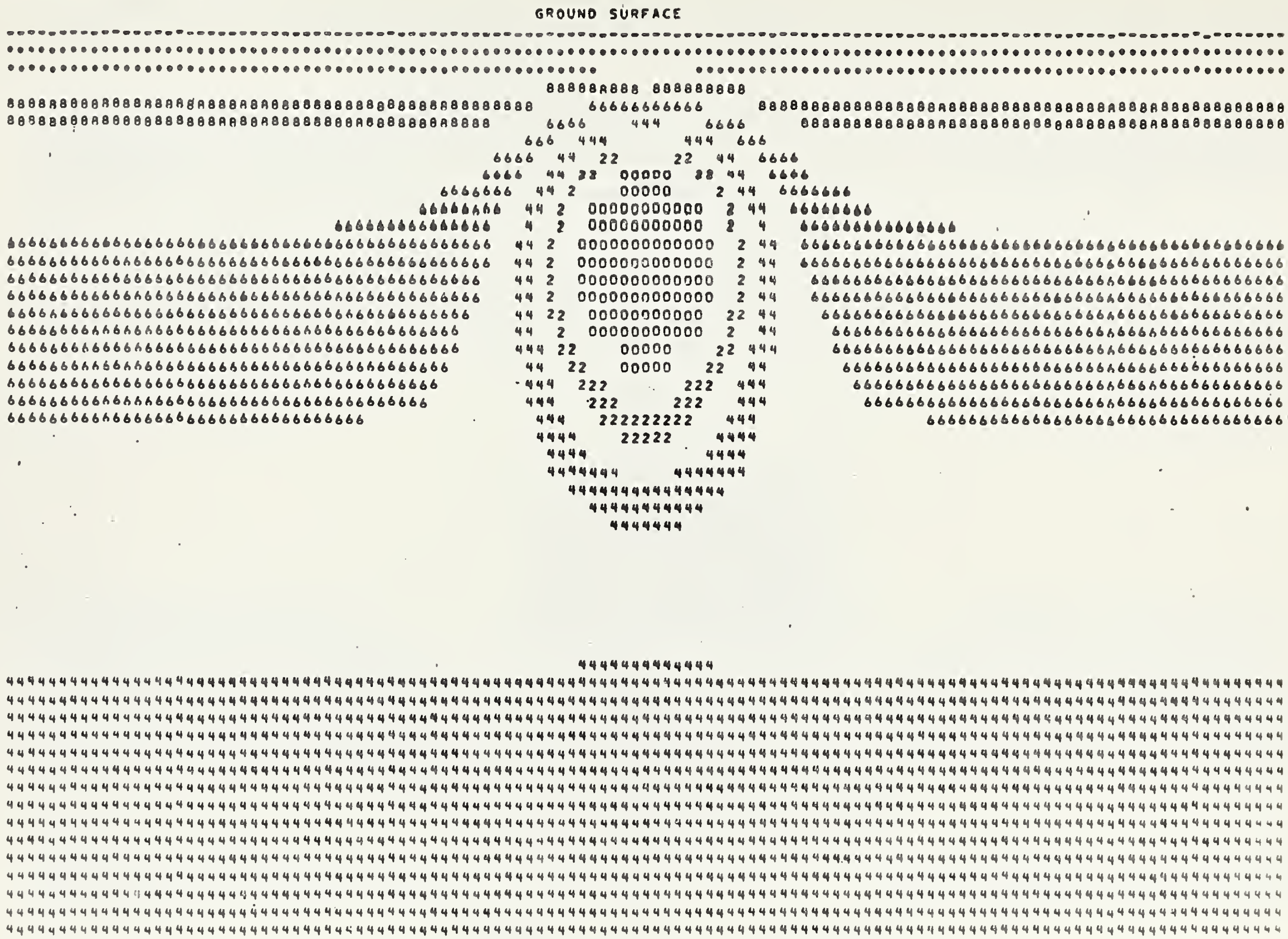


Fig. 10 GRID DESIGN FOR A FINITE DIFFERENCE SOLUTION OF THE HEAT CONDUCTION EQUATION

EARTH TEMPERATURE PROFILES



0 =-200.04866
500

Figure 11 Temperature zone indices: 0 = 40 °F, 2 = 50 °F, 4 = 60 °F, 6 = 70 °F, 8 = 80 °F, * = 90 °F

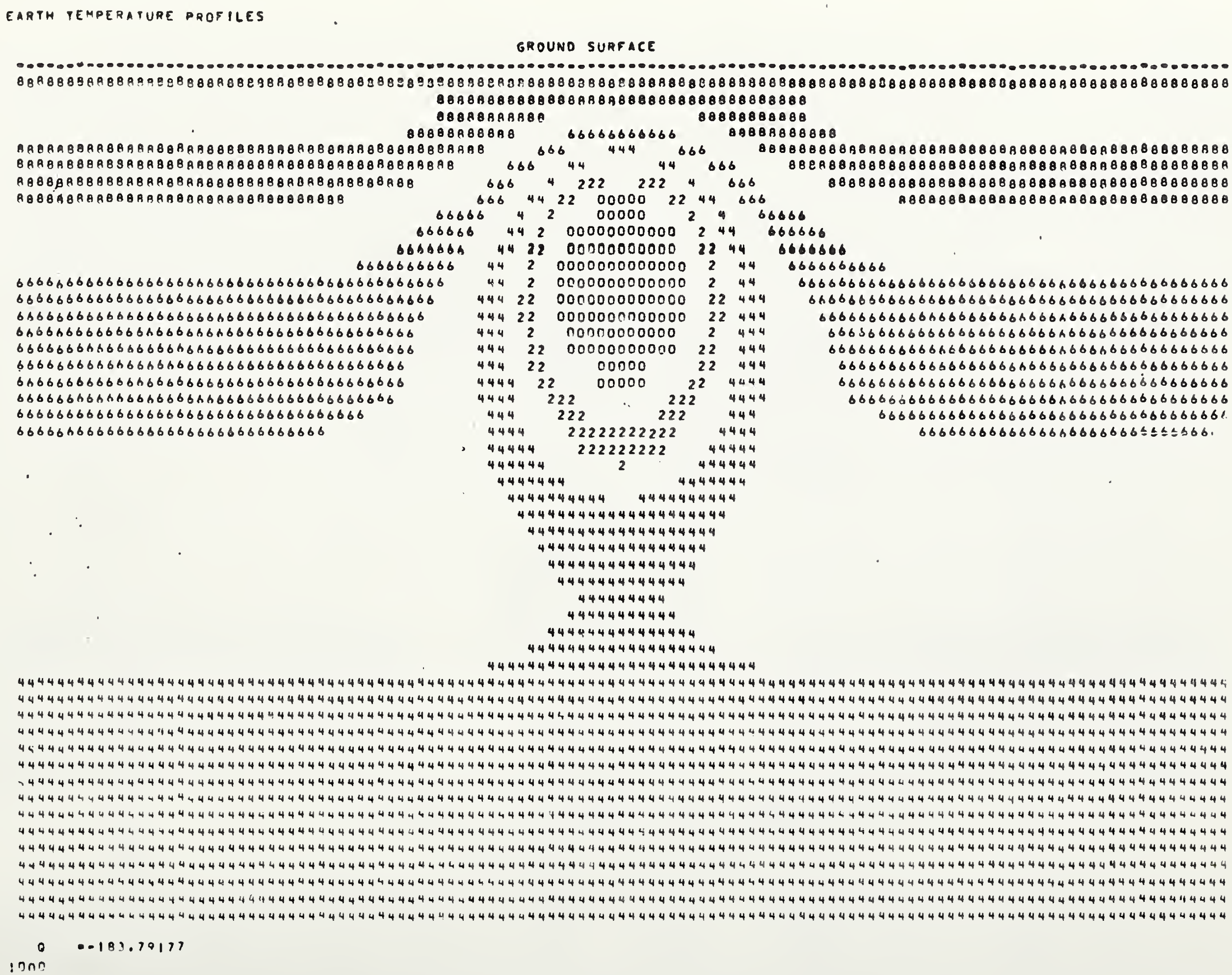


Figure 12 Temperature zone indices: 0 = 40 °F, 2 = 50 °F, 4 = 60 °F, 6 = 70 °F, 8 = 80 °F, * = 90 °F

EARTH TEMPERATURE PROFILES

0 =-166.71699
2000

Figure 13 Temperature zone indices: 0 = 40 °F, 2 = 50 °F, 4 = 60 °F, 6 = 70 °F, 8 = 80 °F, * = 90 °F

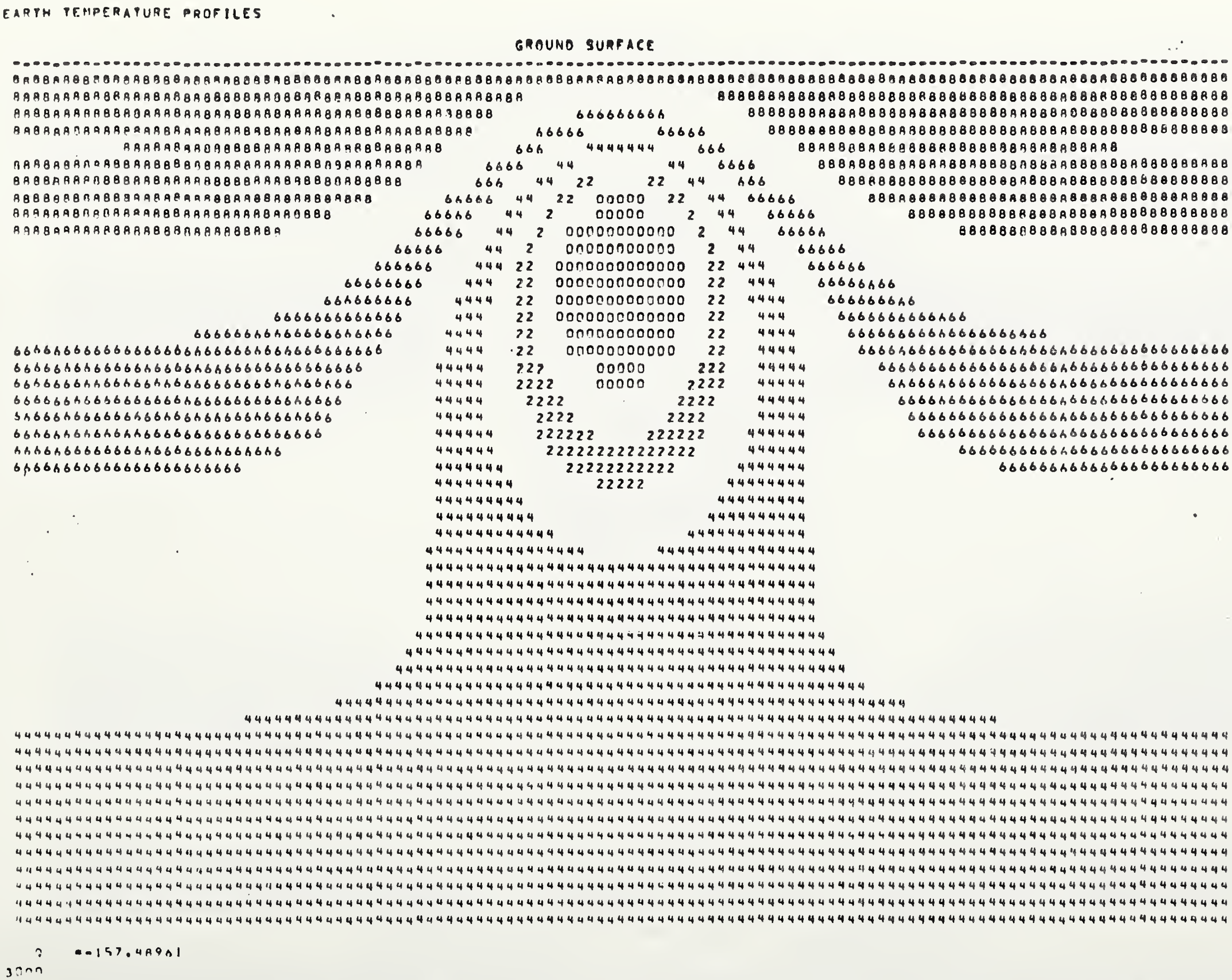


Figure 14 Temperature zone indices: 0 = 40 °F, 2 = 50 °F, 4 = 60 °F, 6 = 70 °F, 8 = 80 °F, * = 90 °F

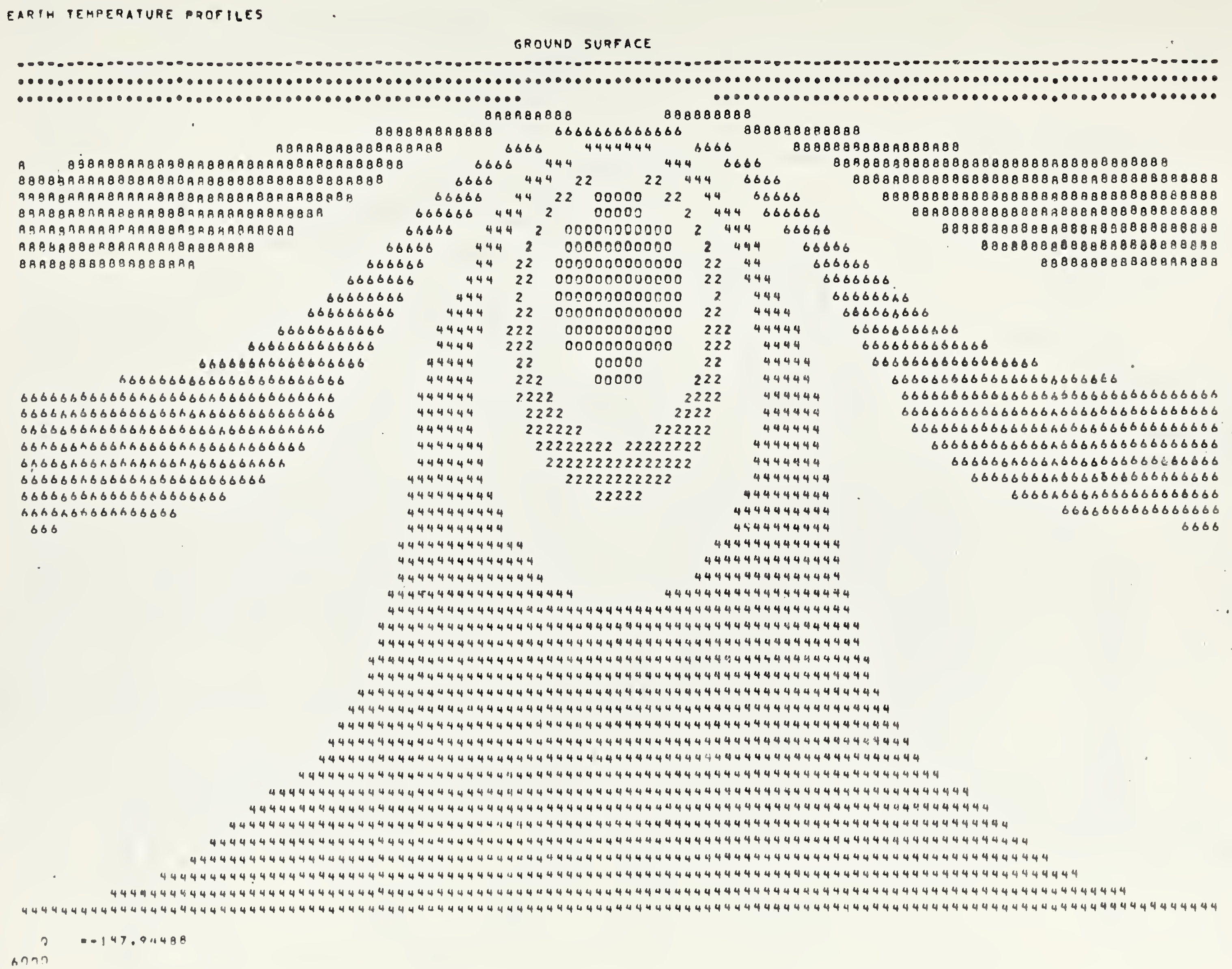


Figure 15 Temperature zone indices: 0 = 40 °F, 2 = 50 °F, 4 = 60 °F, 6 = 70 °F, 8 = 80 °F, * = 90 °F

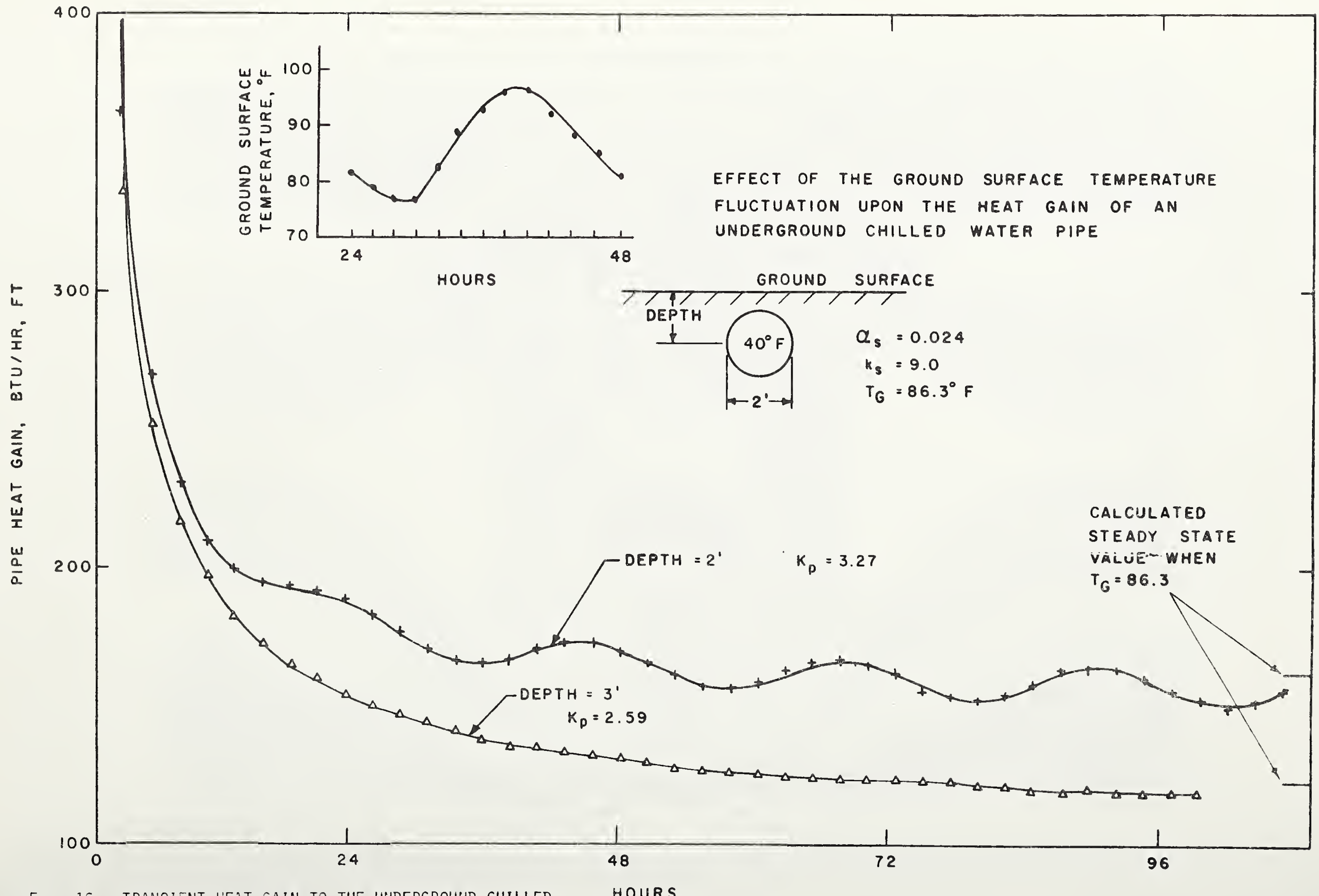
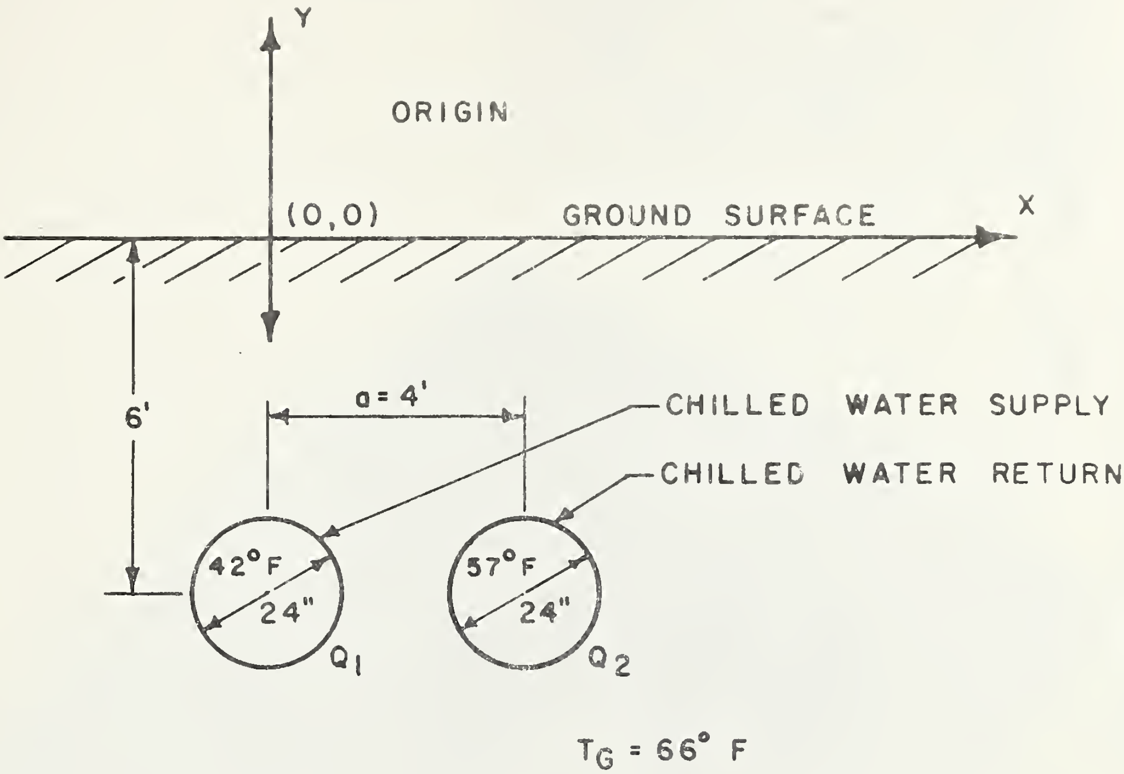


FIG. 16 TRANSIENT HEAT GAIN TO THE UNDERGROUND CHILLED WATER PIPE



CASE	a	k_s	Q_1	Q_2
1	5'	10	− 50.79	0.565
2	∞	10	− 50.57	− 18.96
3	4'	10	− 53.21	5.687
4	4	5	− 26.60	2.843
5	∞	5	− 25.29	− 9.48
6	10	5	− 24.37	− 5.11

FIG. 17 SAMPLE DOUBLE PIPE PROBLEM

TEMPERATURE CONTOURS FOR UNDERGROUND PIPES

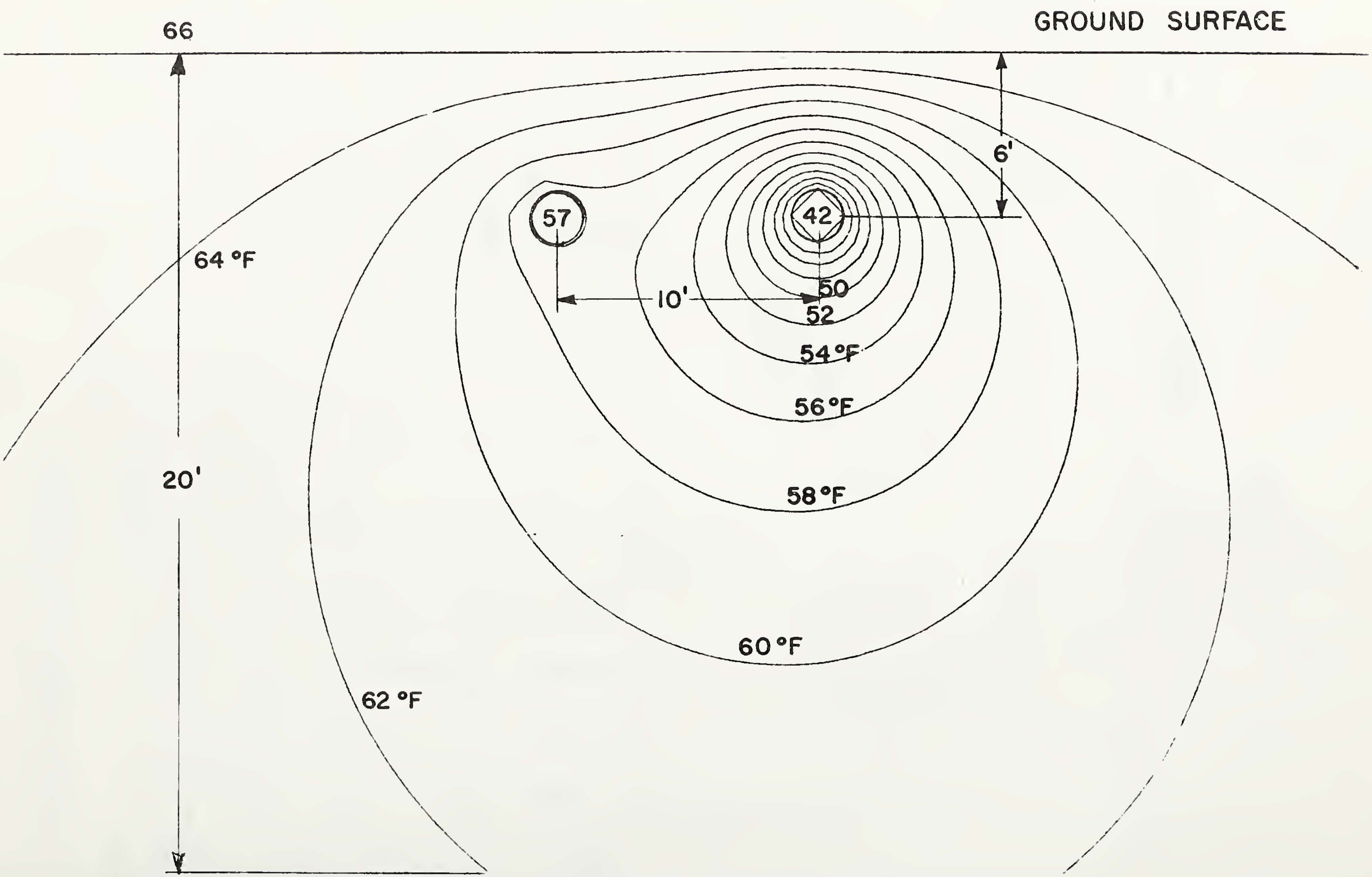
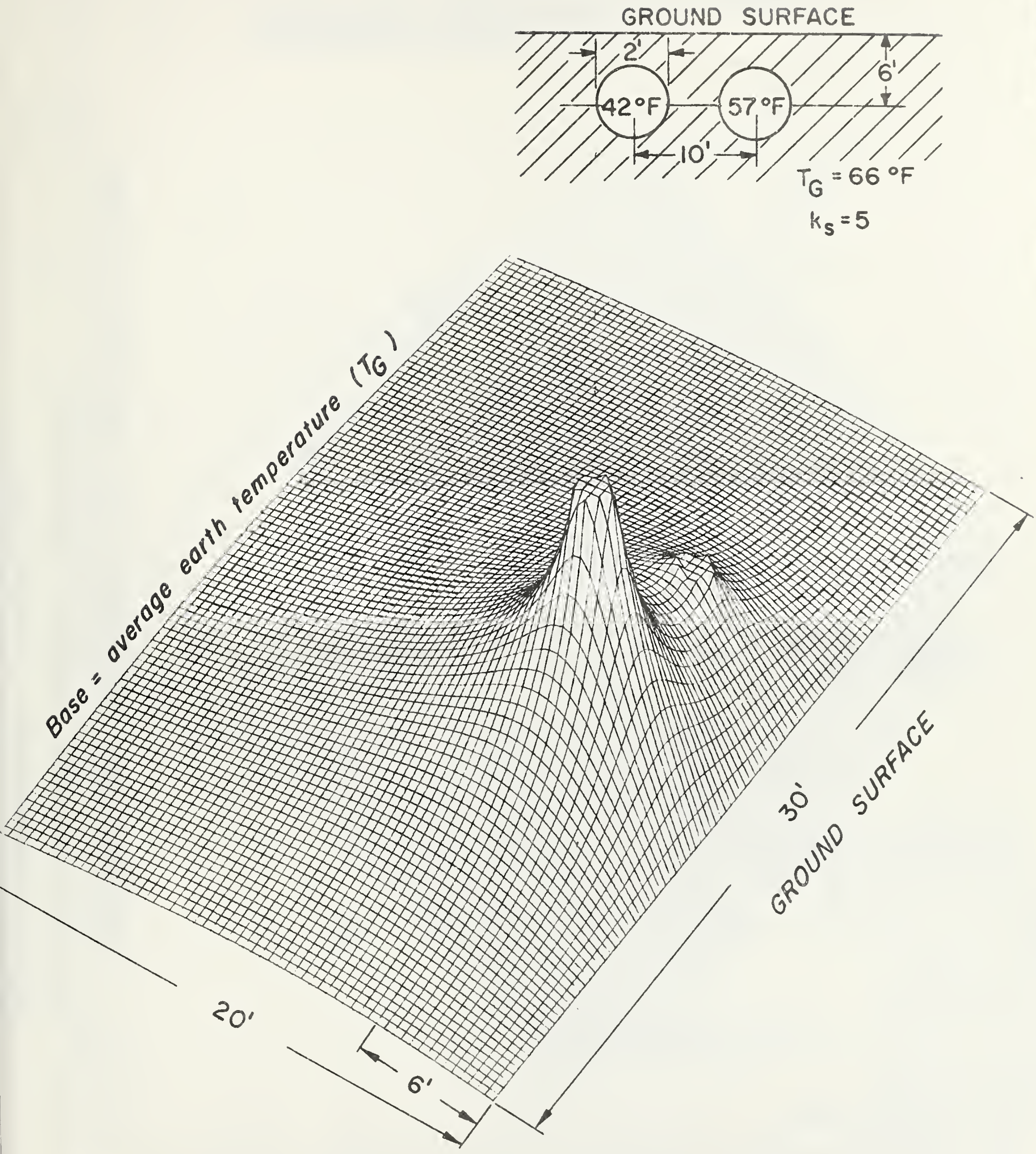
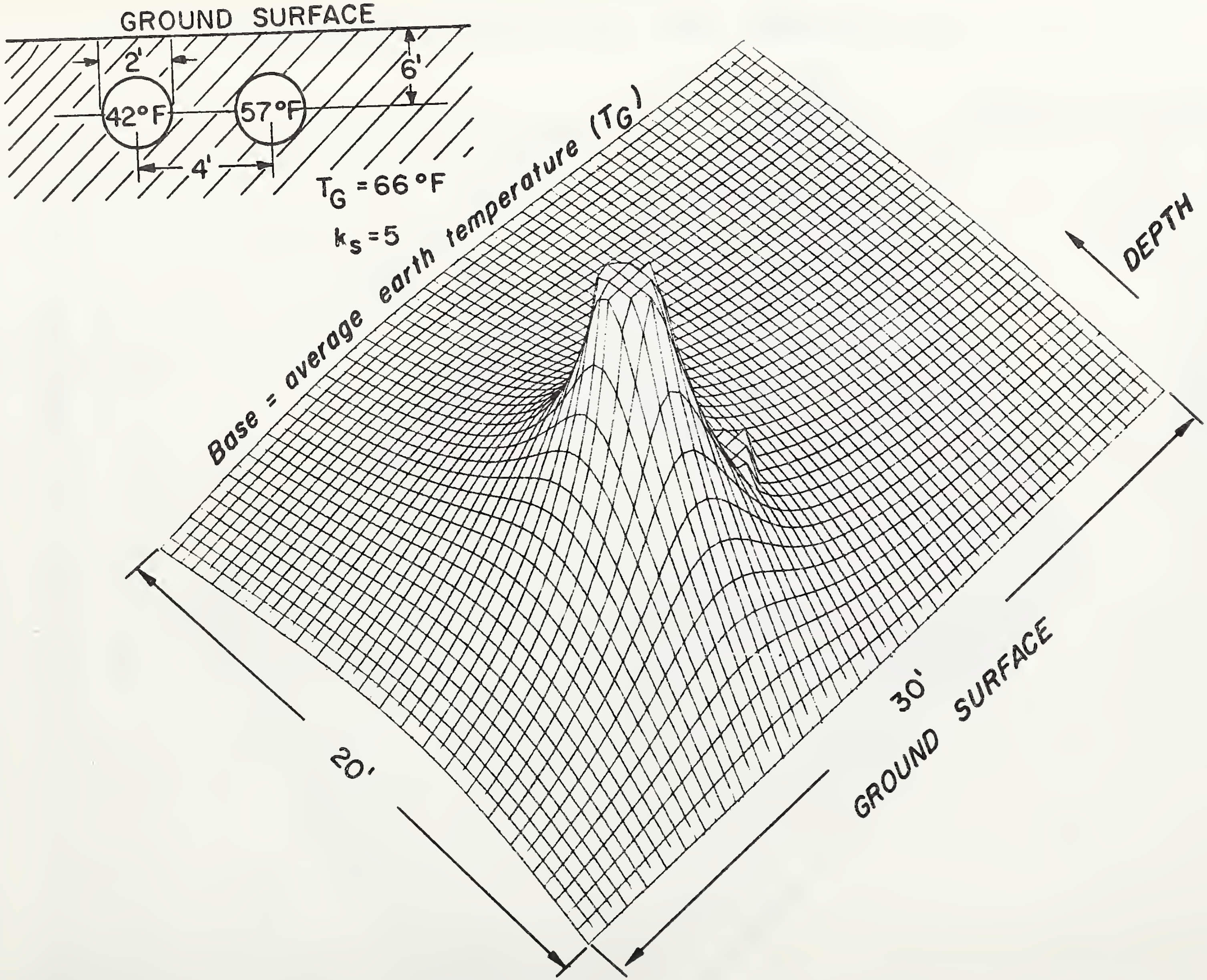


FIG. 18 TEMPERATURE PROFILE AROUND THE CHILLED WATER PIPES



TEMPERATURE CONTOURS FOR UNDERGROUND PIPES

Fig. 19 TEMPERATURE PROFILE AROUND THE CHILLED WATER PIPES



TEMPERATURE CONTOURS FOR UNDERGROUND PIPES

FIG. 20 THREE DIMENSIONAL REPRESENTATION OF THE ISOTHERMS AROUND UNDERGROUND PIPES

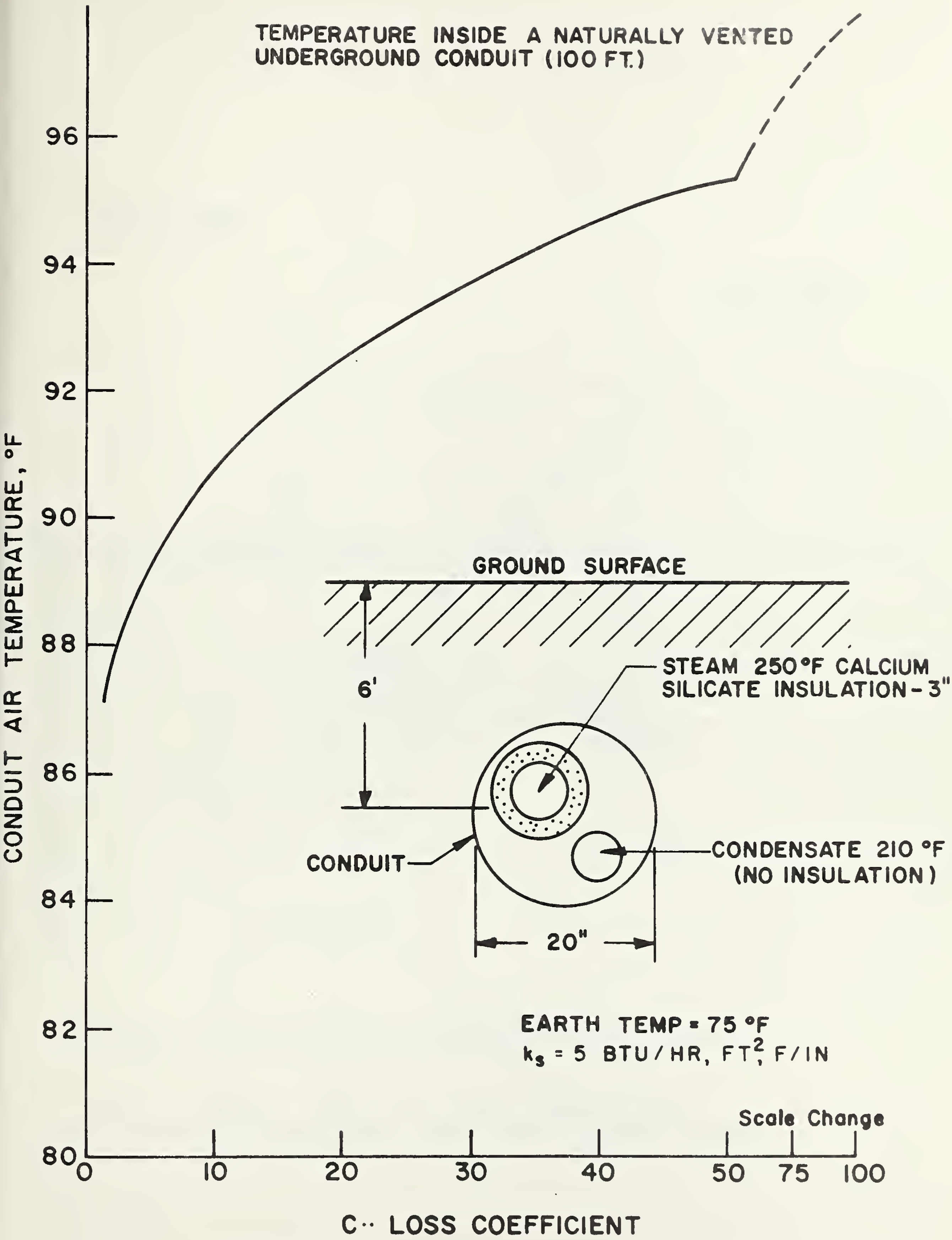
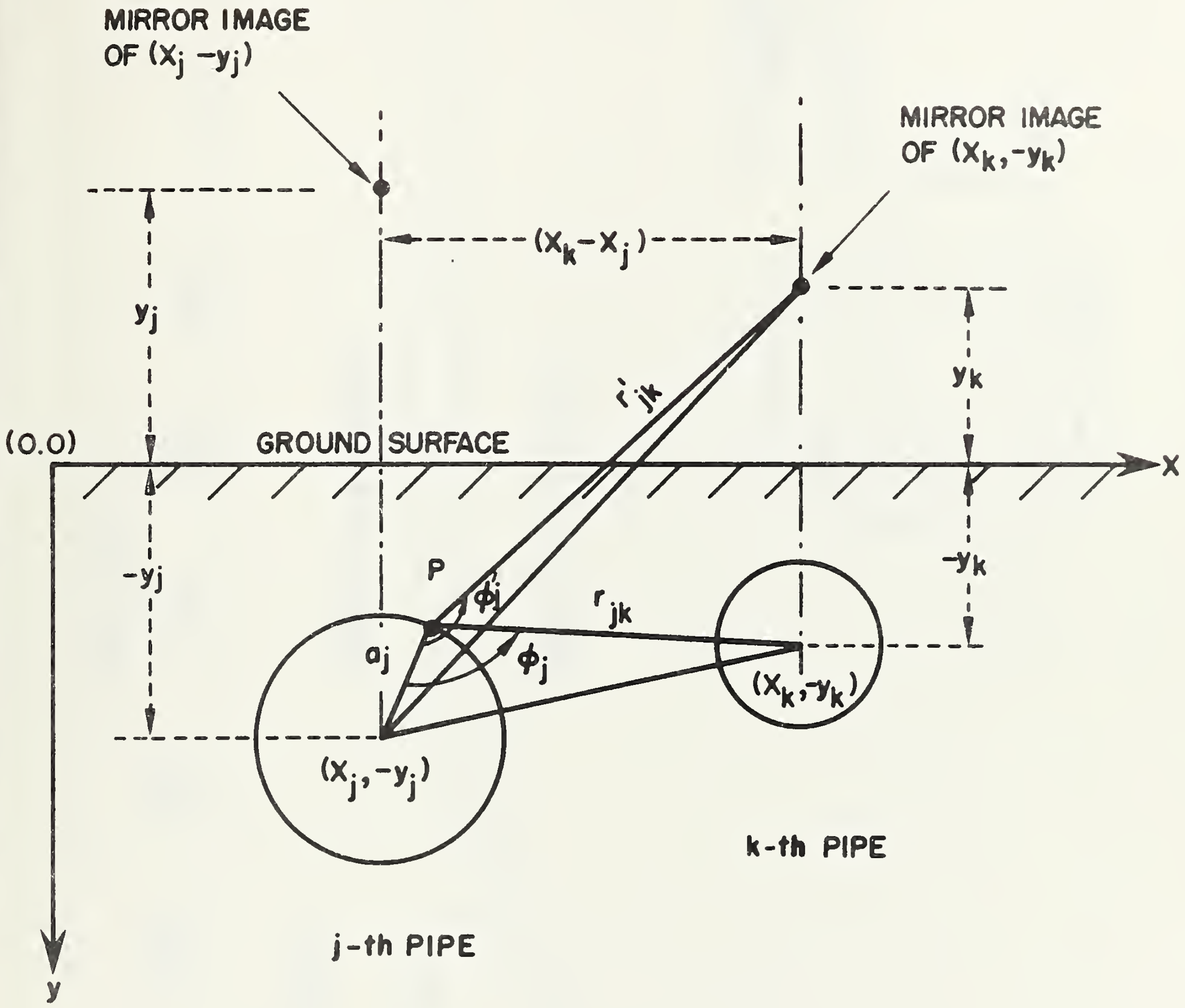


FIG. 21 TEMPERATURE WITHIN A VENTED UNDERGROUND CONDUIT

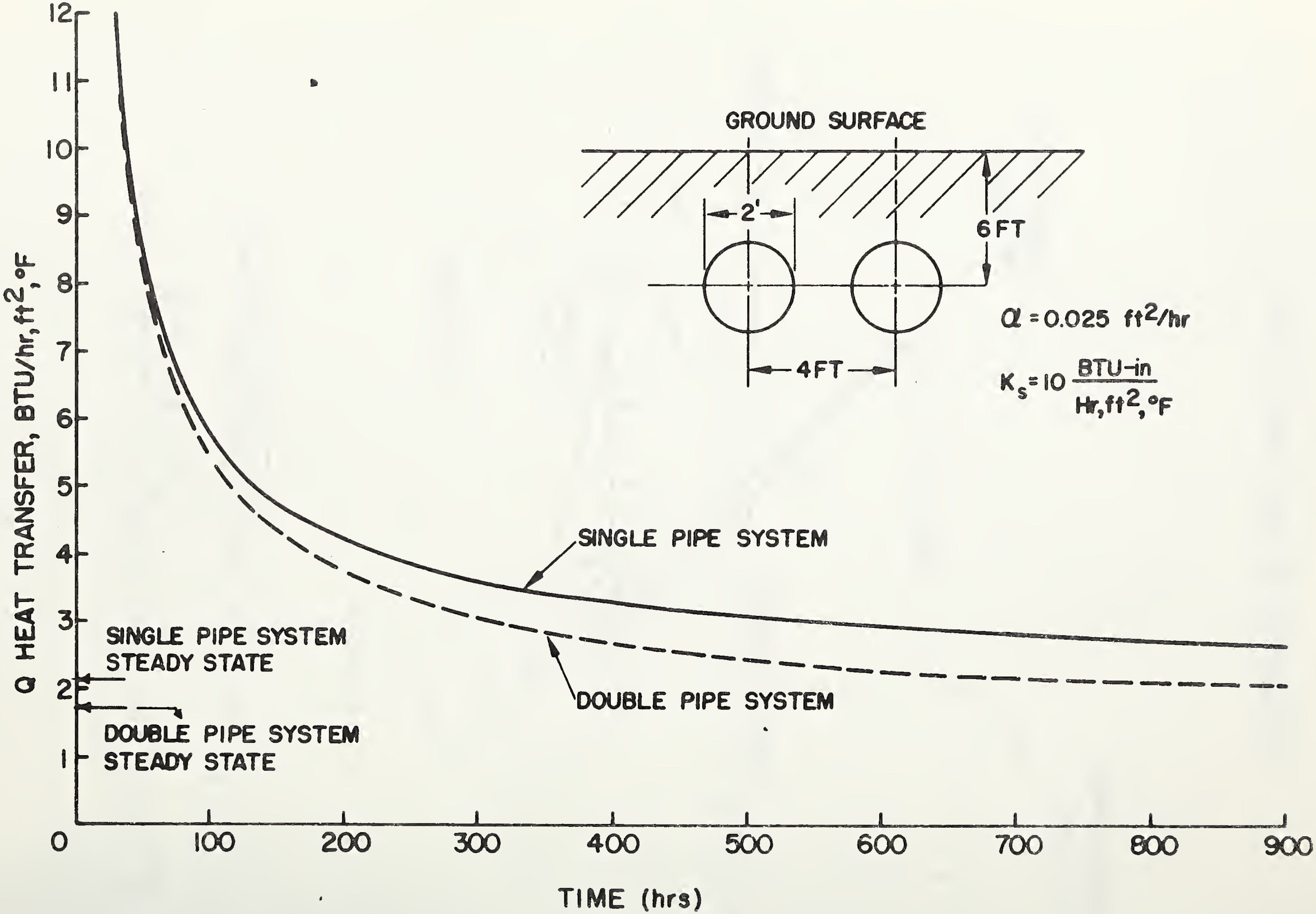
INTERACTION OF TWO PIPES, j ank k



$$r_{jk}^2 = (X_j - X_k)^2 + (y_j - y_k)^2 + a_j^2 - 2a_j\sqrt{(X_j - X_k)^2 + (y_j - y_k)^2}\ \cos\phi_j$$

$$r_{jk}'^2 = (X_j - X_k)^2 + (y_j + y_k)^2 + a_j^2 - 2a_j\sqrt{(X_j - X_k)^2 + (y_j + y_k)^2}\ \cos\phi_j'$$

FIG. 1-B



GROUND SURFACE
2'
6 FT
4 FT
α = 0.025 ft²/hr
K_s = 10 BTU-in / Hr, ft², °F
SINGLE PIPE SYSTEM
DOUBLE PIPE SYSTEM
SINGLE PIPE SYSTEM STEADY STATE
DOUBLE PIPE SYSTEM STEADY STATE
Q HEAT TRANSFER, BTU/hr, ft², °F
TIME (hrs)
0
1
2
3
4
5
6
7
8
9
10
11
12
100
200
300
400
500
600
700
800
900

Fig. 2-B