

**PIPECAR - Version 1.0**

**A Microcomputer Program for the Structural Analysis and Design  
of Circular and Horizontal Elliptical Reinforced  
Concrete Pipe Culverts**

**USER AND PROGRAMMER MANUAL**

**Developed by**

**Simpson Gumpertz & Heger Inc.  
Arlington, Massachusetts**

**in Cooperation with**

**The Federal Highway Administration  
and  
The American Concrete Pipe Association**

## To Potential Users of PIPECAR:

This Manual provides user and programmer information for the computer program PIPECAR. To use this program you will need the following hardware and software:

- IBM PC, XT, AT or a similar IBM compatible computer.
- Printer. The output is formatted for 8.5 in. wide paper.
- An operating system equivalent to PC DOS Version 2.0 or higher.
- An 8087 or 80287 math coprocessor.
- A minimum of 640k bytes of memory.
- Two double density disk drives or a single double density disk drive and a hard disk drive.
- A minimum of 3 FILES and 1 BUFFER must be specified in the CONFIG.SYS file on the operating system boot disk. The number of FILES and BUFFERS are normally set to values higher than these. If you have not made any changes since the purchase of your computer, the number of each should be adequate. Refer to your DOS Manual for further information on FILE and BUFFER sizes.

PIPECAR is a computer program that is easy to use. A user with little computer experience may operate the program very quickly and with minimal reference to this manual; however, please do not be deceived by the simple operating characteristics of the program. Virtually all input parameters are user controlled and many are specified by various design codes and change for different applications and load conditions. Users should be qualified engineers capable of selecting proper input values based on the appropriate design code and capable of interpreting and evaluating the program output. To emphasize this, the following warning is printed during program start up and with each output file:

The application of this non-proprietary software is the responsibility of the user. The user must select input values suitable to his specific installation. The use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or any other agents.

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16. Abstract  This Manual presents an overview, user instructions and technical backup for the computer program PIPECAR. PIPECAR is a program for the structural analysis and design of circular and horizontal reinforced concrete pipe. It has been written to run on IBM or IBM compatible microcomputers. The input routines are user friendly; only minimal experience with computers is required prior to use.  PIPECAR completes structural analyses for loads due to pipe weight, soil weight, internal gravity fluid weight, live loads and internal pressures up to 50 ft of head. Loads may be applied via the radial load system (commonly called the Olander analysis), the uniform load system (commonly called the Paris coefficients) or the manual load system, which is a modified uniform system.  Forces resulting from each load condition may be printed out separately. Structural design is in accordance with AASHTO Section 17.4. Design criteria include ultimate flexure, radial tension and diagonal tension, and service load crack control. Most variables can be controlled by the user. Knowledge of structural design codes for culverts is required.  The quantity of output is controlled by the user. All output is formatted for 8.5-in. by 11-in. paper.  User instructions include descriptions of all input variables and design examples. The programmer manual includes listings of all technical subroutines.					
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## CONVERSION FACTORS TO SI METRIC UNITS

Multiply	by	to obtain
inches (in)	0.0254	meters (m)
inches (in)	2.54	centimeters (cm)
inches (in)	25.4	millimeters (mm)
feet (ft)	0.3048	meters (m)
yards (yd)	0.9144	meters (m)
miles (mi)	1.609	kilometers (km)
degrees (°)	0.01745	radians (rad)
acres (acre)	0.4047	hectares (ha)
acre-feet (acre-ft)	1233.	cubic meters (m <sup>3</sup> )
gallons (gal)	3.785 x 10 <sup>-3</sup>	cubic meters (m <sup>3</sup> )
gallons (gal)	3.785	liters (l)
pounds (lb)	0.4536	kilograms (kg)
tons (2000 lb)	907.2	kilograms (kg)
pounds force (lbf)	4.448	newtons (N)
pounds per sq in (psi)	6895.	newtons per sq m (N/m <sup>2</sup> )
pounds per sq ft (psf)	47.88	newtons per sq m (N/m <sup>2</sup> )
foot-pounds (ft-lb)	1.356	joules (J)
horsepowers (hp)	746.	watt (W)
British thermal units (Btu)	1055.	joules (J)

### Some Definitions

newton - force that will accelerate a 1 kg mass at 1 m/s<sup>2</sup>

joule - work done by a force of 1 N moving through a displacement of 1 m

1 newton per sq m (N/m<sup>2</sup>) = 1 pascal (Pa)

1 kilogram force (kgf) = 9.807 N

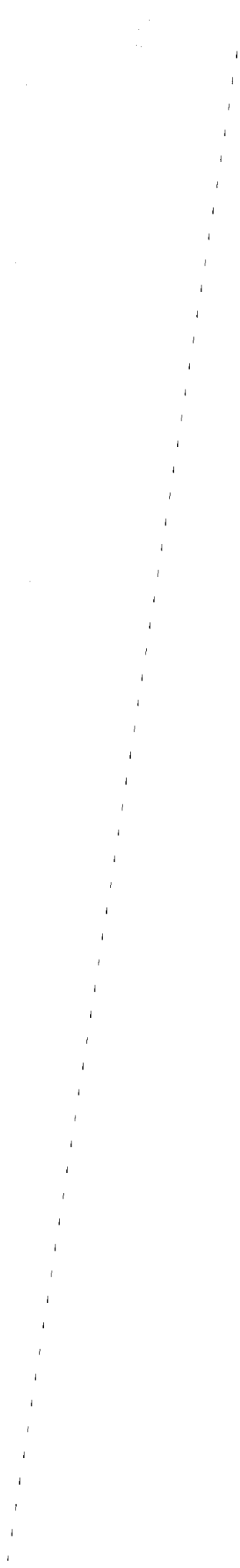
1 gravity acceleration (g) = 9.807 m/s<sup>2</sup>

1 hectare (ha) = 10,000 m<sup>2</sup>

1 kip (k) = 1000 lb = 4448 N = 453.6 kgf = 0.5 ton

3

1



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## PART I – GENERAL

### 1. INTRODUCTION

PIPECAR is a computer program that performs structural analysis and design of circular and horizontal elliptical reinforced concrete pipe. The name PIPECAR is derived from the phrase "PIPE Culvert Analysis and Reinforcing design." Internal dimensions of pipe culverts are sized based on hydraulic or other service requirements and are then structurally designed to support the weight of earth, live, or other loads that are imposed on them. A large number of references are available for the hydraulic design of pipe. PIPECAR provides the structural analysis and reinforcing design. This computerized method of design allows the user to obtain reinforcing steel areas for user-specified pipe geometry, material properties, and loading data.

PIPECAR completes the structural analysis and design of pipe sections by the following steps:

- Compute loads on the structure.
- Apply the calculated load to the structure through an assumed pressure distribution.
- Complete a structural analysis.
- Design reinforcing to carry the resulting moments thrusts and shears.

Other structural analysis programs are available that model the structure and the soil using the finite element technique; however, these programs offer a level of sophistication that is not required for the typical design situation and, while some finite element programs are being written for microcomputers, they require considerable computer time to process.

PIPECAR is intended to be a design tool for the practicing engineer. For routine designs the engineer may input as little information as the diameter, wall thickness, depth of fill, and method of load application and then utilize a default file to generate the remainder of the input. For non-standard designs the engineer can override the default input parameters and use all the input menus to address the special conditions of his project. The user may quickly evaluate the effects of varying any of the input parameters to

select the optimum design for a particular set of conditions. Because of its flexibility, PIPECAR is intended for use by engineers. Many of the input values require knowledge of design specifications with which the user must be familiar. PIPECAR emphasizes this by printing the following warning with all output files:

The application of this non-proprietary software is the responsibility of the user. The user must select input values suitable to his specific installation. The use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or any other agents.

This manual assumes the user has some basic understanding of computer usage. The user should be familiar with turning the computer on, activating the disk operating system (DOS), changing disk drives, and basic DOS commands.

## 1.1 Purpose of Manual

This User and Programmer Manual provides PIPECAR users with the information necessary to operate and interpret the program. The user information includes step-by-step procedures for running the program, entering data, and obtaining structural designs. Programming information includes general information on the program structure, Input/Output (I/O) generation, and descriptive program listings. This manual is organized as follows:

- Section 1 introduces the Manual and provides background information;
- Section 2 summarizes the program in general detail;
- Section 3 is the User Manual that provides step-by-step operating procedures;
- Section 4 describes the program output;
- Section 5 presents four example designs; and
- Section 6 describes the program structure including general flow charts and technical subroutine listings.

A list of the input parameters, with their corresponding default values, and the reinforcing design methods are included as Appendices to this manual.

## 1.2 Program History

PIPECAR and a similar program, BOXCAR (for the design of reinforced concrete box culverts) were first released in 1982 as part of a Federal Highway Administration (FHWA) project to develop standard designs for improved inlets. This project was initiated to produce a design method for tapered culvert end structures. After an initial review, however, the method selected was to analyze and design one foot wide slices without consideration of the taper. This resulted in a program that was applicable to all pipe culverts, and hence the project report was titled "Structural Design Manual for Improved Inlets and Culverts" (Reference 1). As originally released, PIPECAR ran only on mainframe computers, and did not include any provisions for treatment of live loads.

The original version of PIPECAR incorporated analysis for the effects of earth loads using an extension of the sinusoidal pressure distribution first developed by Olander (Reference 2) and also considered the effects of structure weight and internal gravity fluid load. PIPECAR incorporated the direct design method for reinforced concrete pipe that is in Section 17.4.6 of the 13th Edition of "Standard Specifications for Highway Bridges" (Reference 3) published by the American Association of State Highway and Transportation Officials (AASHTO). This method, developed by Heger and McGrath (Reference 4), considers the strength and serviceability performance limits based on known moments, thrusts, and shears in the pipe wall. Strength performance criteria include flexural strength as governed by the tensile reinforcement, concrete compression, concrete radial tension strength and concrete diagonal tension strength. Serviceability performance criteria include consideration of crack control based on a limiting crack width.

The version of PIPECAR presented in this manual is the result of a current FHWA project undertaken to upgrade the program. The upgraded version of PIPECAR has the following new features:

- PIPECAR now runs on an IBM or IBM compatible personal computer.
- Input and output routines are designed to make the program accessible to the inexperienced computer user.
- Capability of analysis and design for live loading in accordance with AASHTO and American Railway Engineering Association (AREA) specifications.
- Capability of applying loads either as a sinusoidally-distributed normal pressure, a uniform pressure based on the depth of fill, or as a uniform pressure based on user specified magnitudes.

- Capability of design for low head (up to 50 ft) internal pressures for circular pipe.
- Capability for design using several reinforcing layouts including mats and elliptical cages.
- Analysis and design for the three edge bearing load condition (also referred to as D-load design or indirect design).
- Interactive design of stirrups when stirrups are required.

These additional features provide greater usefulness and versatility as well as ease of use to PIPECAR users. The related program for box culverts, BOXCAR, has also been upgraded.

## 2. PROGRAM OVERVIEW

### 2.1 Application

PIPECAR designs buried reinforced concrete circular and horizontal elliptical pipe culverts in accordance with AASHTO earth and live load requirements and AASHTO reinforcing design requirements. Railroad live load requirements are computed in accordance with the American Railway Engineering Association (AREA) Manual for Railway Engineering (Reference 5). The program is general and can be used to design any circular or horizontal elliptical pipe. Parameters that may be specified by the user include the following:

- Pipe Geometry - diameter for circular pipe, or for horizontal elliptical pipe, elliptical radii, horizontal offset, and vertical offset, and wall thickness.
- Loading Data - depth of fill over crown of pipe, density of fill, load system, soil structure interaction factor, depth of internal fluid, internal pressure (circular pipe only), density of fluid, truck loading, and vertical and lateral surcharge loads. For three edge bearing design the user specifies the D-load.
- Material Properties - reinforcing tensile yield strength, concrete compressive strength and concrete density.
- Design Data - load factors, concrete cover over inner and outer reinforcement, reinforcing diameters, reinforcing spacing, reinforcing type and layout, layers of reinforcing, capacity reduction factors, crack control factor, shear process factor and radial tension process factor.

Only the pipe geometry, depth of fill and load system must be specified by the user. If no values are specified for the remaining parameters, the computer program uses standard default values. The default values may be easily changed to suit the user's particular needs.

The program has the following limitations:

- The range of diameters (span for elliptical pipe) permitted is 12 to 144 inches.
- The specified bedding angle must be between 10 and 180 degrees.
- Only circumferential reinforcement is designed.

- Wall thicknesses must be selected by the designer.
- Internal pressure is limited to 50 ft of head (21.7 psi).

The in-ground behavior of pipe culverts is dependent on the methods and materials used in the installation of the pipe. While PIPECAR provides a powerful tool for analyzing and designing reinforced concrete pipe culverts, it is the responsibility of the user and the installation designer to assure that assumptions made during the analysis and design phase can be and are met during the installation phase of the project.

## **2.2 Method of Analysis and Design**

### **2.2.1 Load Cases**

PIPECAR performs a separate structural analysis for each of the load conditions. These include:

- Pipe culvert dead weight
- Soil weight
- Gravity weight of internal fluid
- Internal pressure
- Live load vehicle weight

Culvert dead weight is computed based on the user specified wall thickness and concrete density. The program default for support of the pipe weight is a line support at the invert as shown in Figure 2-1. This assumes that the pipe is laid directly on a flat bedding. The user may override the program default by specifying a pipe bedding angle. The installation designer is responsible for assuring that the assumed bedding angle can be achieved in the field.

Vertical soil load is computed as the soil prism load times a soil structure interaction factor (also known as an arching factor). The soil prism load is the weight of the column of earth directly above the pipe, computed as the product of the soil density, the outside diameter of the pipe and the depth of fill. AASHTO Section 17.4.4.2 provides a method for computing the soil structure interaction factor. The vertical soil load is supported



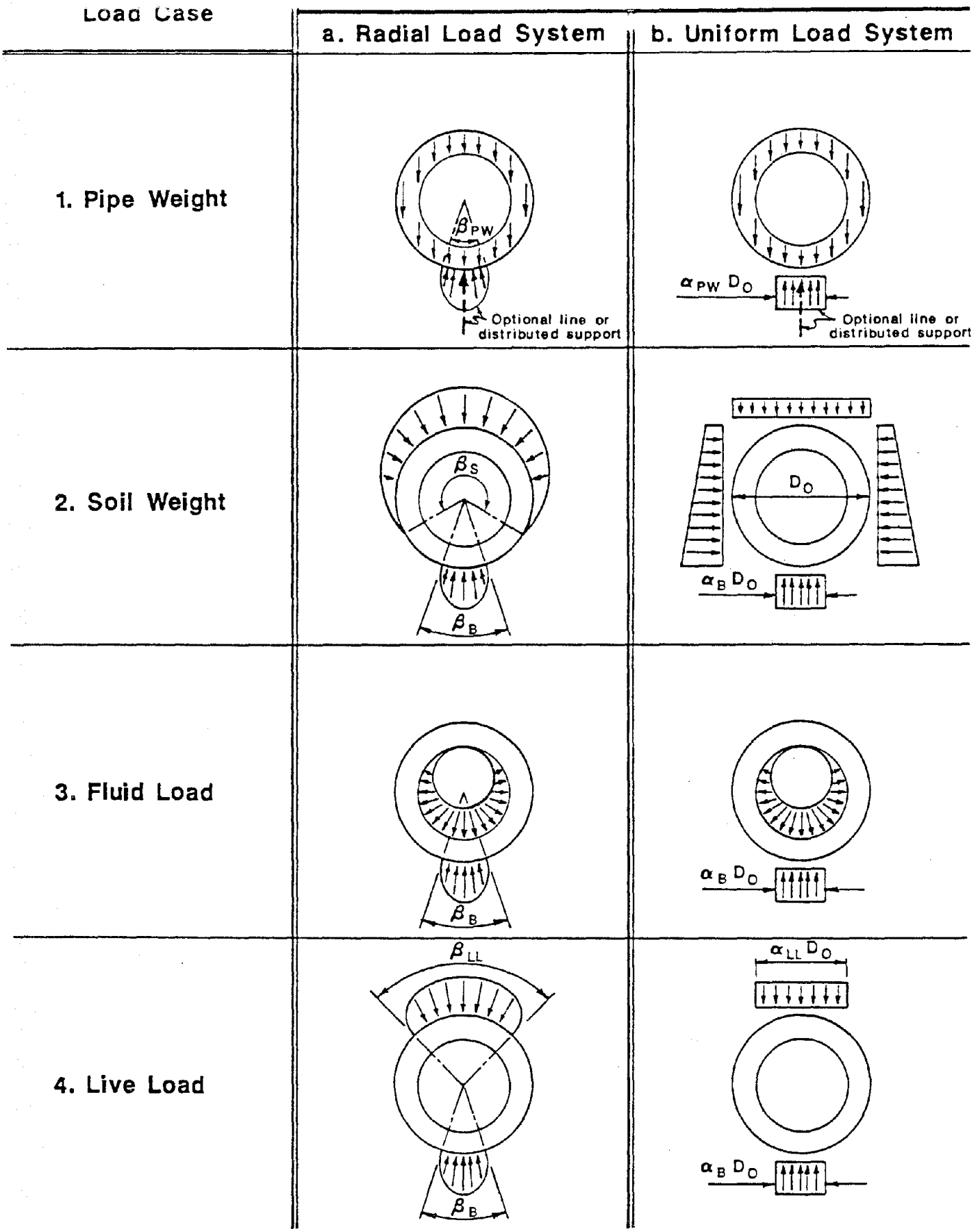


FIGURE 2-1 PIPE CULVERT PRESSURE DISTRIBUTIONS FOR RADIAL AND UNIFORM LOAD SYSTEMS

by a soil reaction over a user specified width. Lateral soil pressure is considered as part of the same load case as the vertical soil pressure. Section 2.2.2 on Pressure Distribution discusses the user input variables for determining the vertical and lateral soil pressures.

As an alternate to the soil load condition the user may specify vertical and lateral loads directly in pounds per square foot using the uniform/manual load condition.

The internal fluid load is computed from the user specified depth of fluid in the culvert and the density of the fluid. The weight of fluid is supported by an external soil reaction which is the same width as specified to support vertical soil load. The internal fluid load condition is for the gravity weight of the internal fluid only.

Internal pressures may be considered for circular pipe only. The analysis assumes that the internal pressure creates a pure tension force in the pipe wall equal to the inside radius times the specified pressure. This tension force is assumed to be uniform around the perimeter of the pipe.

The user may specify a live load as an AASHTO HS series truck, the AASHTO Alternate Military Loading (called the interstate truck herein), an AREA Cooper series locomotive or "Other" which allows input of the live load magnitude and the length and width over which the load is distributed at the top of the pipe. Wheel loads are distributed through earth fills in accordance with the requirements of AASHTO Section 6.4 or AREA Chapter 8, Part 10, as appropriate. The pressure distribution neglects any effects of pavement. Impact factors are applied to live loads in accordance with the appropriate standard. No impact factor is applied when "other" is specified. Live load vehicles are assumed to be located directly over the crown of the pipe, and live loads are computed and applied at all depths unless the user specifies no live load. For the HS-series truck, the user may specify the magnitude (i.e. HS-20, HS-15, etc.). When the interstate truck is specified PIPECAR also checks the HS-20 truck and designs for the most conservative condition. PIPECAR distributes truck loads through earth fills in accordance with AASHTO Section 6.4. Two conditions are considered to allow for passing trucks:

Condition A - Condition A is a single lane with a fully overloaded truck.

Condition B - Condition B is a four lane road with a truck in each lane; however, to consider the low probability of overloaded trucks being in each lane at the same time, the beta factor (see AASHTO Section 3.22) is taken as 1.0.

Condition B controls service loads at all depths. Condition A controls the ultimate loads to a depth of about 10 ft.

### 2.2.2 Pressure Distribution

PIPECAR allows the user to select from two pressure distributions that are commonly used in the direct design of pipe.

#### Radial Load System

The radial load system is developed from the pressure distribution first proposed by Olander (Reference 2). It assumes that all external loads are applied normal to the pipe wall, i.e. no load is applied to the pipe by tangential shear forces. Figure 2-1a shows how this load system is used for the four load conditions used in PIPECAR.

The distribution of the applied load and supporting forces are determined by simple sinusoidal functions:

pressure from applied load:

$$p_t = p_o \cos (\pi (\pi - \theta) / \beta_S)$$

reaction pressure:

$$p_b = p_i \cos (\pi \theta / \beta_B)$$

where:

$p_t$  = applied load pressure (psi) at angle  $\theta$  from invert

$p_o$  = applied load pressure (psi) at crown of pipe

$\beta_S$  = angle over which applied load is distributed

$\theta$  = angle from invert

- $p_b$  = applied reaction pressure (psi) at angle  $\theta$  from invert  
 $p_i$  = applied reaction pressure (psi) at invert of pipe  
 $\beta_B$  = angle over which reaction is distributed

As proposed by Olander, the sum of the load and reaction angles ( $\beta_S + \beta_B$ ) always add up to 360 degrees. PIPECAR allows the user to specify load and reaction angles that total less than 360 degrees, allowing consideration of the condition of poor support to the pipe haunches.

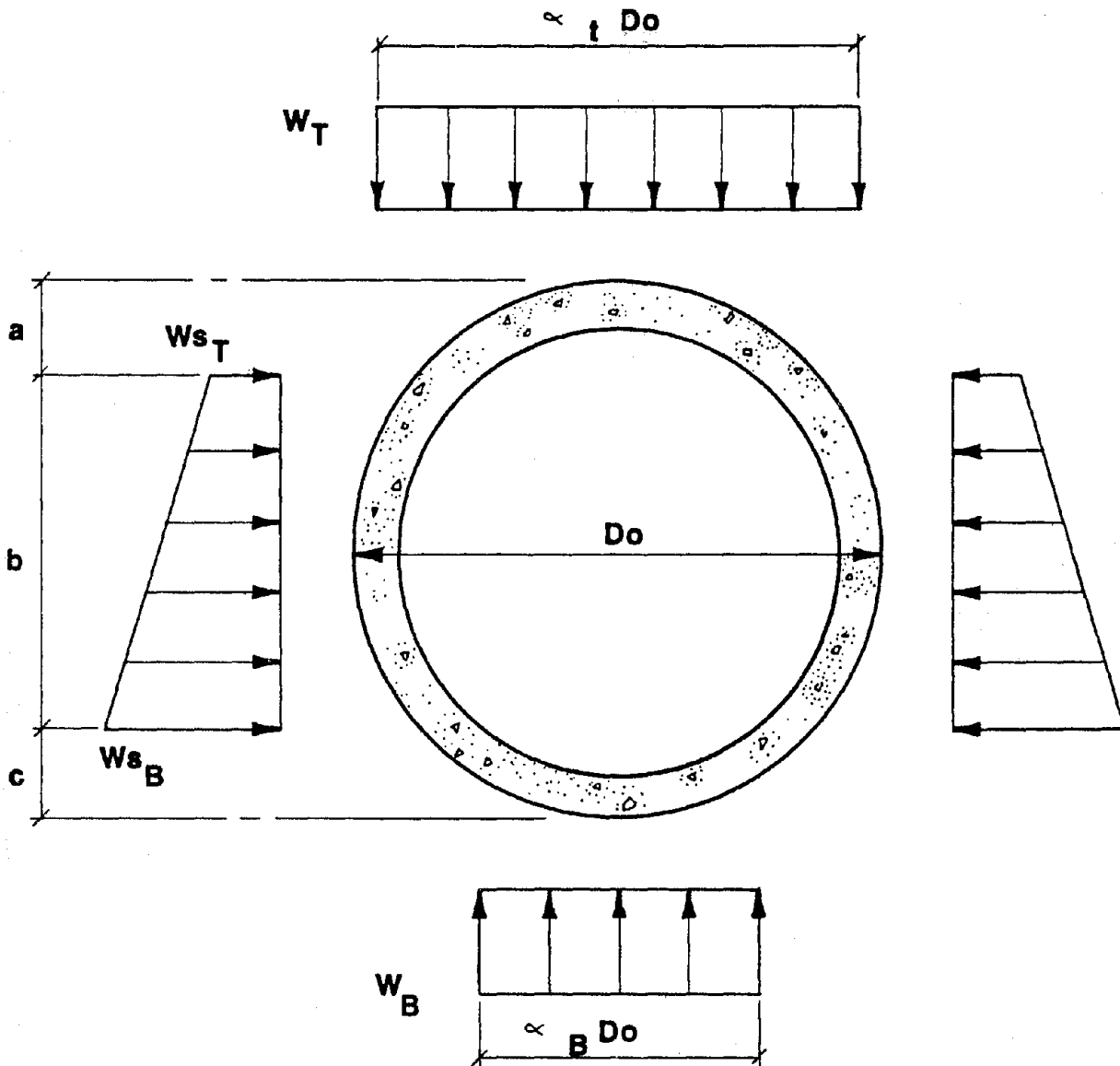
The load angle over which a live load is distributed ( $\beta_{LL}$ ) is a function of the depth of the pipe and the surface distribution of the live load. The live load angle is 180 degrees for deeply buried pipe.

### Uniform Load System

The uniform load system, sometimes called the Paris distribution because of the common use of tables of moment coefficients published by Paris (Reference 6), consists of uniformly distributed vertical and horizontal pressures, as shown in Figure 2-1b. In the "automatic" mode the total vertical earth load is computed as the soil prism load times the soil structure interaction factor and is applied to the top 180 degrees of the pipe. The lateral pressure is taken as the vertical soil prism pressure times the user input lateral pressure coefficient. The lateral pressure is applied over the entire height of the pipe. The bedding reaction is equal in magnitude to the vertical applied load and is spread over the user specified bedding width.

As an alternative to the automatic mode, the user may apply earth pressures using the "manual" mode, which allows specifying the vertical and lateral applied pressures directly in pounds per square foot. When using this mode the user may also specify the vertical load width, which may be less than 180 degrees; the supporting reaction width (just like the reaction width in the automatic mode) and the location and distribution of the lateral pressures, as shown in Figure 2-2.

The treatment of pipe weight, internal fluid and vehicle weight are the same whether the manual or automatic modes of the uniform load system are specified, as shown in Figure 2-1b.



**FIGURE 2-2 USER-SPECIFIED PRESSURES FOR UNIFORM "MANUAL" LOAD SYSTEM**

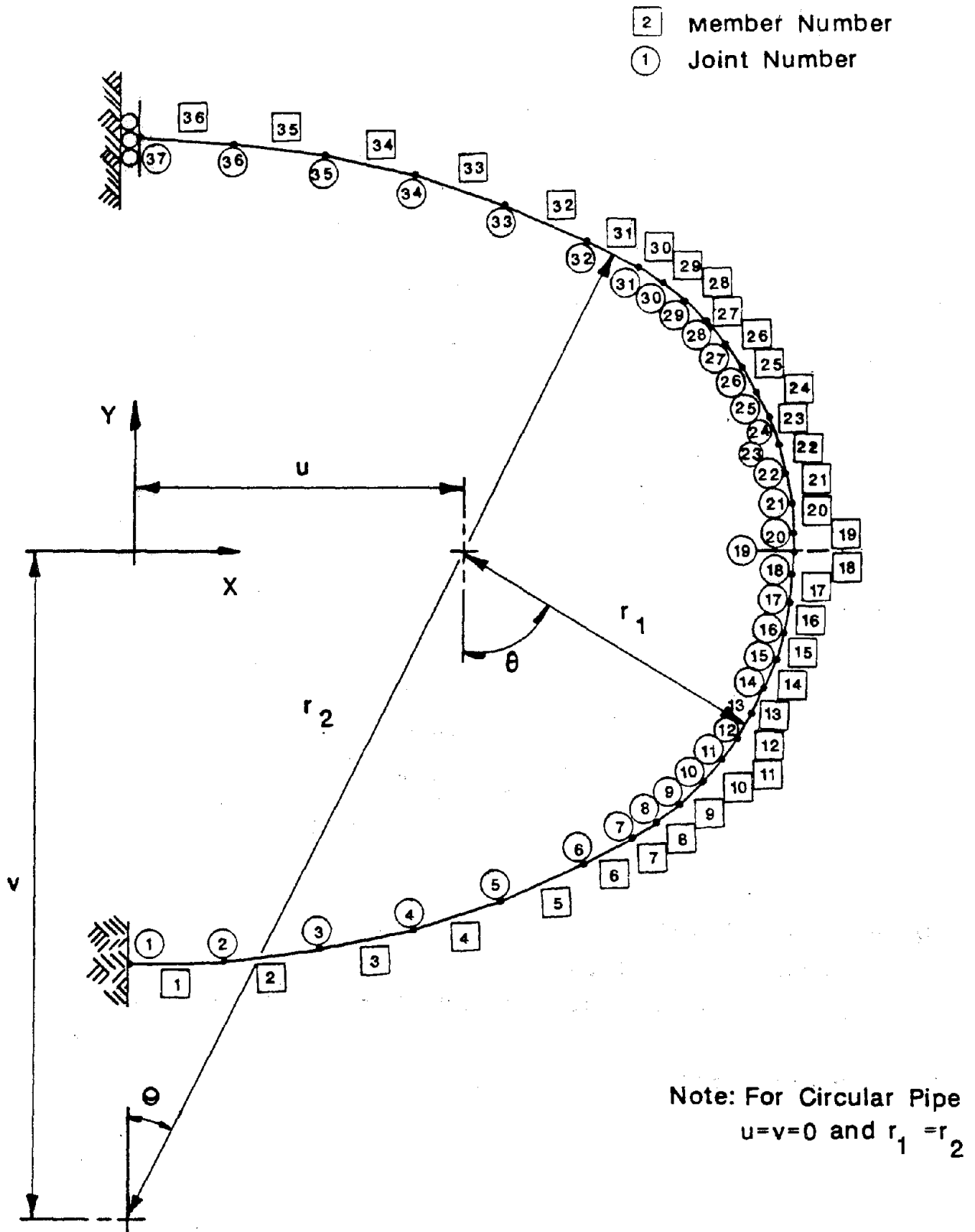
### 2.2.3 Structural Analysis

PIPECAR analyzes one half of the pipe section using the model in Figure 2-3. The pipe is modelled as a 36 member plane frame with boundary supports at the crown and invert. Each member spans 5 degrees and is located at mid depth of the pipe wall. For each member of the frame, a member stiffness matrix is formed, and then transformed into a global coordinate system. The loads on the pipe are calculated as pressures applied normal and tangential to each of the 36 members. These pressures are converted into nodal pressures that act radially and tangentially to the pipe. Loads at each joint are assembled into a joint load matrix and a solution is obtained by a recursion algorithm from which member end forces are obtained at each joint. Analysis is completed separately for each load condition.

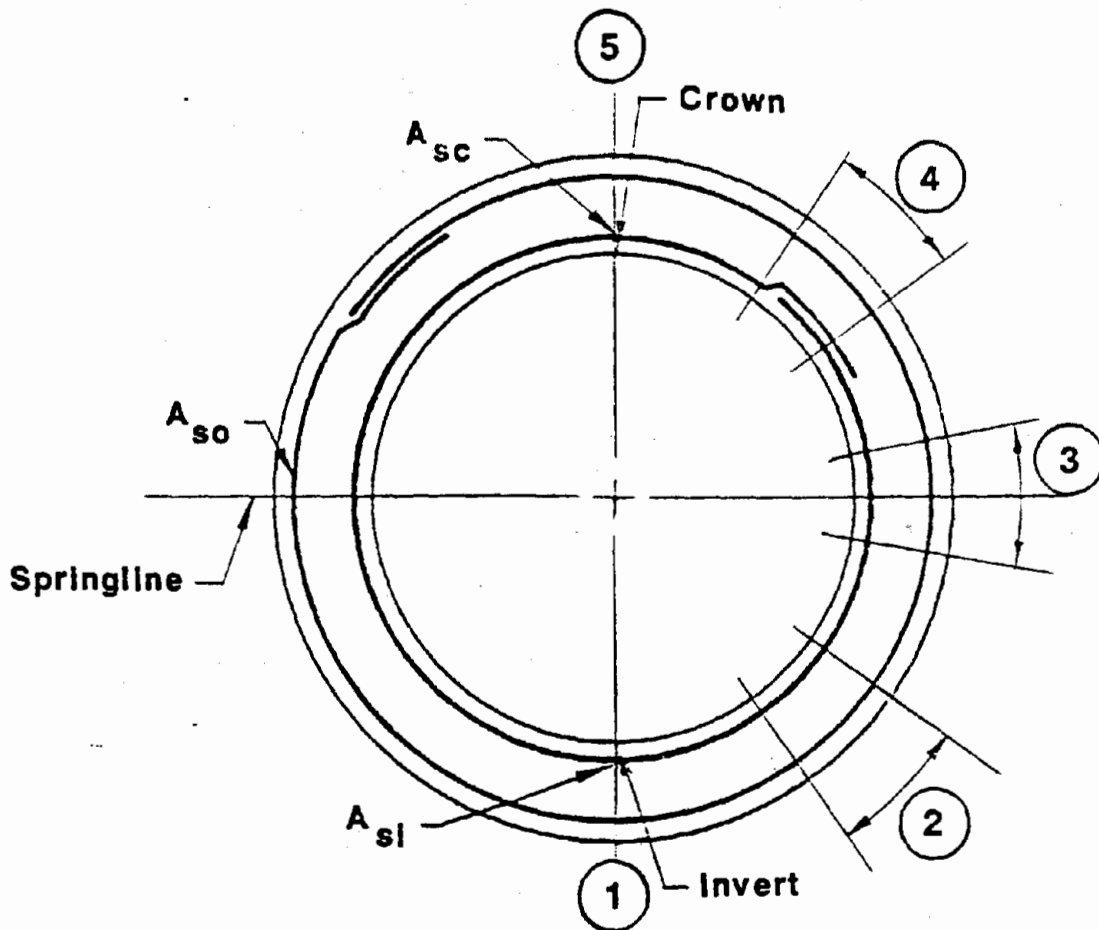
After the structural analysis is completed for each load condition, PIPECAR combines the moments, thrust and shears as required to obtain the governing forces at the five design locations shown on Figure 2-4. Locations 1, 3 and 5 are for the design of flexural reinforcement, and locations 2 and 4 are for evaluation of diagonal tension.

Because of the symmetry in all the load conditions, PIPECAR assumes that maximum positive moments always occur at the crown (design location 5) and invert (design location 1). These moments are used to design the top inside and bottom inside reinforcement, respectively. PIPECAR searches for the location of the maximum negative moment in the springline area (design location 3) and uses this moment to design the springline outside reinforcement. Users should note that if too much lateral load is applied to the pipe then there may not be any positive moment at the crown or invert or there may not be any negative moment at the springline. If this occurs, the program will stop execution and print an error message to the screen.

Based on AASHTO requirements, shear is assumed to be critical in the positive moment regions where the ratio  $M/V\phi d$  is equal to 3, which occurs near the crown (design location 4) and invert (design location 2). PIPECAR determines these locations and calculates the design forces.



**FIGURE 2-3 FRAME MODEL USED FOR COMPUTER ANALYSIS OF PIPE SECTIONS**



**Flexure Design Locations:**

- 1,5 Maximum Positive Moment Locations at Invert and Crown.
- 3 Maximum Negative Moment Location Near Springline.

**Shear Design Locations:**

- 2,4 Locations Near Invert and Crown Where  $M/V\phi_v d = 3.0$

**FIGURE 2-4 LOCATION OF CRITICAL SECTIONS FOR SHEAR AND FLEXURE DESIGN IN PIPE SECTIONS**



## 2.2.4 Design of Reinforcing

Reinforcing design is completed in accordance with AASHTO Section 17.4.6. The design equations are reproduced in Appendix B of this Manual. The development of this design method is documented in Reference 4.

Flexural reinforcement is designed in accordance with the following criteria:

- Ultimate flexural strength based on yielding of the tensile reinforcement
- Minimum reinforcement
- Maximum reinforcement based on concrete compression to ensure ductile behavior
- Control of cracking at service loads
- Ultimate radial tension strength

If maximum reinforcement governs, an informative message is printed, warning the user that concrete compression governs, and the design is halted for that particular design section. To obtain a design, the user must increase the wall thickness, or the concrete strength, or otherwise modify the input. Shear forces at the two design locations are compared against allowable values calculated by AASHTO Equation 17-16. If the shear strength of either section is exceeded, informative messages are printed and the interactive stirrup design routine of PIPECAR is activated.

Users should note that the theories for 0.01 inch crack and diagonal tension strength are semi-empirical in nature and were developed from tests on slabs and large diameter pipe (Reference 4). Experience has shown that these equations become increasingly conservative as the pipe diameter decreases below 48 inches.

For circular pipe the user may specify several reinforcing configurations as shown in Figure 2-5.

## 2.2.5 Indirect Design Method

PIPECAR includes the option of designing reinforcing by the indirect method, also known as the three edge bearing load condition. Reinforced concrete pipe designs in ASTM Standards C 76 (circular pipe), C 506 (arch pipe) and C 507 (horizontal and vertical elliptical pipe) are all based on the three edge bearing load condition which is shown on

Figure 2-6. The indirect design module of PIPECAR designs reinforcing for all of these pipe shapes. The basis of the indirect method is that the design D-Load is selected to produce a bending moment at the invert that is equal to the bending moment at the invert under installed conditions.

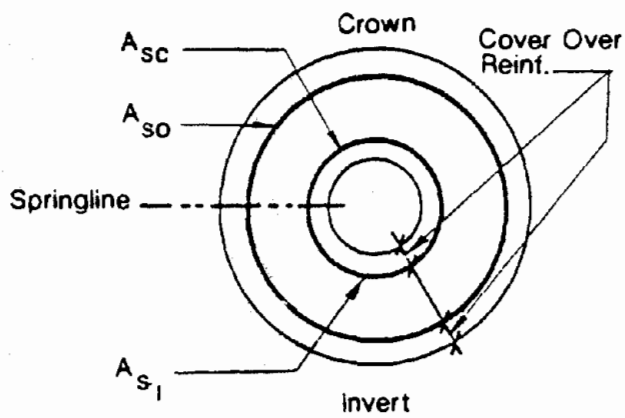
The PIPECAR indirect design module was developed from an existing program. It is completely independent of the remainder of the program and will appear different to the user, but is easily operated. The module has its own input and output routines. Results are printed initially to the screen and, upon the user's request, to the printer. No files are written to or read from disk storage.

Design of inside reinforcing is based on the same criteria as the direct design module of PIPECAR: ultimate flexure, 0.01 inch crack, diagonal tension and radial tension. The design equations are based on the equations for direct design but are modified for the specific shear and moments of the three edge bearing condition.

The practice of ASTM standards is to size the outside reinforcing as a percentage of the inside reinforcing. This rule is followed in the PIPECAR indirect design method when the inside reinforcing is governed by ultimate flexure or 0.01 inch crack; however, when the inside reinforcing is increased to improve the diagonal tension strength the outside reinforcing is not increased because the outside reinforcing has no effect on the diagonal tension strength. If the design requires stirrups the indirect module will present a screen that requests input for developable stirrup yield strength and stirrup spacing. Complete stirrup requirements are computed and printed with the circumferential reinforcing requirements.

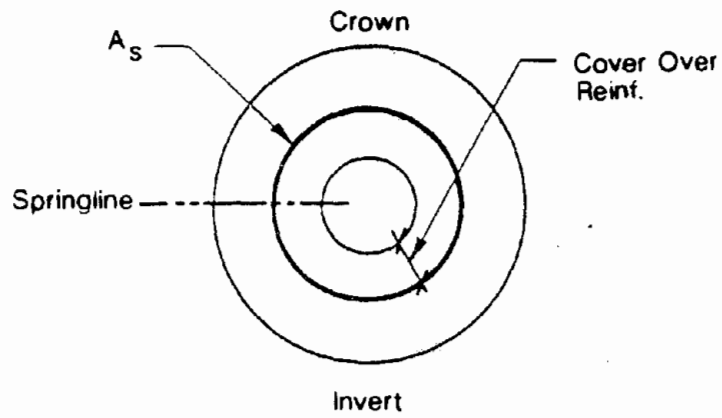
Users of this module of PIPECAR should remember that the ASTM standards for reinforced concrete pipe have been largely developed from experience and testing. This module uses semi-empirical equations that do not always match that experience. The equivalence between the standards and the PIPECAR indirect design module is obviously affected by the strength reduction factors that are selected for input and experience has shown that method of manufacture and local variations in materials, particularly aggregates have a significant effect on the diagonal and radial tension strength.

As stated for the direct design method, the equations for 0.01 inch crack and diagonal tension become increasingly conservative for diameters below 48 inches.



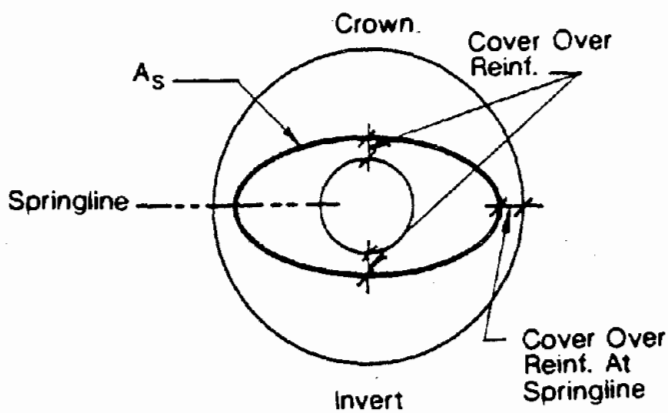
Double Circular Cages

Fig. 2-5a



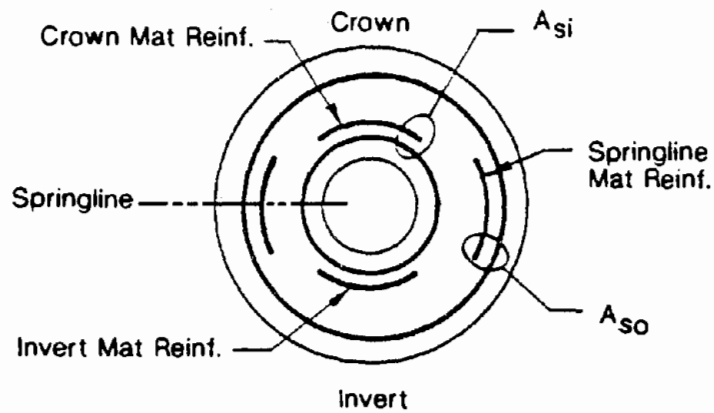
Single Circular Cage

Fig. 2-5b



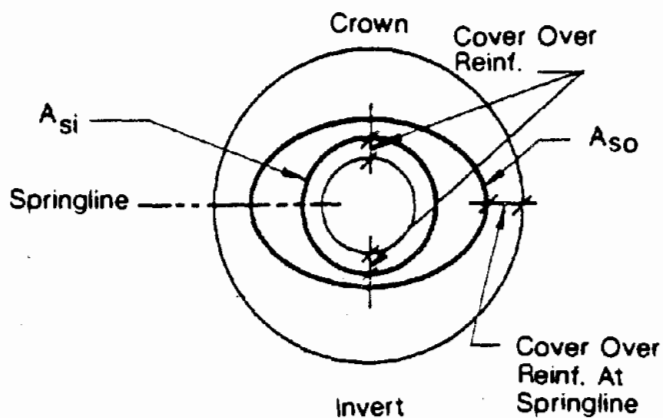
Single Elliptical Cage

Fig. 2-5c



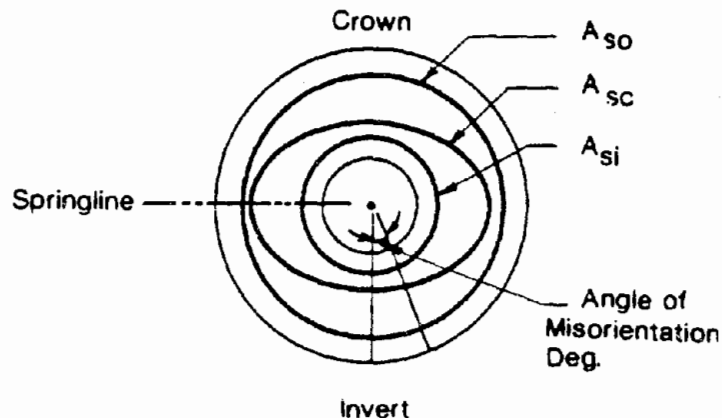
Double Circular Cages + MAT Reinforcement

Fig. 2-5d



Single Circular Cage + Elliptical Cage

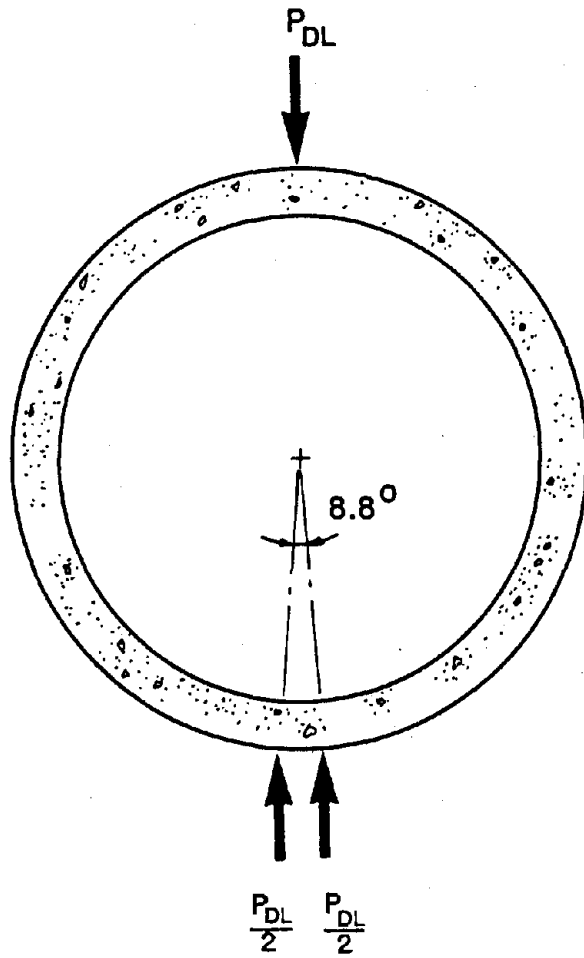
Fig. 2-5e



Double Circular Cage + Elliptical Cage

Fig. 2-5f

**FIGURE 2-5 CIRCULAR PIPE REINFORCEMENT CONFIGURATIONS**



**FIGURE 2-6 THREE EDGE BEARING LOAD  
CONDITION FOR PIPE**

## **2.3 Input/Output Description**

### **2.3.1 Input**

PIPECAR data input files for the direct design method are created through a series of input screens that prompt the user for the required parameters. Each screen presents a general category of parameters such as Pipe Geometry, Material Properties, Loads etc. The user must input values for the pipe geometry, depth of fill, and load application system. For all other parameters the input screens present default values that the user may accept or override. All the input screens are discussed in detail in Section 3 of this Manual.

Appendix A presents a list of all input parameters and their initial default values. The user may permanently change the default values to suit his or her particular typical design requirements by using the default configuration utility discussed in Section 3.2.7.

### **2.3.2 Output**

Upon completion of program execution, PIPECAR will write the reinforcing requirements to the screen. At this time the User may elect to save the file, using one of several possible output levels or, if a visual examination is adequate, to destroy the output file. The amount of output is controlled by the user as discussed in Section 4.1 of this manual. The minimum amount of output printed is an echo of the input data and a one page summary of the design. Additional available output includes displacements, member end forces, moments, thrusts and shears at critical sections, and shear and flexure design tables. Output is printed to a disk file. The complete output file can be reviewed using a text editor (not part of this software package) or sent to a printer for a hard copy. Printer output is formatted for 8.5 x 11 in. paper.

## **2.4 Hardware and Software Requirements**

The following hardware and software are required to run the program:

- IBM PC, XT, AT or a similar IBM compatible computer.
- Printer. The output is formatted for 8.5 in. wide paper.

- An operating system equivalent to PC DOS Version 2.0 or higher.
- An 8087 or 80287 math coprocessor.
- A minimum of 640k bytes of memory.
- Two double density disk drives or a single double density disk drive and a hard disk drive.
- A minimum of 3 FILES and 1 BUFFER must be specified in the CONFIG.SYS file on the operating system boot disk. The number of FILES and BUFFERS are normally set to values higher than these. If you have not made any changes since the purchase of your computer, the number of each should be adequate. Refer to your DOS Manual for further information on FILE and BUFFER sizes.

## PART II – USER MANUAL

### 3. OPERATION

#### 3.1 Installation and Start-up

PIPECAR is supplied on three single sided, double density floppy diskettes. To use PIPECAR you must have the hardware and software described in Section 2.4 of this manual. Before running PIPECAR, make a working copy of Program Disks 1, 2, and 3 so that the original disks may be used as backups. The procedure for this and for program installation and start-up is as follows:

##### Dual Disk Drives:

1. Use the DOS command "FORMAT" to format four blank diskettes. If you are unfamiliar with this procedure refer to your DOS manual for instruction. Three of these diskettes will be used for making working copies of the Program Disks. The fourth disk will be your Data Disk and will be used for storing input and output files.
2. Set your default drive to A. Place one of the formatted blank diskettes in drive B and Program Disk 1 in drive A.
3. Copy the contents of Program Disk 1 to the new blank diskette by typing the following:

```
COPY A:*.* B: [Enter]
```

4. Place the second formatted blank diskette in drive B and Program Disk 2 in drive A and copy the contents of Program Disk 2 to the blank diskette with the same "COPY" command. Repeat this again for Program Disk 3.
5. The new diskettes are now your working Program Disks. You should use these diskettes when running PIPECAR and keep the original diskettes in a safe place.
6. Copy the "COMMAND.COM" file that resides on your DOS diskette onto Program Disks 1, 2, and 3. Do this for each disk by placing your DOS disk in drive A, your program disk in drive B and typing:

```
COPY A:COMMAND.COM B: [Enter]
```

7. With your default drive still set to A, insert the working copy of Program Disk 3 into drive A and type the following:

```
PINSTALL [Enter]
```

When prompted, select the option that you will use to execute PIPECAR. Press "4" to run PIPECAR on dual floppy disk drives. The Program Disks must always be run from drive A and the Data Disk from drive B.

8. When execution of the INSTALL Program is completed, insert Program Disk 1 into drive B and copy the "PSYSTEM.DEF" file that resides on Program Disk 3 to Program Disk 1 in the same manner that you copied COMMAND.COM above. Repeat this for Program Disk 2.
9. To begin execution of PIPECAR, insert Program Disk 1 into drive A and the Data Disk into drive B and type:

PIPECAR [Enter]

After executing this statement the introductory screen of PIPECAR appears. You may now run the program as shown in Section 3.2.

#### Hard Drive

1. Start from the main directory of your hard drive and create a subdirectory called "PIPECAR" by typing the following:

MD\PIPECAR [Enter]

2. Log into the newly created subdirectory by typing:

CD\PIPECAR [Enter]

3. Place Program Disk 3 in drive A and type the following:

A: [Enter]  
PINSTALL [Enter]

When prompted, select the option that specifies the system configuration that you will use to execute PIPECAR. Options 1, 2, or 3 are to run PIPECAR with a hard disk drive. Follow the displayed instructions for inserting the Program Disks. If option 2 or 3 is selected, refer to dual disk drive instructions for making working copies of the program and copying the COMMAND.COM and PSYSTEM.DEF files onto the floppy disks.

4. Log back into the PIPECAR subdirectory of your hard disk by typing:

C: [Enter]

The hard disk is now your working Program Disk. The original Program Disks should be stored in a safe place. Always log into the PIPECAR subdirectory whenever running PIPECAR.

5. To begin execution of PIPECAR, type:

PIPECAR [Enter]



After executing this statement the introductory screen of PIPECAR appears. You may now run the program as discussed below.

## Running the Program

After typing PIPECAR, program execution begins by printing the introductory screen. This lists the version number and date of the program that you are using. By pressing any key the user warning will be printed to the screen. This screen reminds the user of the responsibility they have when using PIPECAR, as discussed in Section 1. of this Manual. By again pressing any key the Main Menu will appear. This menu offers eight choices that lead to additional screens depending on the choice made.

For each screen displayed, enter the input data when prompted. General features of the program are:

- The number of characters for each parameter input must be less than or equal to the highlighted space provided on the screen for that parameter.
- After typing in the data requested for any field, press the [Enter] key to move on to the next input parameter.
- Within each screen, the arrow, [Home], and [End] keys may be used to move around to the different input fields displayed.
- To move to the next screen or to view a previous screen, press the [PgDn] or [PgUp] key, respectively.
- Help screens are available for each input menu. These screens are quick references for explaining the input parameters for that particular screen. To display a help screen, press the [F2] key. To leave a help screen, press any key.
- You may leave the input menus at any time by pressing the [F1] key. The program will ask if you wish to save the file and execute PIPECAR, save the file and return to the main menu or not save the file and return the main menu.
- Decimal points are optional for whole number input.

Before the direct design program can be executed, you must create an input file. The data that you enter is stored on your disk with the filename you assign to it. The indirect design program is an independent module that generates its own input.

All input and output files for direct designs are stored on your data disk. If a file is no longer needed, you may use the DOS command ERASE to delete it from your disk. The indirect design method does not write any files to disk.

## 3.2 Main Menu Choices

PROGRAM: PIPECAR	
MAIN MENU	
Input Options	1. Create a new direct design input file 2. Retrieve a direct design input file
Execute Options	3. Execute PIPECAR/Direct Design 4. Execute PIPECAR/Three Edge Bearing Design
Print Options	5. Print a direct design input file 6. Print a direct design output file
System Options	7. Reconfigure default parameters 8. Exit
Selection	

The eight main menu options provide the following functions:

1. Selection 1 allows you to create a new input file. The input data you supply is saved on disk for program execution and for later modifications.
2. Selection 2 allows you to retrieve a previously created input file that you may wish to review or modify. The file may then be re-saved with the same file name or a different name as you desire.
3. Selection 3 executes the direct design method program and completes the analysis and design of a pipe section based on the specified input file.
4. Selection 4 executes the indirect (three edge bearing) design method.
5. Selection 5 allows you to print any previously created input file. This selection also formats the file for printing on 8.5 in. by 11 in. paper. It puts headings and page numbers on each page and inserts form feed commands where appropriate.
6. Selection 6 allows you to print an output file after program execution. This selection also formats the file for printing on 8.5 in. by 11 in. paper. It puts headings and page numbers on each page and inserts form feed commands where appropriate.
7. Selection 7 allows you to change the default values that are stored on the Program Disk. The default values supplied with the PIPECAR program you have received are listed in Appendix A.
8. Selection 8 exits the program and returns you to the operating system.

Additional details on each of these selections is provided in the following sections.

### 3.2.1 Main Menu Selection 1: Create a File

Entering Selection 1 from the main menu leads to a series of screens that create a new pipe culvert input file.

```
PROGRAM: PIPECAR

Filename          .PIP
Job Description

Pipe Shape      (C/E) Circular
                Elliptical

SCREEN 1

<F1> = FINISHED EDITING → RETURN TO MAIN MENU
                <PgDn> View Next Screen
                <F2> = HELP
```

Filename - Enter the name under which you wish to save the input file. Do not provide an extension because the extension .PIP is automatically appended. See your DOS manual for rules pertaining to filenames.

Job Description - Any project description containing up to 50 characters of text. The job description must not contain any quotations (").

Pipe Shape - C) Circular Pipe  
E) Horizontal Elliptical Pipe

Note: Output files generated by PIPECAR will have the same filenames as the input files except that the extension will be .OUT.

```

PROGRAM: PIPECAR          CURRENT FILE:
PROJECT:

GEOMETRY AND INSTALLATION CONDITIONS - CIRCULAR PIPE

Pipe Inner Diameter      in.
Pipe Wall Thickness      in.
Load System (R/U/M)     Radial
                        Uniform
                        Uniform/Manual

SCREEN 2C

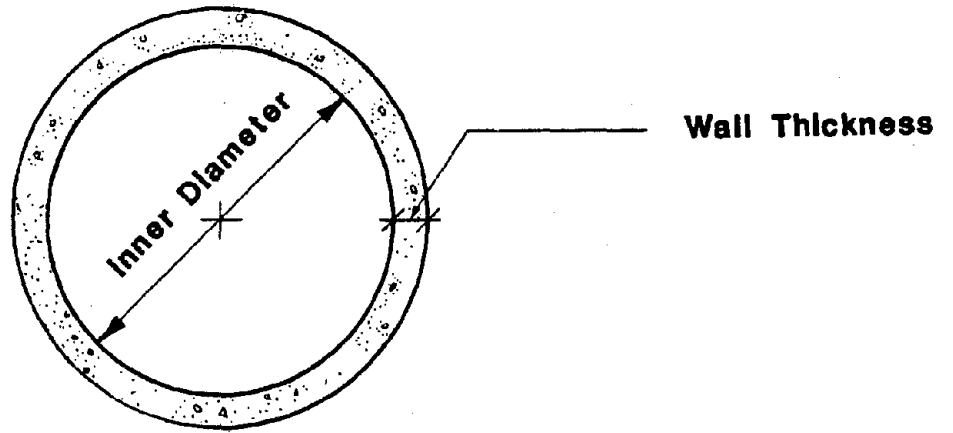
```

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen                      <PgDn> View Next Screen

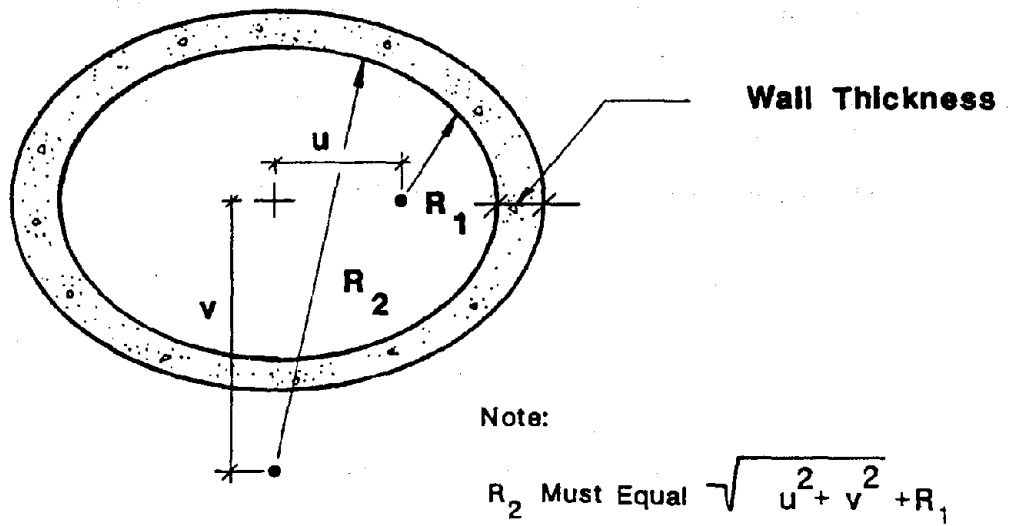
### Geometry and Installation Conditions for Circular Pipe

- Pipe Inner Diameter - (in.). The allowable range of diameters is 12 to 144 in.. See Figure 3-1a.
- Pipe Wall Thickness - (in.). See Figure 3-1a.
- Load System -
- R) Loads are applied as sinusoidally distributed pressures acting normal to the pipe. See Figure 2-1a.
  - U) Loads are applied as uniform pressures on the top and bottom of the pipe and as linearly varying pressures on the side of the pipe. See Figure 2-1b.
  - M) The user will specify the pressure magnitudes at the top and sides of the pipe for the uniform load system (Figures 2-1b and 2-2). These pressures are considered by the program instead of the earth load condition.

For a more detailed discussion of the various load systems, refer to Section 2.2.2 of this manual.



a. Circular Pipe



b. Horizontal Elliptical Pipe

FIGURE 3-1 PIPE CULVERT GEOMETRY

PROJECT:

## GEOMETRY AND INSTALLATION CONDITIONS - ELLIPTICAL PIPE

Pipe Inside Radius, Springline	in.
Pipe Inside Radius, Crown/Invert	in.
Horizontal Offset	in.
Vertical Offset	in.
Pipe Wall Thickness	in.
Load System (R/U/M)	Radial Automatic Uniform Automatic Uniform/Manual

SCREEN 2E

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen      <PgDn> View Next Screen

## Geometry and Installation Conditions for Horizontal Elliptical Pipe

Pipe Inside Radius - Springline	Radius R1 (in.). See Figure 3-1b.
Pipe Inside Radius - Crown/Invert	Radius R2 (in.). See Figure 3-1b.
Horizontal Offset -	Distance u from c.g. of pipe to origin of radius R1 (in.). See Figure 3-1b.
Vertical Offset -	Distance v from c.g. of pipe to origin of radius R2 (in.). See Figure 3-1b.
Pipe Wall Thickness -	(in.). See Figure 3-1b.
Load System -	See Screen 2C - Geometry and Installation Condition for Circular Pipe.

```

PROGRAM: PIPECAR          CURRENT FILE:
PROJECT:

INSTALLATION CONDITIONS - Radial Load System

Depth of Fill           ft
Soil Structure Interaction Coefficient
Load Angle              deg
Bedding Angle           deg
Bedding Angle for Pipe Weight Reaction  deg

SCREEN 3R

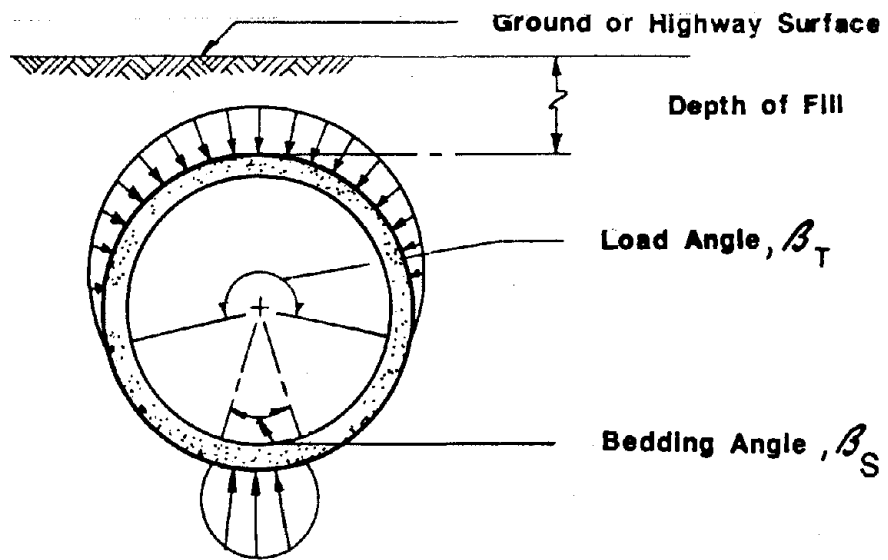
```

<F1> = FINISHED EDITING + RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen                      <PgDn> View Next Screen

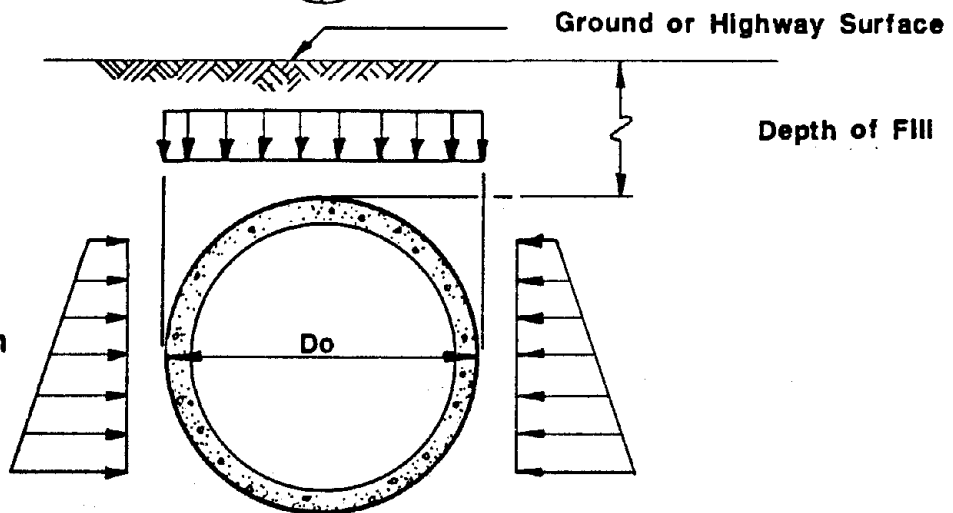
Installation Conditions -Radial Load System

- Depth of Fill -                      Height of soil cover from the ground or highway surface to the top of the culvert (ft). Depths must be greater than 1 ft. See Figure 3-2. See AASHTO 17.4.4.3 for additional restrictions on the minimum depth.
- Soil Structure Inter-                      Ratio of actual load on the pipe to the soil prism load. See action Coefficient -                      AASHTO Section 17.4.4.2 for methods of calculating this factor.
- Load Angle -                              Angle over which soil pressure is distributed on the pipe,  $\beta_S$ . See Figure 3-2.
- Bedding Angle -                              Angle over which resisting soil pressure acts on the pipe for applied earth, fluid and live loads,  $\beta_B$ . See Figure 3-2.
- Bedding Angle for                              Angle over which resisting soil pressure acts on the pipe for Pipe Weight -                              applied pipe weight,  $\alpha_{PW}$ . If set equal to 0, line support is assumed. See Figure 2-1.

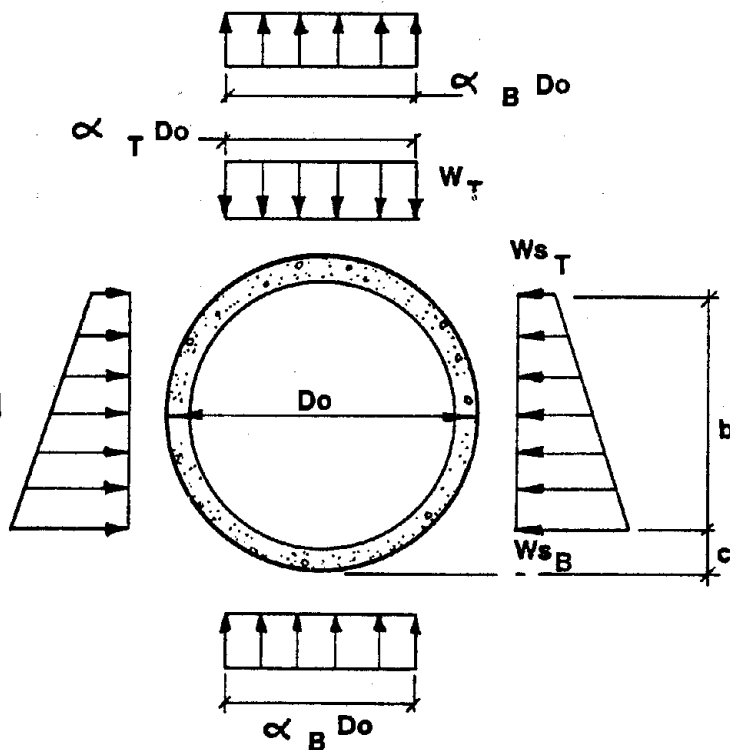
**a. Radial Load System**



**b. Uniform Load System**



**c. Uniform Manual Load System**



**FIGURE 3-2 PIPE CULVERT LOAD SYSTEM NOTATION**



```

PROGRAM: PIPECAR          CURRENT FILE:
PROJECT:

INSTALLATION CONDITIONS - Uniform Load System

Depth of Fill                ft
Soil Structure Interaction Coefficient
Lateral Pressure Coefficient
Bottom Reaction Width (soil,water, live)  %
Bottom Reaction Width (pipe weight)      %

SCREEN 3U

```

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen                      <PgDn> View Next Screen

### Installation Conditions - Uniform Load System

- Depth of Fill -                      Height of soil cover from the ground or highway surface to the top of the culvert (ft). Depths must be greater than 1 ft. See Figure 3-2. See AASHTO 17.4.4.3 for additional restrictions on the minimum depth.
- Soil Structure Inter-                      Ratio of actual load on the pipe to the soil prism load. See action Coefficient -                      AASHTO Section 17.4.4.2 for methods of calculating this factor.
- Lateral Pressure                      Fraction of vertical soil prism earth pressure acting as lateral Coefficient -                      pressure. Allowable range is 0 to 1.
- Bottom Reaction                      Percent of outside pipe diameter or span over which resisting soil Width -                      pressure acts on the pipe for applied earth, fluid and live loads,  $\alpha_B$ . See Figure 3-2.
- Bottom Reaction                      Percent of outside pipe diameter or span over which resisting soil Width for Pipe Wt. -                      pressure acts on the pipe for applied pipe weight,  $\alpha_{PW}$ . If set equal to 0, a line support is assumed. See Figure 2-1.

PROJECT:

## INSTALLATION CONDITIONS - Uniform/Manual Load System

Vertical Pressure	psf
Lateral Pressure at Top	psf
Lateral Pressure at Bottom	psf
Top Load Width	%
Bottom Reaction Width (soil,water, live)	%
Bottom Reaction Width (pipe weight)	%
Invert to bottom of side pressure	in.
Height of side load	in.
Depth of Fill (Used for Calculating Live Load Pressure Distribution Only)	ft

SCREEN 3M

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen      <PgDn> View Next Screen

## Installation Conditions - Uniform/Manual Load System

- Vertical Pressure - Magnitude of pressure,  $W_T$ , at the top of pipe (psf). See Figure 3-2.
- Lateral Pressure at Top - Magnitude of pressure,  $W_{sT}$ , acting as lateral pressure at the top of the pipe (psf). See Figure 3-2.
- Lateral Pressure at Bottom - Magnitude of pressure,  $W_{sB}$ , acting as lateral pressure at the bottom of the pipe (psf). See Figure 3-2.
- Top Load Width - Percent of the outside pipe diameter or span over which vertical pressure is applied,  $\alpha_T$ .
- Bottom Reaction Width - Percent of outside pipe diameter or span over which resisting soil pressure acts on the pipe for applied earth, fluid, and live loads,  $\alpha_B$ . See Figure 3-2.
- Bottom Reaction Width for Pipe Weight - Percent of outside pipe diameter or span over which resisting soil pressure acts on the pipe for applied pipe weight,  $\alpha_{PW}$ . If set equal to 0, a line support is assumed. See Figure 2-1.
- Invert to Bottom of Side Load - Distance  $c$  from bottom of pipe to location where lateral pressure is applied (in.). See Figure 3-2.
- Height of Side Load - Distance  $b$  over which lateral pressure is applied (in.). See Figure 3-2.
- Depth of Fill - Height of cover (ft) from the ground or highway surface to the top of the culvert. This is used only for calculating the live load pressure distribution on the pipe.

PROJECT:

MATERIAL PROPERTIES

Steel Reinforcing Yield Strength	ksi
Reinforcing Type	No. of Layers
Design Concrete Strength	ksi
Concrete Density	pcf

LOAD FACTORS

Dead Load Factor (Shear and Moment)
Dead Load Factor (Thrust)
Live Load Factor (Shear and Moment)
Live Load Factor (Thrust)
Internal Pressure Factor (Thrust)

SCREEN 4

<F1> = FINISHED EDITING → RETURN TO MAIN MENU                      <F2> = HELP  
 <PgUp> View Previous Screen    <PgDn> View Next Screen

- Reinforcing Yield Strength - Specified yield strength of circumferential reinforcement, (ksi).
- Reinforcing Type -
  - 1) Smooth wire
  - 2) Smooth welded wire fabric
  - 3) Deformed weld wire fabric, deformed bars, or any reinforcing with stirrups.
- Number of Layers - Enter the number of layers of reinforcing that you anticipate will be required to achieve the required design steel areas. The choices are limited to 1 or 2.
- Design Concrete Strength - 28 day compressive strength of concrete (ksi).
- Concrete Density - (pcf).
- Load Factors - Load factors used for ultimate strength design. Note that AASHTO and AREA require different dead and live load factors.

PROJECT:

## PHI FACTORS

Flexure  
 Radial Tension  
 Diagonal Tension

## PROCESS FACTORS

Limiting Crack Width Factor  
 Radial Tension Process Factor  
 Shear Process Factor

SCREEN 5

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen      <PgDn> View Next Screen

- Phi Factors - Capacity reduction factors used in ultimate strength design.
- Crack Width Factor - Factor for modifying the limiting 0.01 in. maximum crack width criteria.
- Radial Tension Process Factor - Factor for modifying the radial tension strength of plant produced pipe when justified by tests.
- Shear Process Factor - Factor for modifying the shear strength of plant produced pipe when justified by tests.

```

PROGRAM: PIPECAR          CURRENT FILE:
PROJECT:

SOIL LOAD DATA
    Soil Density                pcf

FLUID LOAD DATA
    Depth of Fluid              in.
    Fluid Density               pcf
    Pressure Head ( for circular pipe only )  ft.

LIVE LOAD DATA
    Live Load      (H/T/C/O/N)  HS-SERIES
                                INTERSTATE
                                COOPER E-SERIES
                                OTHER
                                NONE

```

SCREEN 6

<F1> = FINISHED EDITING → RETURN TO MAIN MENU                      <F2> = HELP  
 <PgUp> View Previous Screen    <PgDn> View Next Screen

- Soil Density -                      Density of fill material above the top of the pipe (pcf).
- Depth of Fluid -                      Depth of fluid inside the pipe (in.).
- Fluid Density -                      Density of fluid inside the pipe (pcf).
- Pressure Head -                      Internal pressure in ft of head (limited to 50 ft).
- Live Loads -
  - H)    AASHTO HS-series truck load
  - T)    AASHTO Interstate truck load (See AASHTO Section 3.7.4)
  - C)    Cooper E-series railroad load
  - O)    User specified load
  - N)    No live load

If "H", "C", or "O" is selected, a screen will appear prompting you for additional input pertaining to the type of live load you selected.

PROJECT:

LIVE LOAD DATA

You have chosen an AASHTO HS-SERIES load condition.

Enter the series magnitude (i.e. 10,20, etc.)

tons

SCREEN 6H

<F1> = FINISHED EDITING → RETURN TO MAIN MENU

<F2> = HELP

<PgUp> View Previous Screen

<PgDn> View Next Screen

AASHTO HS-Series Truck Load

Magnitude - Weight of truck as defined by AASHTO Specifications (tons).

PROGRAM: PIPECAR      CURRENT FILE:  
PROJECT:

LIVE LOAD DATA

You have chosen a COOPER E-SERIES load condition.

Enter the series magnitude (i.e. 72,80, etc.)

    . kips

SCREEN 6C

<F1> = FINISHED EDITING → RETURN TO MAIN MENU

<F2> = HELP

<PgUp> View Previous Screen

<PgDn> View Next Screen

Cooper E-Series Railroad Loading

Magnitude -      Locomotive axle weight as defined by AREA Specifications (kips).

PROJECT:

LIVE LOAD DATA

You have chosen a wheel load OTHER than the standard AASHTO load conditions given.

Enter the magnitude of the live load kips

Distribution length along pipe diameter in.  
Distribution length along pipe axis in.

This load will be modelled as a single wheel load distributed over the indicated area on top of the pipe. No increase in load will be made for impact.

SCREEN 60

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Next Screen

User Specified Live Load

Magnitude - (kips).

Distribution Length (in.).  
Along Pipe Diameter -

Distribution Length (in.).  
Along Pipe Axis -

NOTE: The specified length and width of load are applied at the horizontal plane of the pipe crown. The load is not spread through the fill.



PROGRAM: PIPECAR      CURRENT FILE:

PROJECT:

REINFORCING CAGE TYPE:

- 1) DOUBLE CIRCULAR
- 2) SINGLE CIRCULAR
- 3) SINGLE ELLIPTICAL
- 4) DOUBLE CIRCULAR + MATS
- 5) SINGLE CIRCULAR + ELLIPTICAL
- 6) DOUBLE CIRCULAR + ELLIPTICAL

SCREEN 7

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
<PgUp> View Previous Screen      <PgDn> View Next Screen

Reinforcing Cage Type - Enter selection for desired reinforcing layout for circular pipe. Only cage type 1 is allowed for an elliptical pipe. See Figure 3-3.

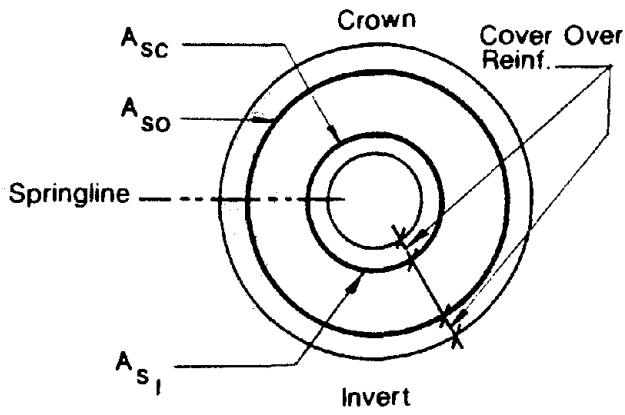
PROGRAM: PIPECAR		CURRENT FILE:
PROJECT:		
REINFORCING CAGE TYPE: DOUBLE CIRCULAR		
CONCRETE COVERS		
Inside Face		in.
Outside Face		in.
REINFORCING DIAMETERS		
Inside Reinforcing Diameter, Asi		in.
Outside Reinforcing Diameter, Aso		in.
MAXIMUM REINFORCING SPACING		
Inside Reinforcing Spacing, Asi		in.
Outside Reinforcing Spacing, Aso		in.
		SCREEN 7-1

<F1> = FINISHED EDITING + RETURN TO MAIN MENU                      <F2> = HELP  
 <PgUp> View Previous Screen    <PgDn> View Screen 1

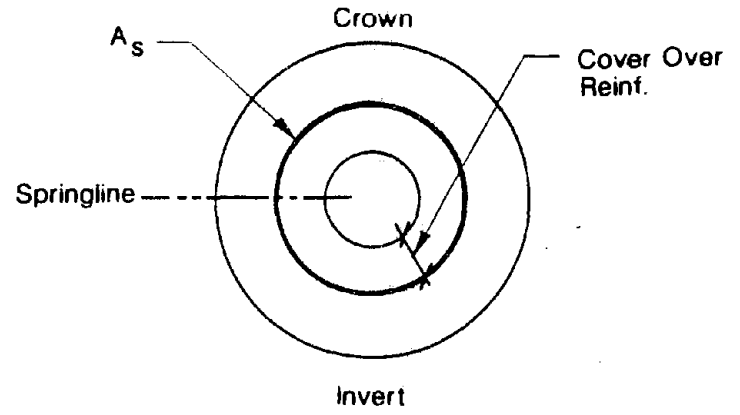
Parameters for double circular reinforcing:

- Concrete Covers - Clear concrete cover over circumferential reinforcing (in.). See Figure 3-3a.
- Reinforcing Diameters - Diameter of wire or bar used for reinforcement (in.). See Figure 3-3a for steel designations. This is used to estimate depth to reinforcing, d.
- Maximum Reinforcing - Maximum center-to-center spacing of main reinforcement (in.).  
 Spacing See Figure 3-3a for steel designations.

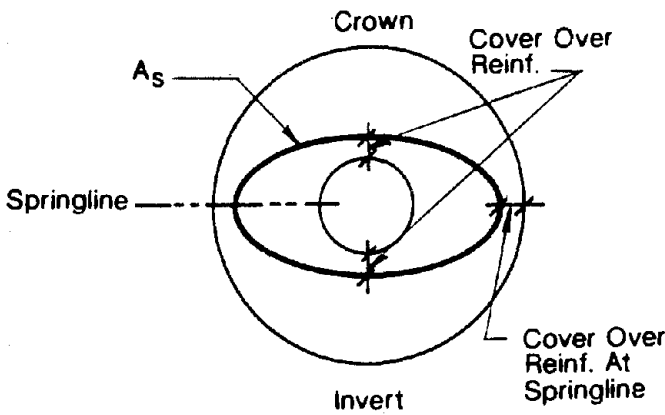
Note: This is the last input screen. After entering the last parameter you may end the file create mode by pressing [F1] or you may review your input by pressing [PgDn], which returns you to Screen 1. If you press [F1] you are asked if you wish to save and execute the file, save the file and return to the main menu or destroy the file and return to the main menu.



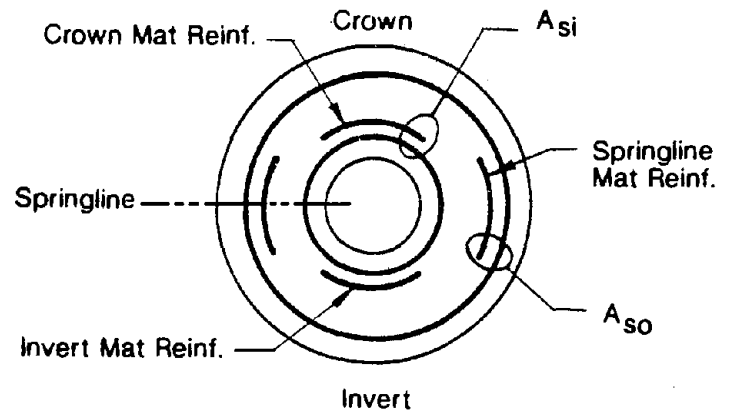
Double Circular Cages



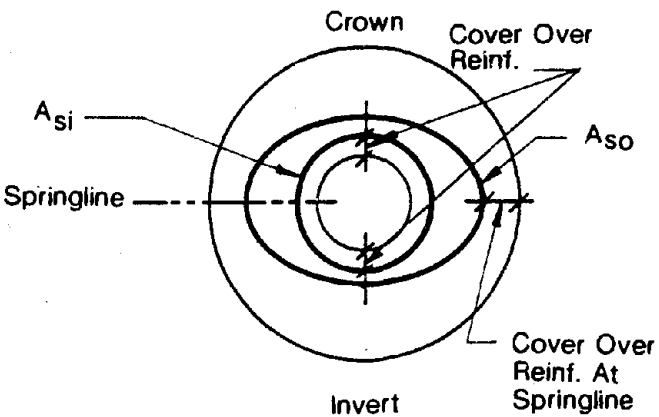
Single Circular Cage



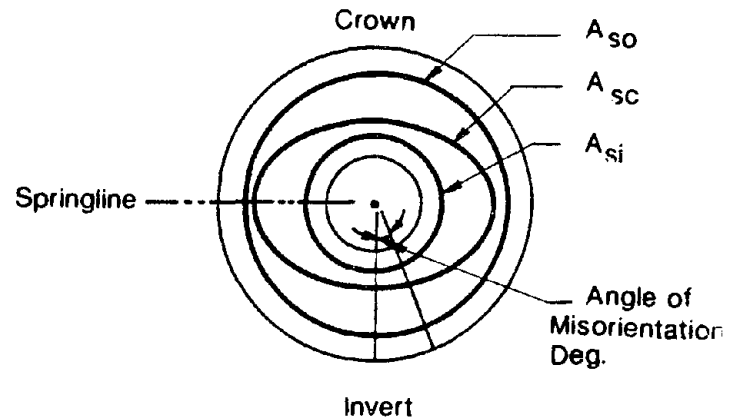
Single Elliptical Cage



Double Circular Cages + MAT Reinforcement



Single Circular Cage + Elliptical Cage



Double Circular Cage + Elliptical Cage

FIGURE 3-3 PIPE CULVERT REINFORCEMENT NOTATION

PROGRAM: PIPECAR		CURRENT FILE:	
PROJECT:			
REINFORCING CAGE TYPE: SINGLE CIRCULAR			
CONCRETE COVER			
Inside Face			in.
REINFORCING DIAMETER			
Reinforcing Diameter, As			in.
MAXIMUM REINFORCING SPACING			
Reinforcing Spacing, As			in.
			SCREEN 7-2

<F1> = FINISHED EDITING → RETURN TO MAIN MENU                      <F2> = HELP  
 <PgUp> View Previous Screen    <PgDn> View Screen 1

Parameters for single circular reinforcing:

- Concrete Covers -            Clear concrete cover over circumferential reinforcing (in.) See Figure 3-3b.
- Reinforcing diameters -    Diameter of wire or bar used for reinforcement (in.). See Figure 3-3b for steel designations.
- Maximum Reinforcing Spacing -    Maximum center-to-center spacing of main reinforcement (in.). See Figure 3-3b for steel designations.

Note:            This is the last input screen. After entering the last parameter you may end the file create mode by pressing [F1] or you may review your input by pressing [PgDn], which returns you to Screen 1. If you press [F1] you are asked if you wish to save and execute the file, save the file and return to the main menu or destroy the file and return to the main menu.

```

PROGRAM: PIPECAR          CURRENT FILE:
PROJECT:

REINFORCING CAGE TYPE:  SINGLE ELLIPTICAL

CONCRETE COVERS
    Inside Face - Crown and Invert      in.
    Outside Face - Springline          in.

REINFORCING DIAMETER
    Reinforcing Diameter, As            in.

MAXIMUM REINFORCING SPACING
    Reinforcing Spacing, As            in.

ANGLE OF ELLIPTICAL CAGE MISORIENTATION      deg.

SCREEN 7-3

```

<F1> = FINISHED EDITING - RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen                      <PgDn> View Screen 1

Parameters for single elliptical reinforcing:

- Concrete Covers -      Clear concrete cover over circumferential reinforcing (in.) See Figure 3-3c.
- Reinforcing diameters -      Diameter of wire or bar used for reinforcement (in.). See Figure 3-3c for steel designations.
- Maximum Reinforcing Spacing      Maximum center-to-center spacing of main reinforcement (in.). See Figure 3-3c for steel designations.
- Angle of Elliptical Cage Misorientation -      Angle of rotation about the center of the pipe (deg) to account for misplacement of the invert. See Figure 3-3c.

Note: This is the last input screen. After entering the last parameter you may end the file create mode by pressing [F1] or you may review your input by pressing [PgDn], which returns you to Screen 1. If you press [F1] you are asked if you wish to save and execute the file, save the file and return to the main menu or destroy the file and return to the main menu.

```

===== PROGRAM: PIPECAR ===== CURRENT FILE:
PROJECT:
    REINFORCING CAGE TYPE:  DOUBLE CIRCULAR + MATS
        CONCRETE COVERS
            Inside Face                in.
            Outside Face               in.
        REINFORCING DIAMETERS
            Inside Circular Reinforcing Diameter    in.
            Inside Mat Reinforcing Diameter - Invert    in.
            Inside Mat Reinforcing Diameter - Crown    in.
            Outside Circular Reinforcing Diameter    in.
            Outside Mat Reinforcing Diameter        in.
        MAXIMUM REINFORCING SPACING
            Inside Reinforcing Spacing, Asi        in.
            Outside Reinforcing Spacing, Aso       in.
        MAT REINFORCING EXTENT
            Angle of Extent Centered on Invert      deg.
            Angle of Extent Centered on Crown      deg.
            Angle of Extent Centered on Springline  deg.
                                                    SCREEN 7-4

```

```

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP
<PgUp> View Previous Screen                       <PgDn> View Screen 1

```

Parameters for double circular + mat reinforcing:

- Concrete Covers - Clear concrete cover over circumferential reinforcing (in.) See Figure 3-3d.
- Reinforcing diameters - Diameter of wire or bar used for reinforcement (in.). See Figure 3-3d for steel designations.
- Maximum Reinforcing Spacing - Maximum center-to-center spacing of main reinforcement (in.). See Figure 3-3d for steel designations.
- Mat Reinforcing - Extent - Angle to extend mat reinforcing from invert, crown, or springline (deg.) measured from the center of the pipe. See Figure 3.3.d.

Note: This is the last input screen. After entering the last parameter you may end the file create mode by pressing [F1] or you may review your input by pressing [PgDn], which returns you to Screen 1. If you press [F1] you are asked if you wish to save and execute the file, save the file and return to the main menu or destroy the file and return to the main menu.

```

PROGRAM: PIPECAR          CURRENT FILE:
PROJECT:
REINFORCING CAGE TYPE:  SINGLE CIRCULAR + ELLIPTICAL
CONCRETE COVERS
    Inside Face - Crown and Invert          in.
    Outside Face - Springline              in.
REINFORCING DIAMETERS
    Inside Circular Reinforcing Diameter, Asi    in.
    Elliptical Reinforcing Diameter, Aso        in.
MAXIMUM REINFORCING SPACING
    Inside Reinforcing Spacing, Asi            in.
    Outside Reinforcing Spacing, Aso          in.
ANGLE OF ELLIPTICAL CAGE MISORIENTATION          deg.
                                                SCREEN 7-5

```

<F1> = FINISHED EDITING → RETURN TO MAIN MENU                      <F2> = HELP  
 <PgUp> View Previous Screen    <PgDn> View Screen 1

Parameters for single circular + elliptical reinforcing:

- Concrete Covers -            Clear concrete cover over circumferential reinforcing (in.) See Figure 3-3e.
- Reinforcing diameters -    Diameter of wire or bar used for reinforcement (in.). See Figure 3-3e for steel designations.
- Maximum Reinforcing Spacing -    Maximum center-to-center spacing of main reinforcement (in.). See Figure 3-3e for steel designations.
- Angle of Elliptical Cage Misorientation -    Angle of rotation about the center of the pipe (deg.) to account for misplacement of the invert. See Figure 3.3e.

Note: This is the last input screen. After entering the last parameter you may end the file create mode by pressing [F1] or you may review your input by pressing [PgDn], which returns you to Screen 1. If you press [F1] you are asked if you wish to save and execute the file, save the file and return to the main menu or destroy the file and return to the main menu.

```

PROGRAM: PIPECAR          CURRENT FILE:
PROJECT:
REINFORCING CAGE TYPE:  DOUBLE CIRCULAR + ELLIPTICAL

CONCRETE COVERS
  Inside Face           in.
  Outside Face         in.

REINFORCING DIAMETERS
  Inside Circular Reinforcing Diameter, Asi   in.
  Outside Circular Reinforcing Diameter, Aso  in.
  Elliptical Reinforcing Diameter, Ase       in.

MAXIMUM REINFORCING SPACING
  Inside Reinforcing Spacing, Asi            in.
  Outside Reinforcing Spacing, Aso          in.

ANGLE OF ELLIPTICAL CAGE MISORIENTATION      deg.

SCREEN 7-6

```

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen                      <PgDn> View Screen 1

Parameters for double circular + elliptical reinforcing:

- Concrete Covers - Clear concrete cover over circumferential reinforcing (in.) See Figure 3-3f.
- Reinforcing diameters - Diameter of wire or bar used for reinforcement (in.). See Figure 3-3f for steel designations.
- Maximum Reinforcing Spacing - Maximum center-to-center spacing of main reinforcement (in.). See Figure 3-3f for steel designations.
- Angle of Elliptical - Angle of rotation about the center of the pipe (deg.) to account Cage Misorientation for misplacement of the invert. See Figure 3.3.f.

Note: This is the last input screen. After entering the last parameter you may end the file create mode by pressing [F1] or you may review your input by pressing [PgDn], which returns you to Screen 1. If you press [F1] you are asked if you wish to save and execute the file, save the file and return to the main menu or destroy the file and return to the main menu.



### **3.2.2 Main Menu Selection 2: Retrieve a Direct Design Input File**

You may retrieve input files for review or modification by selecting Option 2. When you make this selection, a list of all available input files appears on the screen. Type in the name of the input file you wish to review, omitting the .PIP filename extension, and press [Enter]. When Screen 1 appears, you may make modifications to the input file by proceeding through the input screens as discussed in Section 3.2.1. When you select the retrieve mode, the default file is not activated. Any changes you wish to make to the retrieved file must be input manually. If you wish to save both the original file and the modified file, you must change the filename on Screen 1. You may return to the main menu at any time by pressing the [F1] key. When returning to the main menu, you are asked if you want to save (and execute if desired) the input file. If you are saving a file that already exists, you are also asked if you wish to overwrite the existing file. If you choose not to overwrite the existing file, the program returns back to Screen 1 for you to change the filename.

### **3.2.3 Main Menu Selection 3: Program Execution - Direct Design Method**

Execution of the direct design program is performed by selecting Option 3 on the main menu. When you make this selection, a list of all the available input files appears on the screen. Type in the filename of the desired input file, omitting the .PIP filename extension and press [Enter].

After designing the flexural reinforcing PIPECAR will print the required reinforcing areas to the screen for review by the user. This screen also indicates if stirrups are required to provide adequate shear strength. After reviewing this screen the user may select the level of output, if any, that he desires (Output options are presented in Section 4. of this Manual). If the file is saved and stirrups are required then the stirrup design module is activated and the user can complete the stirrup design. The stirrup design module is described in Section 3.3 of this Manual.

### **3.2.4 Main Menu Selection 4: Execute PIPECAR - Indirect Design Method**

As an alternative to designing pipe using the direct design method of PIPECAR, the user may activate the indirect design module which allows the user to evaluate pipe for the three-edge bearing load condition. This is a completely independent module of PIPECAR that requires its own input. It does not use the input files created by using main menu

Selection 1 and it does not write any files to disk. The design equations used in the indirect design method are presented in Appendix C. The development of these equations is presented in Reference 4.

When the user selects Option 4, a screen appears that informs the user that the indirect design module has been activated, that it is an independent part of the program, and that no files will be written to disk. This screen is exited by hitting any key, which activates the three-edge bearing program and prints the following menu:

```

-----PIPECAR - THREE EDGE BEARING PROGRAM --- DESIGN PARAMETERS-----
PIPE GEOMETRY <F1>:
Pipe shape = CIRCULAR
Inner diameter or span (in.) = 0
Wall thickness (in.) = 0
Inside reinforcing cover (in.) = 1
Outside reinforcing cover (in.) = 1
DESIGN COEFFICIENTS <F3>:
PhiF = .95 Cs = .6
PhiC = .95 (Aso/Asi)
PhiD = .9
PhiR = .9 Cx = 1

MATERIAL PROPERTIES <F2>:
Reinforcing type = 2
Reinforcing yield stress (psi) = 65000
Reinf. ultimate stress (psi) = 75000
Design criteria (YIELD/ULTIMATE) = ULTIMATE
Concrete strength, f'c (psi) = 5000
No. of reinforcing layers = 1
Circum. reinf. spacing (in.) = 4

WAITING FOR SOFT KEY INPUT

<F1>PIPE GEOM <F2>MAT PROP <F3>DES COEF <F4> MAIN MENU <F5>HELP <F10>CONT

```

As indicated by the menu, the module is run by using the softkeys as follows:

- F1 - Softkey F1 allows the user to change the pipe shape, span, wall thickness, or reinforcing covers. When first accessing the indirect design module, the user must input values for the pipe span and wall thickness.
- F2 - Softkey F2 allows the user to change the material properties that are listed on the main menu.
- F3 - Softkey F3 allows the user to modify the strength reduction factors and a set of design coefficients. The module allows separate strength reduction factors for flexure ( $\Phi_F$ ), 0.01 inch crack ( $\Phi_C$ ), diagonal tension ( $\Phi_D$ ), and radial tension ( $\Phi_R$ ). The program automatically sets the design coefficients ( $C_S$ ,  $C_X$ ) for pipe reinforced with two concentric cages. Appendix C gives alternate values of the design coefficients that may be input if other conditions are desired.
- F4 - Softkey F4 returns to the main PIPECAR menu.

F5 - Softkey F5 activates a help screen for the indirect design method.

F10 - Softkey F10 activates the indirect design program after the input is completed.

When the user presses softkey F10, two choices are presented:

1. Task 1 determines the D-load capacity of a pipe with known reinforcing. When the user makes this choice, he must specify the inside reinforcing area. The program then computes the D-load capacity of the pipe based on flexure, 0.01 inch crack, diagonal tension, and radial tension. The results are printed to screen and the user may then elect to have a copy sent to the printer. Task 1 is limited to evaluating the three-edge bearing strength of pipe based only on the quantity of inside reinforcing. The capacity of the outside reinforcing, or stirrups, if present, are not considered.
2. Task 2 determines the reinforcing requirements for a pipe when the D-loads at the service condition (0.01 inch crack) and at the ultimate condition are input. In the design task the program determines the required inside, outside and, if necessary, stirrup reinforcing. If stirrups are required a screen appears that requests the developable stirrup yield strength and the stirrup spacing. The program will not accept stirrup spacings that are larger than the AASHTO limitation of 0.75 times the reinforcing depth  $d$ .

The results for both tasks are printed to the screen. The user is given the option of obtaining a printed copy of the input and output. The user may then save the input from the design just completed or return to the default values for all parameters.

### **3.2.5 Main Menu Selection 5: Print a Direct Design Input File**

You may obtain a hardcopy of any input file by selecting Option 5. When you make this selection, a list of all available input files appears on the screen. Type in the name of the input file, omitting the .PIP filename extension and press [Enter]. A listing of the input is automatically directed toward your printer. The listing will be formatted for 8.5 in. by 11 in. paper. The print subroutine inserts form feeds where appropriate and places headers and page numbers on each page.

### **3.2.6 Main Menu Selection 6: Print a Direct Design Output File**

After program execution, the output is stored as a file on your disk. You may view the output using text editor software (not included in this software package) or you may obtain a hardcopy by selecting Option 6 on the main menu. When you select this option a list of all the available output files is displayed on the screen. Output files have the

same filename as the input files except that they are given the filename extension .OUT. Type in the name of the output file, omitting the filename extension and press [Enter]. The program will first process the output for printing on 8.5 by 11 inch paper. Form feeds are inserted where needed, and headers and page numbers are placed on the top of each page. After processing, the output is sent to the printer.

### **3.2.7 Main Menu Selection 7: Changing Default Values**

The default values listed in Appendix A of this manual are stored as a file that you may change to meet your own particular typical design requirements. You may change the default parameters by selecting Option 7 on the main menu. The default parameter menus are used in the same manner as the menus for creating a new file using Option 1.

The defaults screens use equations to determine some parameters as follows:

- Defaults for wire diameter are a function of the thickness of the member in which they are placed.

$$\text{Wire Diameter} = x * \text{Thickness (in.)} + y$$

The user may specify values for x and y. This allows the wire diameter to default to either a fraction of the wall thickness by specifying  $y = 0$  or to an absolute diameter by specifying  $x = 0$ .

- The depth of fluid is determined as a fraction of the culvert rise. The user inputs the desired fraction.

To store the default values and return to the main menu pres [Esc] [PgDn].

### **3.2.8 Main Menu Selection 8: Exiting the Program**

Selection 8 on the main menu exits the program and returns you to the operating system.

## **3.3 Stirrup Design**

If the radial tension or diagonal tension strength of the pipe is inadequate for resisting the applied loads, PIPECAR will automatically activate a routine to design stirrups. The following screen will appear:

PIPECAR STIRRUP REINFORCING ROUTINE

Developable Stirrup Yield Stress	ksi
Stirrup Spacing (maximum=0.75 $\phi$ d)	in.
Required Steel Area for Stirrups	in. <sup>2</sup> /ft/line
Required Number of Lines	
Stirrups Centered on	INVERT

The optional input for this routine is the developable stirrup yield strength and the stirrup spacing. All other information on the screen is taken from program output. When selecting the stirrup yield strength, users should be aware that some concrete producers use bent sections of smooth cold drawn wire for stirrup reinforcement that do not provide sufficient anchorage to develop the full yield strength of the wire. This is why PIPECAR uses the terminology "developable" yield strength and defaults to a value of 40 ksi. You should be cautious in selecting a design value for the stirrup yield strength.

You may accept the stirrup yield strength and spacing displayed by pressing the [Enter] key or make changes to these values as required. Press the [Enter] key after making changes to each parameter. The program will compute the required stirrup area and number of lines required. This information is displayed on the screen, and you are asked if this is a final design. If you say no by pressing "N", the program allows you to make changes to the stirrup yield strength and spacing. The arrow keys allow you to move from one parameter to the other to make changes. If you say yes by pressing "Y", then the program appends the design information to the output file. This design procedure is iterated for both shear design locations, if required.



#### 4. REPORT OUTPUT

##### 4.1 Output Control

The first program output that the user sees is the summary of the flexural reinforcing that is printed to the screen after program execution:

```
                PIPECAR PIPE CULVERT DESIGN SUMMARY
            84.0 INCH DIAMETER REINFORCED CONCRETE CIRCULAR PIPE
*****
R E I N F O R C I N G   D A T A
-----
REINFORCING CAGE TYPE                                DOUBLE CIRCULAR
INVERT- INSIDE REINFORCING, SQ.IN./FT.                .384
SPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.            .171
CROWN- INSIDE REINFORCING, SQ.IN./FT.                  .148
```

DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

D = WRITE TO DISK AND RETURN TO MAIN MENU.  
P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.  
N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

Make Selection....Then Press Enter

At this time the user selects "D" to save the output file on disk, "P" to save the file on disk and post-process the file for printing, or "N" to return to the Main Menu without saving the file. If the user elects to save the output file the following screen appears, allowing selection of an output level:

##### OUTPUT SELECTIONS

1. Print Input and Design Summary
2. Print Above + Total Loads, Ultimate Forces Design Tables
3. Print Above + Applied Pressures and Service Load Forces
4. Print Above + Computer Model Geometry and Displacements

Make Selection....Then Press Enter

The four options displayed give the user control the amount of output to be written to the output file. Options 1 through 4 may be specified, with each increasing option number providing more output, as listed below. Tables 4-1a to 4-1i show sample output in the order that it is printed.

#### 4.1.1 Output Option 1

**Echo print of input data:** The program prints the input screens with the assigned values for each parameter to allow the designer to check the input and to identify the design (Table 4-1a).

**Summary table for design:** Table 4-1i lists all important design parameters for the pipe section. A row of stars (\*\*\*) under the steel area column shows that steel design at that location was governed by concrete compression and the member must be designed with a thicker section or greater concrete strength. Otherwise, the section may be designed as a compression member according to AASHTO ultimate strength design methods. If stirrups are required at certain locations, the program will interactively design the required stirrup steel area and spacing and print the shear reinforcement design as part of this table.

#### 4.1.2 Output Option 2

**Pipe, soil, fluid, and live load weights:** Table 4-1d lists the total applied loads on the pipe for each load condition. Units are kips per longitudinal foot of pipe.

**Table of ultimate forces:** Table 4-1g lists the ultimate moments, thrusts, and shears at each of the five design locations (Figure 2-3) in the pipe. These are the forces used to complete the reinforcing design.

**Reinforcing design table:** Table 4-1h lists the reinforcing requirements for flexure, and design indices for crack control, diagonal tension, and radial tension. Also cited is the governing design, the steel ratio produced by that design, and stirrup requirements if the radial tension or diagonal tension indices are greater than 1.0. The governing mode is also listed.

#### 4.1.3 Output Option 3

**Pressures at each joint:** Table 4-1c lists the radial and tangential pressure at each joint due to earth, soil, fluid, and live load. The units are kips per circumferential inch per longitudinal foot of pipe.

**Service load forces:** Table 4-1f lists the service load moments, thrusts, and shears at each joint. The forces are listed separately for the four load conditions.



#### 4.1.4 Option 4

**Pipe geometry:** Table 4-1b lists the node coordinates, member angle from vertical, member lengths, and unit sines and cosines for each member angle. The pipe model is shown in Figure 2-3.

**Joint displacement:** Table 4-1e lists the displacements for each joint due to each load condition. The displacements are in a global coordinate system, with positive x and y displacements as shown in Figure 2-2 and rotations positive counterclockwise from the y to the x axis. The displacements are based on an elastic analysis of an uncracked concrete section and are not estimates of expected field displacements. They are used only for consistency checks.

P I P E C A R

A Microcomputer Program for the Analysis and  
Design of Circular and Horizontal Elliptical  
Reinforced Concrete Pipe Culverts

VERSION 1.0 - NOVEMBER 1988

Developed by

Simpson Gumpertz & Heger Inc.  
Arlington Massachusetts  
in cooperation with

The Federal Highway Administration  
and  
The American Concrete Pipe Association

The application of this non-proprietary software product is the responsibility of the user. The user must select input values suitable to his specific installation. Use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application, and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or other agents.

DATE: 01-12-1989  
TIME: 11:34:18

TABLE 4-1a LISTING OF INPUT DATA

Filename                   SAMPLE.OUT  
 Job Description           SAMPLE OUTPUT FOR PIPECAR

GEOMETRY: CIRCULAR PIPE ANALYSIS AND DESIGN

Pipe Inside Diameter           84 in.  
 Pipe Wall Thickness            8 in.

INSTALLATION CONDITIONS - Radial Load System

Depth of fill                   7.5 ft  
 Soil-Structure Interaction Coefficient   1.2  
 Load Angle                    270 deg  
 Bedding Angle for Soil, Water and Live Load   60 deg  
 Bedding Angle for Pipe Weight Reaction    0 deg

MATERIAL PROPERTIES

Steel Reinforcing Yield Stress           65 ksi  
 Reinforcing Type            2            No. of Layers    1  
 Design Concrete Strength               5 ksi  
 Concrete Density                        150 pcf

TABLE 4-1a CONTINUED

LOAD FACTORS

Dead Load Factor (Shear and Moment)	1.3
Dead Load Factor (Thrust)	1
Live Load Factor (Shear and Moment)	2.17
Live Load Factor (Thrust)	1
Internal Pressure Factor (Thrust)	1.8

PHI FACTORS

Flexure	.95
Radial Tension	.9
Diagonal Tension	.9

PROCESS FACTORS

Limiting Crack Width Factor	.9
Radial Tension Process Factor	1
Shear Process Factor	1

TABLE 4-1a CONTINUED

SOIL LOAD DATA

Soil Density 120 pcf

FLUID LOAD DATA

Depth of Fluid 84 in  
 Fluid Density 62.4 pcf  
 Pressure Head 0 ft

LIVE LOAD DATA

Live Load HS- 20

CAGE REINFORCING TYPE

DOUBLE CIRCULAR

CONCRETE COVERS

Inside Face 1 in.  
 Outside Face 1 in.

REINFORCING DIAMETERS

Inside Circular Reinforcing Diameter, Asi .32 in.  
 Outside Circular Reinforcing Diameter, Aso .32 in.

MAXIMUM REINFORCING SPACING

Inside Reinforcing Spacing, Asi 2 in.  
 Outside Reinforcing Spacing, Aso 2 in.

TABLE 4-1a CONTINUED

GEOMETRY  
JOINT COORDINATES

I JOINT	ANGLE FROM VERTICAL		INCHES FROM CENTER	
	DEGREES	RADIANS	X(I)	Y(I)
1	0.	.000	.000	-46.000
2	5.	.087	4.009	-45.825
3	10.	.175	7.988	-45.301
4	15.	.262	11.906	-44.433
5	20.	.349	15.733	-43.226
6	25.	.436	19.440	-41.690
7	30.	.524	23.000	-39.837
8	35.	.611	26.385	-37.681
9	40.	.698	29.568	-35.238
10	45.	.785	32.527	-32.527
11	50.	.873	35.238	-29.568
12	55.	.960	37.681	-26.385
13	60.	1.047	39.837	-23.000
14	65.	1.134	41.690	-19.440
15	70.	1.222	43.226	-15.733
16	75.	1.309	44.433	-11.906
17	80.	1.396	45.301	-7.988
18	85.	1.484	45.825	-4.009
19	90.	1.571	46.000	.000
20	95.	1.658	45.825	4.009
21	100.	1.745	45.301	7.988
22	105.	1.833	44.433	11.906
23	110.	1.920	43.226	15.733
24	115.	2.007	41.690	19.440
25	120.	2.094	39.837	23.000
26	125.	2.182	37.681	26.385
27	130.	2.269	35.238	29.568
28	135.	2.356	32.527	32.527
29	140.	2.443	29.568	35.238
30	145.	2.531	26.385	37.681
31	150.	2.618	23.000	39.837
32	155.	2.705	19.440	41.690
33	160.	2.793	15.733	43.226
34	165.	2.880	11.906	44.433
35	170.	2.967	7.988	45.301
36	175.	3.054	4.009	45.825
37	180.	3.142	.000	46.000

TABLE 4-1b GEOMETRY

GEOMETRY  
MEMBER LENGTHS, UNIT SINES & COSINES

I MEMBER	LENGTH IN.	SI(I)	CO(I)
1	4.013	.044	.999
2	4.013	.131	.991
3	4.013	.216	.976
4	4.013	.301	.954
5	4.013	.383	.924
6	4.013	.462	.887
7	4.013	.537	.843
8	4.013	.609	.793
9	4.013	.676	.737
10	4.013	.737	.676
11	4.013	.793	.609
12	4.013	.843	.537
13	4.013	.887	.462
14	4.013	.924	.383
15	4.013	.954	.301
16	4.013	.976	.216
17	4.013	.991	.131
18	4.013	.999	.044
19	4.013	.999	-.044
20	4.013	.991	-.131
21	4.013	.976	-.216
22	4.013	.954	-.301
23	4.013	.924	-.383
24	4.013	.887	-.462
25	4.013	.843	-.537
26	4.013	.793	-.609
27	4.013	.737	-.676
28	4.013	.676	-.737
29	4.013	.609	-.793
30	4.013	.537	-.843
31	4.013	.462	-.887
32	4.013	.383	-.924
33	4.013	.301	-.954
34	4.013	.216	-.976
35	4.013	.131	-.991
36	4.013	.044	-.999

TABLE 4-1b CONTINUED

PRESSURES AT EACH JOINT, KIPS/IN/FT

I JT.	DEG FROM VERTICAL	DEAD		SOIL	
		RADIAL	TANG	RADIAL	TANG
1	0.	-.0083	.0000	.3389	.0000
2	5.	-.0083	.0007	.3274	.0000
3	10.	-.0082	.0014	.2935	.0000
4	15.	-.0080	.0022	.2397	.0000
5	20.	-.0078	.0029	.1695	.0000
6	25.	-.0076	.0035	.0877	.0000
7	30.	-.0072	.0042	.0000	.0000
8	35.	-.0068	.0048	.0000	.0000
9	40.	-.0064	.0054	.0000	.0000
10	45.	-.0059	.0059	.0000	.0000
11	50.	-.0054	.0064	.0075	.0000
12	55.	-.0048	.0068	.0150	.0000
13	60.	-.0042	.0072	.0224	.0000
14	65.	-.0035	.0076	.0298	.0000
15	70.	-.0029	.0078	.0370	.0000
16	75.	-.0022	.0080	.0441	.0000
17	80.	-.0014	.0082	.0511	.0000
18	85.	-.0007	.0083	.0579	.0000
19	90.	.0000	.0083	.0645	.0000
20	95.	.0007	.0083	.0709	.0000
21	100.	.0014	.0082	.0770	.0000
22	105.	.0022	.0080	.0829	.0000
23	110.	.0029	.0078	.0885	.0000
24	115.	.0035	.0076	.0938	.0000
25	120.	.0042	.0072	.0988	.0000
26	125.	.0048	.0068	.1035	.0000
27	130.	.0054	.0064	.1078	.0000
28	135.	.0059	.0059	.1117	.0000
29	140.	.0064	.0054	.1153	.0000
30	145.	.0068	.0048	.1185	.0000
31	150.	.0072	.0042	.1212	.0000
32	155.	.0076	.0035	.1236	.0000
33	160.	.0078	.0029	.1255	.0000
34	165.	.0080	.0022	.1270	.0000
35	170.	.0082	.0014	.1281	.0000
36	175.	.0083	.0007	.1288	.0000
37	180.	.0083	.0000	.1290	.0000

TABLE 4-1c PRESSURES AT EACH JOINT



PRESSURES AT EACH JOINT, KIPS/IN/FT

I JT.	DEG FROM VERTICAL	FLUID		LIVE	
		RADIAL	TANG	RADIAL	TANG
1	0.	.0476	.0000	.0358	.0000
2	5.	.0449	.0000	.0345	.0000
3	10.	.0370	.0000	.0310	.0000
4	15.	.0245	.0000	.0253	.0000
5	20.	.0082	.0000	.0179	.0000
6	25.	-.0108	.0000	.0093	.0000
7	30.	-.0310	.0000	.0000	.0000
8	35.	-.0302	.0000	.0000	.0000
9	40.	-.0293	.0000	.0000	.0000
10	45.	-.0284	.0000	.0000	.0000
11	50.	-.0273	.0000	.0000	.0000
12	55.	-.0261	.0000	.0000	.0000
13	60.	-.0249	.0000	.0000	.0000
14	65.	-.0236	.0000	.0000	.0000
15	70.	-.0223	.0000	.0000	.0000
16	75.	-.0209	.0000	.0000	.0000
17	80.	-.0195	.0000	.0000	.0000
18	85.	-.0181	.0000	.0000	.0000
19	90.	-.0166	.0000	.0000	.0000
20	95.	-.0152	.0000	.0013	.0000
21	100.	-.0137	.0000	.0026	.0000
22	105.	-.0123	.0000	.0038	.0000
23	110.	-.0109	.0000	.0050	.0000
24	115.	-.0096	.0000	.0062	.0000
25	120.	-.0083	.0000	.0074	.0000
26	125.	-.0071	.0000	.0084	.0000
27	130.	-.0059	.0000	.0095	.0000
28	135.	-.0049	.0000	.0104	.0000
29	140.	-.0039	.0000	.0113	.0000
30	145.	-.0030	.0000	.0121	.0000
31	150.	-.0022	.0000	.0127	.0000
32	155.	-.0016	.0000	.0133	.0000
33	160.	-.0010	.0000	.0138	.0000
34	165.	-.0006	.0000	.0142	.0000
35	170.	-.0003	.0000	.0145	.0000
36	175.	-.0000	.0000	.0147	.0000
37	180.	.0000	.0000	.0147	.0000

\*\*\*\*\*TOTAL APPLIED LOADS ON PIPE\*\*\*\*\*

PIPE WEIGHT = 2.408 KIPS/FT  
 SOIL WEIGHT = 10.071 KIPS/FT  
 FLUID WEIGHT = 2.401 KIPS/FT  
 LIVE LOAD = 1.063 KIPS/FT

TABLE 4-1d TOTAL LOADS ON PIPE

		DISPLACEMENTS, IN			
		LOADING			
		1	2	3	4
JOINT 1					
X	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
Y	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
ROT	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
JOINT 2					
X	.16209E-05	-.16264E-04	.99782E-05	-.18218E-06	
Y	-.91279E-04	-.26943E-03	-.62082E-04	-.35462E-04	
ROT	-.44044E-04	-.13313E-03	-.30974E-04	-.17576E-04	
JOINT 3					
X	.31094E-04	.58088E-04	.40940E-04	.11626E-04	
Y	-.34052E-03	-.10559E-02	-.24328E-03	-.13923E-03	
ROT	-.79662E-04	-.25835E-03	-.60126E-04	-.34238E-04	
JOINT 4					
X	.10877E-03	.30166E-03	.11110E-03	.45999E-04	
Y	-.71022E-03	-.22965E-02	-.52909E-03	-.30371E-03	
ROT	-.10731E-03	-.36851E-03	-.85805E-04	-.49150E-04	
JOINT 5					
X	.24645E-03	.77093E-03	.23356E-03	.11089E-03	
Y	-.11634E-02	-.38951E-02	-.89732E-03	-.51726E-03	
ROT	-.12751E-03	-.45782E-03	-.10668E-03	-.61623E-04	
JOINT 6					
X	.44812E-03	.14936E-02	.41482E-03	.21078E-03	
Y	-.16650E-02	-.57341E-02	-.13208E-02	-.76542E-03	
ROT	-.14082E-03	-.52248E-03	-.12189E-03	-.71181E-04	
JOINT 7					
X	.71094E-03	.24668E-02	.65430E-03	.34642E-03	
Y	-.21834E-02	-.76885E-02	-.17707E-02	-.10326E-02	
ROT	-.14783E-03	-.56110E-03	-.13112E-03	-.77601E-04	
JOINT 8					
X	.10264E-02	.36602E-02	.94518E-03	.51500E-03	
Y	-.26911E-02	-.96401E-02	-.22198E-02	-.13035E-02	
ROT	-.14916E-03	-.57486E-03	-.13464E-03	-.80937E-04	
JOINT 9					
X	.13816E-02	.50230E-02	.12759E-02	.71089E-03	
Y	-.31657E-02	-.11490E-01	-.26451E-02	-.15650E-02	
ROT	-.14547E-03	-.56641E-03	-.13308E-03	-.81402E-04	
JOINT 10					
X	.17605E-02	.64905E-02	.16316E-02	.92623E-03	
Y	-.35902E-02	-.13160E-01	-.30291E-02	-.18059E-02	
ROT	-.13742E-03	-.53869E-03	-.12708E-03	-.79240E-04	
JOINT 11					
X	.21454E-02	.79900E-02	.19957E-02	.11516E-02	
Y	-.39532E-02	-.14601E-01	-.33593E-02	-.20183E-02	
ROT	-.12568E-03	-.49475E-03	-.11730E-03	-.74717E-04	
JOINT 12					
X	.25180E-02	.94467E-02	.23506E-02	.13767E-02	
Y	-.42489E-02	-.15782E-01	-.36289E-02	-.21968E-02	
ROT	-.11090E-03	-.43768E-03	-.10439E-03	-.68115E-04	
JOINT 13					
X	.28608E-02	.10789E-01	.26794E-02	.15910E-02	

TABLE 4-1e DISPLACEMENTS

Y	-.44764E-02	-.16698E-01	-.38363E-02	-.23389E-02
ROT	-.93756E-04	-.37045E-03	-.88997E-04	-.59734E-04
	JOINT 14			
X	.31578E-02	.11953E-01	.29667E-02	.17842E-02
Y	-.46397E-02	-.17363E-01	-.39840E-02	-.24451E-02
ROT	-.74875E-04	-.29589E-03	-.71757E-04	-.49887E-04
	JOINT 15			
X	.33957E-02	.12884E-01	.31994E-02	.19471E-02
Y	-.47463E-02	-.17806E-01	-.40788E-02	-.25181E-02
ROT	-.54874E-04	-.21665E-03	-.53274E-04	-.38896E-04
	JOINT 16			
X	.35643E-02	.13541E-01	.33672E-02	.20721E-02
Y	-.48071E-02	-.18069E-01	-.41302E-02	-.25629E-02
ROT	-.34338E-04	-.13523E-03	-.34127E-04	-.27096E-04
	JOINT 17			
X	.36570E-02	.13900E-01	.34634E-02	.21531E-02
Y	-.48348E-02	-.18202E-01	-.41501E-02	-.25862E-02
ROT	-.13817E-04	-.53914E-04	-.14860E-04	-.14823E-04
	JOINT 18			
X	.36711E-02	.13949E-01	.34849E-02	.21868E-02
Y	-.48432E-02	-.18262E-01	-.41515E-02	-.25959E-02
ROT	.61835E-05	.25211E-04	.40245E-05	-.24207E-05
	JOINT 19			
X	.36075E-02	.13694E-01	.34323E-02	.21717E-02
Y	-.48466E-02	-.18303E-01	-.41477E-02	-.26005E-02
ROT	.25201E-04	.10028E-03	.22068E-04	.97681E-05
	JOINT 20			
X	.34709E-02	.13153E-01	.33096E-02	.21092E-02
Y	-.48581E-02	-.18379E-01	-.41514E-02	-.26083E-02
ROT	.42824E-04	.16967E-03	.38862E-04	.21403E-04
	JOINT 21			
X	.32690E-02	.12358E-01	.31240E-02	.20029E-02
Y	-.48899E-02	-.18535E-01	-.41740E-02	-.26274E-02
ROT	.58696E-04	.23196E-03	.54047E-04	.32168E-04
	JOINT 22			
X	.30122E-02	.11351E-01	.28851E-02	.18587E-02
Y	-.49514E-02	-.18809E-01	-.42248E-02	-.26644E-02
ROT	.72514E-04	.28601E-03	.67323E-04	.41789E-04
	JOINT 23			
X	.27130E-02	.10182E-01	.26048E-02	.16839E-02
Y	-.50499E-02	-.19229E-01	-.43107E-02	-.27245E-02
ROT	.84034E-04	.33088E-03	.78441E-04	.50036E-04
	JOINT 24			
X	.23852E-02	.89055E-02	.22959E-02	.14873E-02
Y	-.51893E-02	-.19809E-01	-.44358E-02	-.28109E-02
ROT	.93071E-04	.36589E-03	.87215E-04	.56729E-04
	JOINT 25			
X	.20430E-02	.75775E-02	.19722E-02	.12779E-02
Y	-.53706E-02	-.20553E-01	-.46011E-02	-.29248E-02
ROT	.99497E-04	.39059E-03	.93513E-04	.61733E-04
	JOINT 26			
X	.17003E-02	.62529E-02	.16469E-02	.10652E-02
Y	-.55915E-02	-.21450E-01	-.48045E-02	-.30652E-02
ROT	.10325E-03	.40478E-03	.97261E-04	.64961E-04
	JOINT 27			
X	.13702E-02	.49824E-02	.13326E-02	.85810E-03
Y	-.58468E-02	-.22481E-01	-.50413E-02	-.32291E-02
ROT	.10431E-03	.40844E-03	.98443E-04	.66372E-04

TABLE 4-1e CONTINUED

	JOINT 28				
X	.10639E-02	.38102E-02	.10401E-02	.66441E-03	
Y	-.61288E-02	-.23613E-01	-.53042E-02	-.34117E-02	
ROT	.10272E-03	.40179E-03	.97097E-04	.65969E-04	
	JOINT 29				
X	.79085E-03	.27719E-02	.77847E-03	.49071E-03	
Y	-.64275E-02	-.24808E-01	-.55837E-02	-.36065E-02	
ROT	.98595E-04	.38526E-03	.93311E-04	.63799E-04	
	JOINT 30				
X	.55750E-03	.18927E-02	.55406E-03	.34188E-03	
Y	-.67317E-02	-.26020E-01	-.58690E-02	-.38059E-02	
ROT	.92068E-04	.35943E-03	.87223E-04	.59948E-04	
	JOINT 31				
X	.36766E-03	.11867E-02	.37061E-03	.22084E-03	
Y	-.70289E-02	-.27202E-01	-.61485E-02	-.40018E-02	
ROT	.83336E-04	.32509E-03	.79017E-04	.54541E-04	
	JOINT 32				
X	.22215E-03	.65640E-03	.22902E-03	.12854E-03	
Y	-.73066E-02	-.28305E-01	-.64101E-02	-.41856E-02	
ROT	.72633E-04	.28315E-03	.68916E-04	.47733E-04	
	JOINT 33				
X	.11886E-03	.29311E-03	.12739E-03	.63891E-04	
Y	-.75530E-02	-.29281E-01	-.66424E-02	-.43491E-02	
ROT	.60230E-04	.23467E-03	.57179E-04	.39711E-04	
	JOINT 34				
X	.53016E-04	.77551E-04	.61250E-04	.23935E-04	
Y	-.77570E-02	-.30089E-01	-.68350E-02	-.44850E-02	
ROT	.46430E-04	.18083E-03	.44095E-04	.30688E-04	
	JOINT 35				
X	.17482E-04	-.18593E-04	.23872E-04	.40710E-05	
Y	-.79097E-02	-.30693E-01	-.69792E-02	-.45868E-02	
ROT	.31558E-04	.12287E-03	.29980E-04	.20894E-04	
	JOINT 36				
X	.32481E-05	-.30902E-04	.67182E-05	-.16251E-05	
Y	-.80042E-02	-.31067E-01	-.70685E-02	-.46499E-02	
ROT	.15962E-04	.62135E-04	.15166E-04	.10579E-04	
	JOINT 37				
X	.00000E+00	.00000E+00	.00000E+00	.00000E+00	
Y	-.80362E-02	-.31193E-01	-.70987E-02	-.46712E-02	
ROT	.00000E+00	.00000E+00	.00000E+00	.00000E+00	

TABLE 4-1e CONTINUED

SERVICE LOAD FORCES  
 N=THRUST(KIPS/FT), V=SHEAR(KIPS/FT), M=MOMENT(IN.KIPS/FT)

JOINT	DEG FROM VERTICAL	DEAD LOAD			SOIL LOAD		
		N	V	M	N	V	M
1	0.	.19	1.20	26.46	2.86	.00	73.46
2	5.	.29	1.15	21.74	2.90	1.08	71.27
3	10.	.38	1.09	17.25	3.05	2.07	64.88
4	15.	.47	1.02	13.02	3.27	2.86	54.90
5	20.	.54	.94	9.09	3.54	3.38	42.25
6	25.	.61	.86	5.48	3.86	3.58	28.14
7	30.	.67	.77	2.20	4.17	3.40	13.99
8	35.	.71	.68	-.72	4.45	3.03	1.06
9	40.	.75	.59	-3.29	4.70	2.63	-10.30
10	45.	.77	.50	-5.50	4.91	2.21	-20.02
11	50.	.79	.41	-7.34	5.08	1.79	-28.05
12	55.	.79	.32	-8.81	5.22	1.38	-34.41
13	60.	.79	.24	-9.93	5.32	1.00	-39.18
14	65.	.78	.15	-10.71	5.39	.63	-42.45
15	70.	.76	.07	-11.16	5.43	.30	-44.31
16	75.	.73	-.00	-11.30	5.44	-.02	-44.86
17	80.	.69	-.07	-11.15	5.43	-.30	-44.21
18	85.	.65	-.13	-10.73	5.39	-.55	-42.49
19	90.	.60	-.19	-10.07	5.33	-.78	-39.80
20	95.	.55	-.24	-9.21	5.26	-.97	-36.28
21	100.	.49	-.28	-8.16	5.16	-1.13	-32.06
22	105.	.43	-.31	-6.96	5.06	-1.25	-27.27
23	110.	.37	-.34	-5.65	4.95	-1.35	-22.04
24	115.	.31	-.36	-4.25	4.82	-1.41	-16.50
25	120.	.25	-.37	-2.79	4.70	-1.44	-10.78
26	125.	.19	-.37	-1.32	4.57	-1.44	-5.00
27	130.	.13	-.36	.15	4.45	-1.41	.72
28	135.	.08	-.35	1.57	4.33	-1.35	6.26
29	140.	.03	-.33	2.93	4.21	-1.27	11.52
30	145.	-.02	-.30	4.19	4.11	-1.16	16.41
31	150.	-.06	-.27	5.34	4.01	-1.04	20.83
32	155.	-.10	-.23	6.35	3.93	-.89	24.71
33	160.	-.13	-.19	7.20	3.86	-.73	27.98
34	165.	-.16	-.15	7.88	3.80	-.56	30.58
35	170.	-.18	-.10	8.37	3.76	-.38	32.47
36	175.	-.19	-.05	8.67	3.73	-.19	33.62
37	180.	-.19	.00	8.77	3.73	.00	34.00

TABLE 4-1f SERVICE LOAD FORCES

SERVICE LOAD FORCES  
 N=THRUST(KIPS/FT) V=SHEAR(KIPS/FT), M=MOMENT(IN.KIPS/FT)

JOINT	DEG FROM VERTICAL	FLUID LOAD			LIVE LOAD		
		N	V	M	N	V	M
1	0.	-.75	.00	17.13	.18	.00	9.69
2	5.	-.74	.25	16.63	.18	.13	9.44
3	10.	-.70	.48	15.15	.20	.24	8.70
4	15.	-.65	.66	12.85	.22	.33	7.54
5	20.	-.59	.78	9.94	.26	.40	6.05
6	25.	-.52	.82	6.70	.29	.43	4.37
7	30.	-.45	.78	3.45	.33	.42	2.64
8	35.	-.38	.69	.49	.37	.39	1.01
9	40.	-.32	.60	-2.12	.40	.36	-.50
10	45.	-.28	.52	-4.37	.43	.32	-1.87
11	50.	-.23	.43	-6.26	.46	.28	-3.08
12	55.	-.20	.34	-7.79	.48	.24	-4.14
13	60.	-.18	.25	-8.97	.50	.20	-5.03
14	65.	-.16	.17	-9.82	.51	.16	-5.74
15	70.	-.15	.09	-10.34	.52	.11	-6.28
16	75.	-.14	.02	-10.55	.53	.06	-6.63
17	80.	-.14	-.05	-10.47	.54	.02	-6.79
18	85.	-.15	-.12	-10.13	.54	-.03	-6.77
19	90.	-.16	-.17	-9.56	.53	-.08	-6.54
20	95.	-.18	-.22	-8.77	.52	-.12	-6.17
21	100.	-.20	-.26	-7.80	.51	-.16	-5.61
22	105.	-.23	-.29	-6.68	.49	-.19	-4.92
23	110.	-.25	-.32	-5.45	.48	-.21	-4.11
24	115.	-.28	-.34	-4.12	.46	-.23	-3.22
25	120.	-.31	-.35	-2.74	.44	-.24	-2.27
26	125.	-.34	-.35	-1.34	.42	-.25	-1.28
27	130.	-.37	-.35	.06	.39	-.25	-.28
28	135.	-.40	-.33	1.43	.37	-.24	.70
29	140.	-.43	-.31	2.73	.35	-.23	1.65
30	145.	-.46	-.29	3.94	.33	-.21	2.54
31	150.	-.48	-.26	5.04	.31	-.19	3.35
32	155.	-.50	-.22	6.01	.30	-.17	4.06
33	160.	-.52	-.18	6.83	.29	-.14	4.67
34	165.	-.53	-.14	7.48	.28	-.11	5.16
35	170.	-.54	-.10	7.96	.27	-.07	5.51
36	175.	-.55	-.05	8.25	.26	-.04	5.73
37	180.	-.55	.00	8.34	.26	.00	5.80

THRUST (KIP/FT) AT EACH JOINT DUE TO FLUID PRESSURE = .00

TABLE 4-1f CONTINUED

TABLE OF ULTIMATE FORCES

DESIGN LOCATION	MOMENT	THRUST	SHEAR
DEG FROM INVERT	IN.KIPS/FT	KIPS/FT	KIPS/FT
.00	164.776	2.478	.000
14.80	115.991	3.766	6.281
75.00	-95.339	6.561	.110
149.02	43.113	3.817	2.334
180.00	73.994	3.247	.000

TABLE 4-1g ULTIMATE DESIGN FORCES

\*\*\*\*\*REINFORCING DESIGN TABLE\*\*\*\*\*

DESIGN LOCATION DEG FROM INVERT	REINF. DESIG.	DEPTH TO REINF. IN.	FLEXURAL REINFORCING SQ.IN./FT	DESIGN INDICES NOT REINF. AREAS	
				0.01 INCH	RAD. TENS. DIAG.TENS.
.00	ASI	6.84	.384	.746	.624
14.80	ASI	6.84			.103
75.00	ASO	6.84	.171	.000	.000
149.02	ASC	6.84			.000
180.00	ASC	6.84	.148	.000	.257

- NOTES:
1. REINFORCING REQUIRED FOR 0.01 INCH CRACK OR DIAGONAL TENSION IS DETERMINED BY MULTIPLYING THE DESIGN INDICE BY THE FLEXURAL REINFORCEMENT.
  2. STIRRUPS MUST BE USED FOR DIAGONAL TENSION IF THE REINFORCEMENT RATIO IS GREATER THAN 0.02. THIS IS INDICATED BY A "\*" AFTER THE DIAGONAL TENSION INDEX
  3. IF THE RADIAL TENSION INDEX IS GREATER THAN 1, STIRRUPS MUST BE USED.

REINF. DESIG.	DEPTH TO REINF. IN.	GOVERNING DESIGN			
		REQUIRED AREA SQ.IN./FT	REINF. RATIO	STIRRUPS REQUIRED?	GOVERNING MODE
ASI	6.84	.384	.0047	NO	FLEXURE
ASO	6.84	.171	.0021	NO	FLEXURE
ASC	6.84	.148	.0018	NO	FLEXURE

TABLE 4-1h REINFORCING DESIGN TABLE



PIPECAR PIPE CULVERT DESIGN SUMMARY  
 84.0 INCH DIAMETER REINFORCED CONCRETE CIRCULAR PIPE

\*\*\*\*\*

I N S T A L L A T I O N   D A T A

HEIGHT OF FILL ABOVE CROWN, FT,	7.50
SOIL UNIT WEIGHT, PCF	120.00
SOIL-STRUCTURE INTERACTION COEFFICIENT	1.20
LOAD SYSTEM	RADIAL LOAD SYSTEM
LOAD ANGLE, DEGREES	270.
BEDDING ANGLE, DEGREES	60.
PIPE WEIGHT REACTION BED ANGLE, DEGREES.	0.

M A T E R I A L   P R O P E R T I E S

REINFORCING - MINIMUM SPECIFIED YIELD STRENGTH, KSI	65.
REINFORCING TYPE	SMOOTH WELDED WIRE FABRIC
NO. OF LAYERS OF REINFORCING	1
CONCRETE - SPECIFIED COMPRESSIVE STRENGTH, KSI	5.

L O A D I N G   D A T A

DEAD LOAD FACTOR - MOMENT AND SHEAR	1.30
DEAD LOAD FACTOR - THRUST	1.00
LIVE LOAD FACTOR - MOMENT AND SHEAR	2.17
LIVE LOAD FACTOR - THRUST	1.00
INTERNAL PRESSURE FACTOR - THRUST	1.80
STRENGTH REDUCTION FACTOR-FLEXURE	.95
STRENGTH REDUCTION FACTOR-DIAGONAL TENSION	.90
STRENGTH REDUCTION FACTOR-RADIAL TENSION	.90
LIMITING CRACK WIDTH FACTOR	.90
RADIAL TENSION PROCESS FACTOR	1.00
DIAGONAL TENSION PROCESS FACTOR	1.00
LIVE LOAD TYPE	AASHTO HS-20.

P I P E   D A T A

WALL THICKNESS, IN.	8.00
INSIDE CONCRETE COVER OVER REINFORCING, IN.	1.00
OUTSIDE CONCRETE COVER OVER REINFORCING, IN.	1.00

F L U I D   D A T A

FLUID DENSITY, PCF.	62.40
DEPTH OF FLUID, INCHES ABOVE INVERT	84.00
PRESSURE HEAD, FT	.00

TABLE 4-1i SUMMARY TABLE FOR DESIGN

R E I N F O R C I N G    D A T A

REINFORCING CAGE TYPE	DOUBLE CIRCULAR
INVERT- INSIDE REINFORCING, SQ.IN./FT.	.384
SPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.	.171
CROWN- INSIDE REINFORCING, SQ.IN./FT.	.148

>>> IF THIS PIPE IS MANUFACTURED WITH ANY REINFORCING SCHEME OTHER THAN A SINGLE OR DOUBLE CIRCULAR CAGE, THE MANUFACTURER MUST CLEARLY MARK THE PIPE TO INDICATE THE PROPER ORIENTATION IN THE GROUND. REINFORCING DESIGNS SHOULD ALLOW FOR SOME TOLERANCE IN LOCATION OF PIPE INVERT IN THE FIELD INSTALLATION.

TABLE 4-1i CONTINUED

## 5. DESIGN EXAMPLES

### 5.1 Example Problem #1

This example problem demonstrates how to obtain a design with the minimum amount of input. Before trying this example problem, be sure that you have the hardware and software requirements described in Section 2.4 of this manual, and the program is installed using the procedures listed in Section 3.1 of this manual. This example demonstrates the design of a circular pipe with a 72 inch inner diameter and a 7 inch wall thickness as shown in Figure 5-1. The pipe is supported on a 60 degree bedding, and is buried in 10 feet of earth fill. The remaining design parameters are the program default parameters listed in Appendix A. The design will use the radial load system discussed in Section 2.2.2 of this manual. To obtain a printed design of this problem, perform the following steps:

- 1) To begin execution of PIPECAR, type:

PIPECAR [Enter]

- 2) The introductory screen will appear. Press any key and the user warning will appear. Read this carefully as it states your responsibility while using the program. Again press any key and the main menu of the program will appear as shown in Table 5-1a. To create a new pipe culvert input file for this example problem, press "1".

- 3) Screen 1 now appears. Enter a filename that the input will be stored under on the computer disk. If you call the file EXAMPLE 1, then type:

EXAMPLE1

Because you completely filled the highlighted field the cursor automatically moves to the next input item. If you select a filename of less than eight characters you will need to press [Enter].

- 4) Enter a brief description of the design problem for future identification. The following description, in this case, is:

Example 1: 72 in. Diameter Pipe with 10 ft of Fill [Enter]

- 5) Enter the Pipe Shape (Circular by default) by pressing the [Enter] key. Before pressing [Enter], your computer screen should appear identical to that shown in Table 5-1b.

- 6) After Screen 2C appears, enter the Pipe Diameter, Wall Thickness, and Load System by typing:

72.0 [Enter]  
7.0 [Enter]  
R

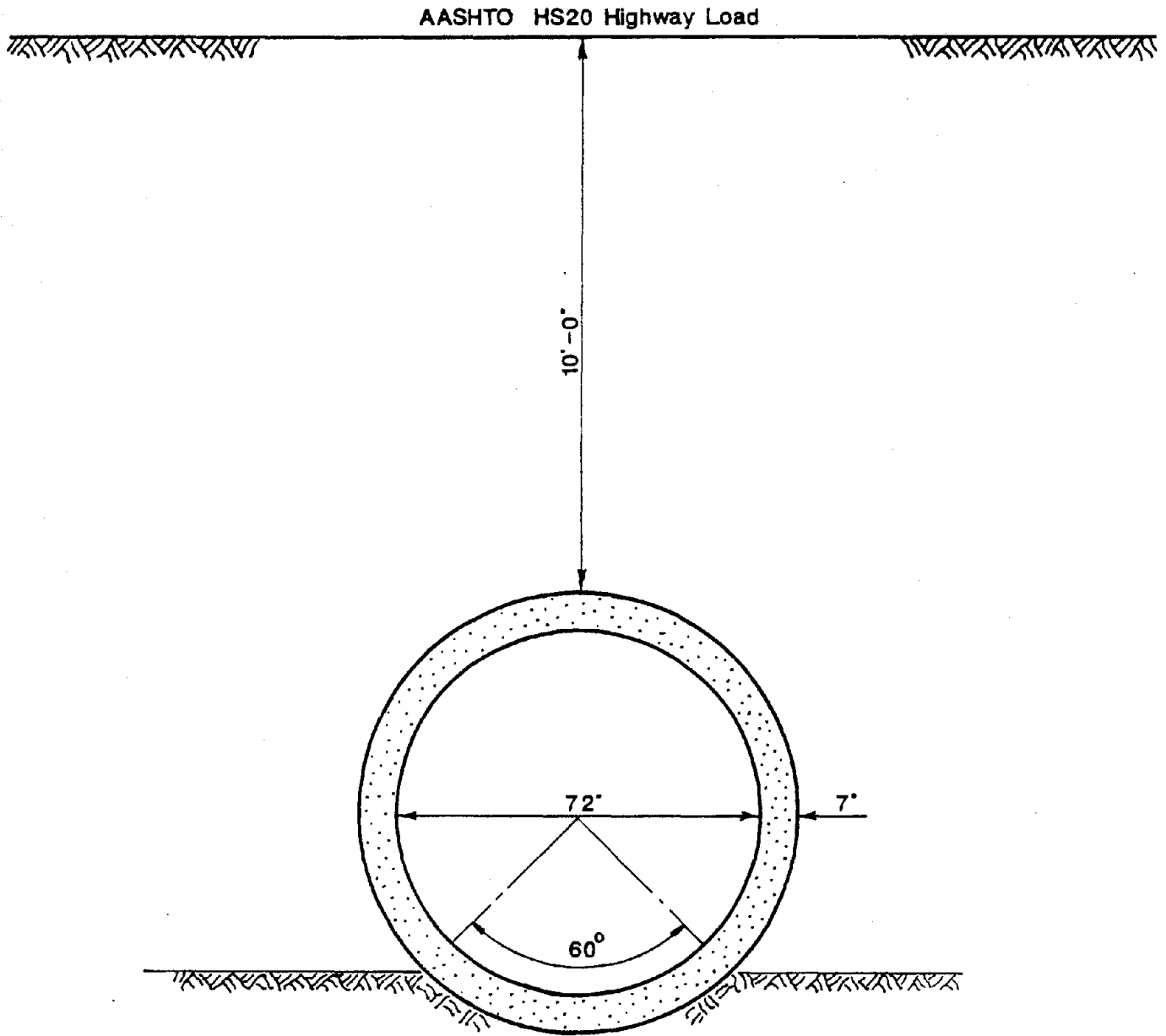
Before pressing "R", your computer screen should appear identical to that shown in Table 5-1c. When you press "R" the program will move to the next screen.

- 7) When Screen 3R appears, enter the Depth of Fill by typing:

10.0 [Enter]

Your computer screen should appear identical to that shown in Figure 5-1d. At this point, you have entered the minimum amount of data required for the program to execute. Complete your editing by pressing the [F1] key. The screen shown on Table 5-1e will appear. To save and execute the file press 2 .

- 8) Once execution is complete, the program will print the required reinforcing areas to the screen and ask if you wish to save the output. This screen is shown in Table 5-1f.
- 9) Type "P" [Enter] to save and print your output. The Print Option screen (Table 5-1g) will appear. Type "1" [Enter] to obtain minimum output. The program should now write the data to disk and go to the post processor to prepare the file for printing. After post processing, type "1".
- 10) Table 5-1h shows the output you should get for Example 1. See Section 4 of this manual for a description of the output tables. After the output report is printed, the main menu will appear again. Exit the program and return to the operating system by pressing "8", or go on to Example Problem 2.



**FIGURE 5-1 EXAMPLE PROBLEM 1**

PROGRAM: PIPECAR

MAIN MENU

- |                 |  |
|-----------------|--|
| Input Options   | 1. Create a new direct design input file     |
|                 | 2. Retrieve a direct design input file       |
| Execute Options | 3. Execute PIPECAR/Direct Design             |
|                 | 4. Execute PIPECAR/Three Edge Bearing Design |
| Print Options   | 5. Print a direct design input file          |
|                 | 6. Print a direct design output file         |
| System Options  | 7. Reconfigure default parameters            |
|                 | 8. Exit                                      |

Selection 1

TABLE 5-1a MAIN MENU

PROGRAM: PIPECAR

Filename EXAMPLE1.PIP  
Job Description Example 1: 72 in. Diameter Pipe with 10 ft of fill

Pipe Shape C (C/E) Circular  
Elliptical

SCREEN 1

<F1> = FINISHED EDITING → RETURN TO MAIN MENU  
<PgDn> View Next Screen

<F2> = HELP

TABLE 5-1b SCREEN 1

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE1  
PROJECT: Example 1: 72 in. Diameter Pipe with 10 ft of fill

GEOMETRY AND INSTALLATION CONDITIONS - CIRCULAR PIPE

Pipe Inner Diameter 72 in.  
Pipe Wall Thickness 7.0 in.  
Load System (R/U/M) U Radial  
Uniform  
Uniform/Manual

SCREEN 2C

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Next Screen

TABLE 5-1c SCREEN 2

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE1  
PROJECT: Example 1: 72 in. Diameter Pipe with 10 ft of fill

INSTALLATION CONDITIONS - Radial Load System

Depth of Fill 10.0 ft  
Soil Structure Interaction Coefficient 1.200  
Load Angle 270.00 deg  
Bedding Angle 60.000 deg  
Bedding Angle for Pipe Weight Reaction 0.000 deg

You have now entered the minimum input requirements. At this point you may save the file using <F1> and all other parameters will default.

SCREEN 3R

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Next Screen

TABLE 5-1d SCREEN 3

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE1  
PROJECT: Example 1: 72 in. Diameter Pipe with 10 ft of fill

Editing Options

1. Save and return to main menu.
2. Save and execute.
3. Return to main menu without saving data.

Enter selection.....

TABLE 5-1e SAVE SCREEN

PIPECAR PIPE CULVERT DESIGN SUMMARY  
72.0 INCH DIAMETER REINFORCED CONCRETE CIRCULAR PIPE  
\*\*\*\*\*

REINFORCING DATA

REINFORCING CAGE TYPE	DOUBLE CIRCULAR
INVERT- INSIDE REINFORCING, SQ.IN./FT.	.368
SPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.	.161
CROWN- INSIDE REINFORCING, SQ.IN./FT.	.137

DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

- D = WRITE TO DISK AND RETURN TO MAIN MENU.
- P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.
- N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

Make Selection....Then Press Enter

TABLE 5-1f REINFORCING SCREEN



**OUTPUT SELECTIONS**

1. Print Input and Design Summary
2. Print Above + Total Loads, Ultimate Forces Design Tables
3. Print Above + Applied Pressures and Service Load Forces
4. Print Above + Computer Model Geometry and Displacements

Make Selection....Then Press Enter

**TABLE 5-1g OUTPUT OPTIONS SCREEN**

P I P E C A R

A Microcomputer Program for the Analysis and  
Design of Circular and Horizontal Elliptical  
Reinforced Concrete Pipe Culverts

VERSION 1.0 - NOVEMBER 1988

Developed by

Simpson Gumpertz & Heger Inc.  
Arlington Massachusetts  
in cooperation with

The Federal Highway Administration  
and  
The American Concrete Pipe Association

The application of this non-proprietary software product is the responsibility of the user. The user must select input values suitable to his specific installation. Use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application, and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or other agents.

DATE: 01-12-1989  
TIME: 12:30:42

TABLE 5-1h OUTPUT FOR EXAMPLE PROBLEM 1

Filename	EXAMPLE1.OUT
Job Description	Example 1: 72 in. Diameter r Pipe with 10 ft of fill

GEOMETRY: CIRCULAR PIPE ANALYSIS AND DESIGN

Pipe Inside Diameter	72 in.
Pipe Wall Thickness	7 in.

INSTALLATION CONDITIONS - Radial Load System

Depth of fill	10 ft
Soil-Structure Interaction Coefficient	1.2
Load Angle	270 deg
Bedding Angle for Soil, Water and Live Load	60 deg
Bedding Angle for Pipe Weight Reaction	0 deg

MATERIAL PROPERTIES

Steel Reinforcing Yield Stress	65 ksi		
Reinforcing Type	2	No. of Layers	1
Design Concrete Strength	5 ksi		
Concrete Density	150 pcf		

TABLE 5-1h CONTINUED

LOAD FACTORS

Dead Load Factor (Shear and Moment)	1.3
Dead Load Factor (Thrust)	1
Live Load Factor (Shear and Moment)	2.17
Live Load Factor (Thrust)	1
Internal Pressure Factor (Thrust)	1.8

PHI FACTORS

Flexure	.95
Radial Tension	.9
Diagonal Tension	.9

PROCESS FACTORS

Limiting Crack Width Factor	.9
Radial Tension Process Factor	1
Shear Process Factor	1

TABLE 5-1h CONTINUED

SOIL LOAD DATA

Soil Density 120 pcf

FLUID LOAD DATA

Depth of Fluid 72 in  
 Fluid Density 62.4 pcf  
 Pressure Head 0 ft

LIVE LOAD DATA

Live Load HS- 20

CAGE REINFORCING TYPE

DOUBLE CIRCULAR

CONCRETE COVERS

Inside Face 1 in.  
 Outside Face 1 in.

REINFORCING DIAMETERS

Inside Circular Reinforcing Diameter, Asi .56 in.  
 Outside Circular Reinforcing Diameter, Aso .56 in.

MAXIMUM REINFORCING SPACING

Inside Reinforcing Spacing, Asi 4 in.  
 Outside Reinforcing Spacing, Aso 4 in.

TABLE 5-1h CONTINUED

PIPECAR PIPE CULVERT DESIGN SUMMARY  
72.0 INCH DIAMETER REINFORCED CONCRETE CIRCULAR PIPE

\*\*\*\*\*

I N S T A L L A T I O N   D A T A

-----	
HEIGHT OF FILL ABOVE CROWN, FT,	10.00
SOIL UNIT WEIGHT, PCF	120.00
SOIL-STRUCTURE INTERACTION COEFFICIENT	1.20
LOAD SYSTEM	RADIAL LOAD SYSTEM
LOAD ANGLE, DEGREES	270.
BEDDING ANGLE, DEGREES	60.
PIPE WEIGHT REACTION BED ANGLE, DEGREES.	0.

M A T E R I A L   P R O P E R T I E S

-----	
REINFORCING - MINIMUM SPECIFIED YIELD STRENGTH, KSI	65.
REINFORCING TYPE	SMOOTH WELDED WIRE FABRIC
NO. OF LAYERS OF REINFORCING	1
CONCRETE - SPECIFIED COMPRESSIVE STRENGTH, KSI	5.

L O A D I N G   D A T A

-----	
DEAD LOAD FACTOR - MOMENT AND SHEAR	1.30
DEAD LOAD FACTOR - THRUST	1.00
LIVE LOAD FACTOR - MOMENT AND SHEAR	2.17
LIVE LOAD FACTOR - THRUST	1.00
INTERNAL PRESSURE FACTOR - THRUST	1.80
STRENGTH REDUCTION FACTOR-FLEXURE	.95
STRENGTH REDUCTION FACTOR-DIAGONAL TENSION	.90
STRENGTH REDUCTION FACTOR-RADIAL TENSION	.90
LIMITING CRACK WIDTH FACTOR	.90
RADIAL TENSION PROCESS FACTOR	1.00
DIAGONAL TENSION PROCESS FACTOR	1.00
LIVE LOAD TYPE	AASHTO HS-20.

P I P E   D A T A

-----	
WALL THICKNESS, IN.	7.00
INSIDE CONCRETE COVER OVER REINFORCING, IN.	1.00
OUTSIDE CONCRETE COVER OVER REINFORCING, IN.	1.00

F L U I D   D A T A

-----	
FLUID DENSITY, PCF.	62.40
DEPTH OF FLUID, INCHES ABOVE INVERT	72.00
PRESSURE HEAD, FT	.00

TABLE 5-1h CONTINUED

R E I N F O R C I N G   D A T A

REINFORCING CAGE TYPE	DOUBLE CIRCULAR
INVERT- INSIDE REINFORCING, SQ.IN./FT.	.368
SPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.	.161
CROWN- INSIDE REINFORCING, SQ.IN./FT.	.137

>>> IF THIS PIPE IS MANUFACTURED WITH ANY REINFORCING SCHEME OTHER THAN A SINGLE OR DOUBLE CIRCULAR CAGE, THE MANUFACTURER MUST CLEARLY MARK THE PIPE TO INDICATE THE PROPER ORIENTATION IN THE GROUND. REINFORCING DESIGNS SHOULD ALLOW FOR SOME TOLERANCE IN LOCATION OF PIPE INVERT IN THE FIELD INSTALLATION.

TABLE 5-1h CONTINUED

## 5.2 Example Problem #2

This example problem demonstrates the use of additional input screens for designing a culvert. In this example, a pipe having a diameter of 48 in. and a wall thickness of 5 in. is to be buried in 2 ft-6 in. of earth fill and is to be designed for an interstate truck loading as shown in Figure 5-2. The pipe will be supported on a 60 degree bedding and the radial load system will be used for analysis. The cover over the outside reinforcing is 1-1/2 in. and the capacity reduction factors for flexure, radial tension and diagonal tension are 0.9, 0.85, and 0.85 respectively.

- 1) Begin at the Main Menu (see Example 1 if you are not at the Main Menu). To create a new pipe culvert input file for this example problem, press "1".
- 2) Screen 1 now appears. Enter a filename that the input will be stored under on the computer disk. If you call the file "EXAMPLE2", type:

EXAMPLE2

- 3) Enter a brief description of the design problem by typing:

Example 2: 48in. Diameter Pipe with 2.5 ft of Fill [Enter]

- 4) Enter the Pipe Shape (Circular by default) by pressing the [Enter] key. Before pressing the [Enter] key, the screen displayed should be identical to that shown in Table 5-2a.

- 5) On Screen 2C enter the Pipe Diameter, Wall Thickness, and Load System:

48.0 [Enter]  
5.0 [Enter]  
R

When you press "R" the program will automatically go to Screen 3. Before pressing "R", it should appear identical to that shown in Figure 5-2b.

- 6) After Screen 3R appears enter the Depth of Fill by typing:

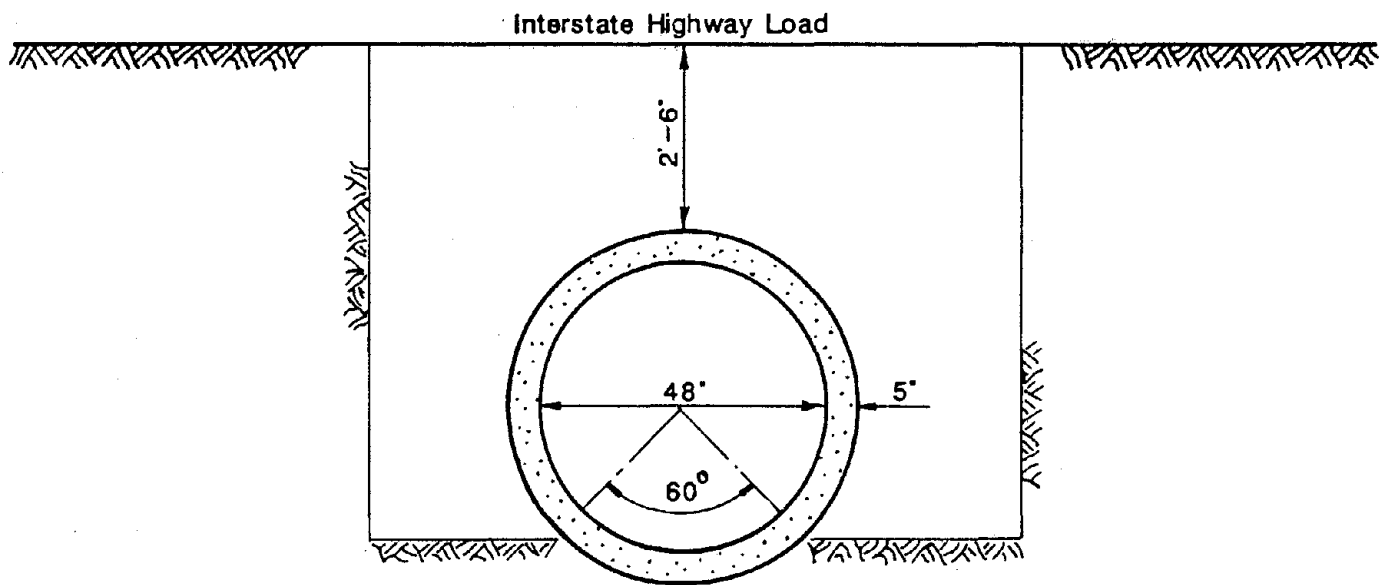
2.5 [Enter]

Screen 3R should appear identical to Table 5-2c. Press the [PgDn] key to move to the next input screen. For each of the subsequent input screens that appear, enter the data where prompted as shown in Figures 5-2d through 5-2h.

- 7) At the end of Screen 7-1, press the [F1] key to get the save option screen (see Table 5-1c). Press "2" to save and execute.

- 8) When program execution is complete the reinforcing requirements will be printed to the screen, which should appear as shown in Table 5-2i. Do not save the output from this example. Press "N" [Enter] to return to the Main Menu.





**FIGURE 5-2 EXAMPLE PROBLEM 2**



PROGRAM: PIPECAR CURRENT FILE: EXAMPLE2  
PROJECT: Example 2: 48 in. Diameter Pipe with 2.5 ft of fil

INSTALLATION CONDITIONS - Radial Load System

Depth of Fill	2.5	ft
Soil Structure Interaction Coefficient	1.200	
Load Angle	270.00	deg
Bedding Angle	60.000	deg
Bedding Angle for Pipe Weight Reaction	0.000	deg

You have now entered the minimum input requirements. At this point you may save the file using <F1> and all other parameters will default.

SCREEN 3R

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
<PgUp> View Previous Screen      <PgDn> View Next Screen

TABLE 5-2c SCREEN 3

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE2  
PROJECT: Example 2: 48 in. Diameter Pipe with 2.5 ft of fil

MATERIAL PROPERTIES

Steel Reinforcing Yield Strength	65	ksi
Reinforcing Type 2      No. of Layers	1	
Design Concrete Strength	5.000	ksi
Concrete Density	150.000	pcf

LOAD FACTORS

Dead Load Factor (Shear and Moment)	1.30
Dead Load Factor (Thrust)	1.00
Live Load Factor (Shear and Moment)	2.17
Live Load Factor (Thrust)	1.00
Internal Pressure Factor (Thrust)	1.80

SCREEN 4

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
<PgUp> View Previous Screen      <PgDn> View Next Screen

TABLE 5-2d SCREEN 4

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE2  
PROJECT: Example 2: 48 in. Diameter Pipe with 2.5 ft of fil

PHI FACTORS

Flexure	0.95
Radial Tension	0.90
Diagonal Tension	0.90

PROCESS FACTORS

Limiting Crack Width Factor	0.900
Radial Tension Process Factor	1.000
Shear Process Factor	1.000

SCREEN 5

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Next Screen

TABLE 5-2e SCREEN 5

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE2  
PROJECT: Example 2: 48 in. Diameter Pipe with 2.5 ft of fil

SOIL LOAD DATA

Soil Density	120.00	pcf
--------------	--------	-----

FLUID LOAD DATA

Depth of Fluid	48	in.
Fluid Density	62.400	pcf
Pressure Head ( for circular pipe only )	0	ft.

LIVE LOAD DATA

Live Load	H (H/T/C/O/N)	HS-SERIES INTERSTATE COOPER E-SERIES OTHER NONE
-----------	---------------	---

SCREEN 6

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Next Screen

TABLE 5-2f SCREEN 6

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE2  
PROJECT: Example 2: 48 in. Diameter Pipe with 2.5 ft of fil

REINFORCING CAGE TYPE:

- 1) DOUBLE CIRCULAR
- 2) SINGLE CIRCULAR
- 3) SINGLE ELLIPTICAL
- 4) DOUBLE CIRCULAR + MATS
- 5) SINGLE CIRCULAR + ELLIPTICAL
- 6) DOUBLE CIRCULAR + ELLIPTICAL

SCREEN 7

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Next Screen

TABLE 5-2g SCREEN 7

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE2  
PROJECT: Example 2: 48 in. Diameter Pipe with 2.5 ft of fil

REINFORCING CAGE TYPE: DOUBLE CIRCULAR

CONCRETE COVERS

Inside Face	1.000 in.
Outside Face	1.000 in.

REINFORCING DIAMETERS

Inside Reinforcing Diameter, Asi	.4 in.
Outside Reinforcing Diameter, Aso	.4 in.

MAXIMUM REINFORCING SPACING

Inside Reinforcing Spacing, Asi	4.000 in.
Outside Reinforcing Spacing, Aso	4.000 in.

SCREEN 7-1

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Screen 1

TABLE 5-2h SCREEN 7-1

PIPECAR PIPE CULVERT DESIGN SUMMARY  
48.0 INCH DIAMETER REINFORCED CONCRETE CIRCULAR PIPE

\*\*\*\*\*

R E I N F O R C I N G   D A T A

---

REINFORCING CAGE TYPE	DOUBLE CIRCULAR
INVERT- INSIDE REINFORCING, SQ.IN./FT.	.180
SPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.	.089
CROWN- INSIDE REINFORCING, SQ.IN./FT.	.082

DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

- D = WRITE TO DISK AND RETURN TO MAIN MENU.
- P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.
- N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

Make Selection....Then Press Enter

TABLE 5-2i REINFORCING TABLE

### 5.3 Example Problem #3

This example problem demonstrates how to make changes to the input of Example Problem 2 and save the modified file under a new file name. Before typing this example problem, you must first have the input file of Example Problem 2 stored on your computer disk. In this example, the depth of burial for the pipe shown in Figure 5-3 is 4 ft and the pipe will have a user-specified live load of 5 kips over an area of 30 x 12 in. at the top of the pipe.

- 1) Begin at the Main Menu (see Example 1 if you are not at the Main Menu). Press "2" to retrieve the previous file from your computer disk.
- 2) A list of the available input files that are stored on your computer disk are displayed on your screen as shown in Table 5-3a. When prompted, enter the name of the file you wish to modify omitting the .PIP filename extension by typing:

EXAMPLE2

- 3) Screen 1 appears with the data you saved for Example 2. Change the file name by typing:

EXAMPLE3

- 4) Give the input a new description by typing:

Example 3: 48 in. Diameter Pipe with 4 ft of Fill [Enter]

Screen 1 should appear as shown in Table 5-3b.

- 5) Use the [PgDn] key to move to Screen 3. Enter the new Depth of Fill by typing:

4.0 [Enter]

Screen 3 should appear as shown in Table 5-3c.

- 6) Use the [PgDn] key to move to Screen 6. Use the arrow key or press the [Enter] key to position the cursor at the Live Load input location. Now enter the user specified option by typing a capital "O"

O

- 7) Enter the magnitude and distribution length and width by typing:

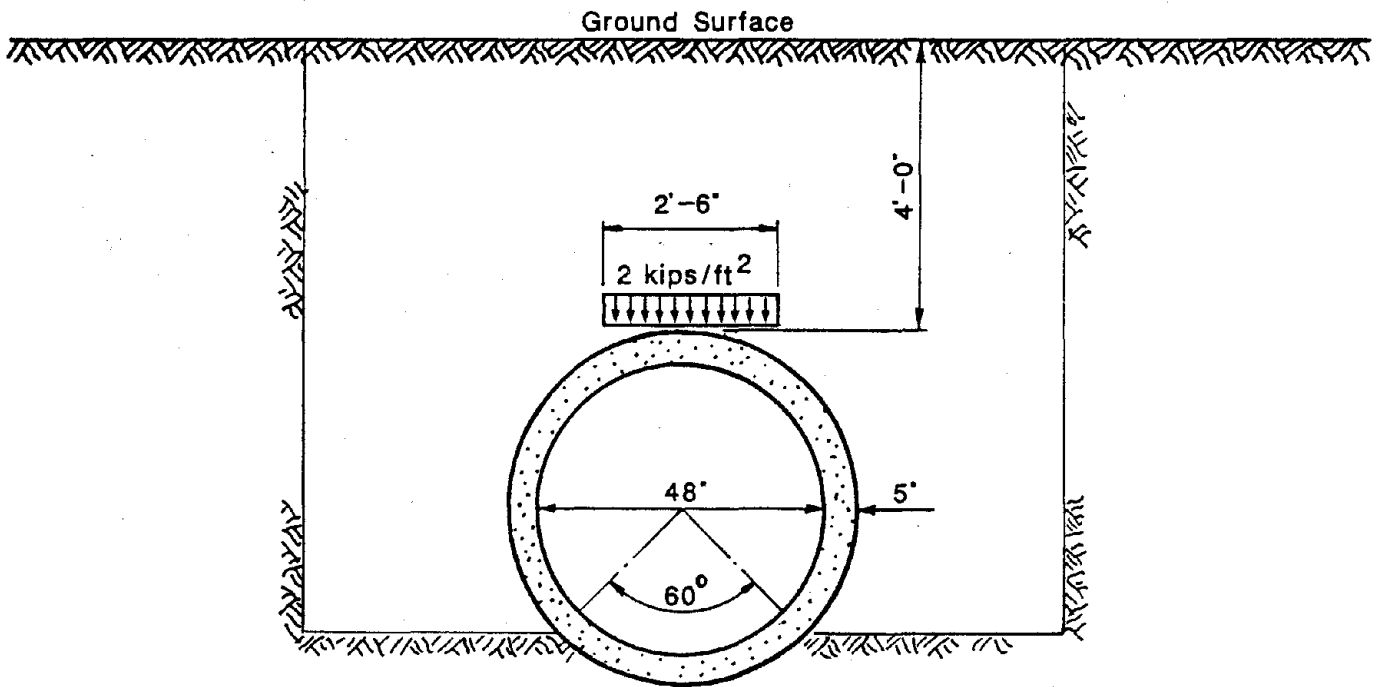
5.0 [Enter]

30.0 [Enter]

12.0 [Enter]

Screens 6 and 60 should appear as shown in Tables 5-3d and 5-3e respectively.

- 8) When program execution is complete the reinforcing requirements will be printed to the screen, which should appear as shown in Table 5-3f. Do not save the output from this example. Press "N" to return to the Main Menu.



**FIGURE 5-3 EXAMPLE PROBLEM 3**



PROGRAM: PIPECAR

The following are the available data files:

Volume in drive E has no label  
Directory of E:\PIPECAR

EXAMPLE1 PIP      EXAMPLE2 PIP  
2 File(s)      323584 bytes free

Retrieve file      .PIP

<Enter> To Return to Main Menu

### TABLE 5-3a RETRIEVE SCREEN

PROGRAM: PIPECAR

Filename            EXAMPLE3.PIP  
Job Description Example 3: 48 in. Diameter Pipe with 4 ft of fill

Pipe Shape          C (C/E)    Circular  
   Elliptical

SCREEN 1

<F1> = FINISHED EDITING → RETURN TO MAIN MENU  
<PgDn> View Next Screen

<F2> = HELP

### TABLE 5-3b SCREEN 1

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE3  
 PROJECT: Example 3: 48 in. Diameter Pipe with 4 ft of fill

INSTALLATION CONDITIONS - Radial Load System

Depth of Fill	4.0	ft
Soil Structure Interaction Coefficient	1.2	
Load Angle	270	deg
Bedding Angle	60	deg
Bedding Angle for Pipe Weight Reaction	0	deg

SCREEN 3R

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen      <PgDn> View Next Screen

TABLE 5-3c SCREEN 3

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE3  
 PROJECT: Example 3: 48 in. Diameter Pipe with 4 ft of fill

SOIL LOAD DATA

Soil Density	120	pcf
--------------	-----	-----

FLUID LOAD DATA

Depth of Fluid	48	in.
Fluid Density	62.4	pcf
Pressure Head ( for circular pipe only )	0	ft.

LIVE LOAD DATA

Live Load	0 (H/T/C/O/N)	HS-SERIES INTERSTATE COOPER E-SERIES OTHER NONE
-----------	---------------	---

SCREEN 6

<F1> = FINISHED EDITING → RETURN TO MAIN MENU      <F2> = HELP  
 <PgUp> View Previous Screen      <PgDn> View Next Screen

TABLE 5-3d SCREEN 6

PROGRAM: PIPECAR CURRENT FILE: EXAMPLE3  
PROJECT: Example 3: 48 in. Diameter Pipe with 4 ft of fill

LIVE LOAD DATA

You have chosen a wheel load OTHER than the standard AASHTO load conditions given.

Enter the magnitude of the live load 5.0 kips

Distribution length along pipe diameter 30.0 in.  
Distribution length along pipe axis 12 in.

This load will be modelled as a single wheel load distributed over the indicated area on top of the pipe. No increase in load will be made for impact.

SCREEN 60

<F1> = FINISHED EDITING → RETURN TO MAIN MENU <F2> = HELP  
<PgUp> View Previous Screen <PgDn> View Next Screen

TABLE 5-3e SCREEN 60

REINFORCING DATA

REINFORCING CAGE TYPE	DOUBLE CIRCULAR
INVERT- INSIDE REINFORCING, SQ.IN./FT.	.415
SPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.	.237
CROWN- INSIDE REINFORCING, SQ.IN./FT.	.279

\*\*\* STIRRUP REINFORCING IS REQUIRED \*\*\*

ALTERNATE REINFORCING WITHOUT STIRRUPS

INVERT- INSIDE REINFORCING, SQ.IN./FT.	.476
SPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.	.237
CROWN- INSIDE REINFORCING, SQ.IN./FT.	.279

DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)

D = WRITE TO DISK AND RETURN TO MAIN MENU.  
P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.  
N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.

Make Selection....Then Press Enter

TABLE 5-3f REINFORCING SCREEN

## 5.4 Example Problem #4

This example problem demonstrates how to obtain an indirect (three-edge bearing) design for a pipe culvert. For this example, a three-edge bearing design is required for a 120 in. diameter pipe having an 11 in. wall thickness. The required D-loads are  $DL_{0.01} = 1000$  lb/ft/ft and  $DL_{ult} = 1500$  lb/ft/ft. All other parameters are the default parameters of the program. To obtain a printed design containing the three-edge bearing reinforcing design, perform the following:

- 1) Begin at the Main Menu (see Example 1 if you are not at the Main Menu). Press "4" to access the three-edge bearing design module.
- 2) An introductory screen will appear, to remind you that the indirect design module is independent of the rest of PIPECAR and that no information is written to disk (Table 5-4a). At the bottom of this screen you may enter a project description:

Example 4: Three Edge Bearing [Enter]

- 3) The input parameters and their default values appear on your screen. Press the [F1] key to enter the pipe geometry. Enter pipe geometry and concrete covers by typing:

```

    [Enter] (Accepts default of circular pipe)
120.0 [Enter]
  11.0 [Enter]
    [Enter] (Accepts default inside cover of 1 in.)
    [Enter] (Accepts default outside cover of 1 in.)
```

- 4) The computer screen should now appear as shown in Table 5-4b. All other parameters will default to those values shown on the screen. To perform a design, press the [F10] key. You are asked if you want to (1) obtain allowable D-Loads for a given reinforcing or (2) determine the required reinforcing for a given D-Load. Press "2".
- 5) Enter the D-Loads for the 0.01 in. crack and ultimate load condition by typing:

```

    1000 [Enter]
    1500 [Enter]
```

The program now determines the required reinforcing and displays the results on the computer screen as shown in Figure 5-4c.

- 6) If you desire a hardcopy of the design press "Y". The output should look like Table 5-1d.
- 7) You are now asked if you wish to save the input you have just entered. Press "N". If "Y" is pressed, all the input parameters you have entered are saved in memory, not on a disk file. Now press the [F4] key to return to the main menu of PIPECAR and press "8" to return to your computer operating system.

PIPECAR INDIRECT DESIGN PROGRAM

Design and analysis of reinforced concrete pipe for the three edge bearing load condition. This is a completely independent module of PIPECAR that requires its own input and does not write any files to disk.

Enter Project Description

TABLE 5-4a INDIRECT DESIGN INTRODUCTORY SCREEN

-----PIPECAR - THREE EDGE BEARING PROGRAM --- DESIGN PARAMETERS-----

PIPE GEOMETRY <F1>:		DESIGN COEFFICIENTS <F3>:	
Pipe shape	= CIRCULAR		
Inner diameter or span (in.)	= 120	PhiF = .95	Cs = .6
Wall thickness (in.)	= 11	PhiC = .95	(Aso/Asi)
Inside reinforcing cover (in.)	= 1	PhiD = .9	
Outside reinforcing cover (in.)	= 1	PhiR = .9	Cx = 1

MATERIAL PROPERTIES <F2>:

Reinforcing type	= 2
Reinforcing yield stress (psi)	= 65000
Reinf. ultimate stress (psi)	= 75000
Design criteria (YIELD/ULTIMATE)	= ULTIMATE
Concrete strength, f'c (psi)	= 5000
No. of reinforcing layers	= 1
Circum. reinf. spacing (in.)	= 4

WAITING FOR SOFT KEY INPUT

<F1>PIPE GEOM <F2>MAT PROP <F3>DES COEF <F4> MAIN MENU <F5>HELP <F10>CONT

TABLE 5-4b INPUT SCREEN

REINFORCING DESIGN CRITERIA

```

-----
FLEXURE STEEL AREA (ULTIMATE) - (SQ.IN./FT)----- 0.520
0.01 INCH CRACK STEEL AREA - (SQ.IN./FT)----- 0.697

DIAGONAL TENSION STEEL AREA - (SQ.IN./FT)----- 0.606
MAXIMUM RADIAL TENSION D-LOAD - (LBS/FT/FT)----- 2031
    
```

GOVERNING REINFORCING DESIGN

```

-----
INNER REINFORCING AREA - (SQ.IN./FT)----- 0.697
OUTER REINFORCING AREA - (SQ.IN./FT)----- 0.418
NO STIRRUPS REQUIRED
DO YOU WANT A PRINTED COPY OF THE RESULTS? (Y/N)
    
```

TABLE 5-4c REINFORCING SCREEN

PIPECAR - 3EB - Example 4: Three Edge Bearing

PAGE 1

PIPECAR  
 3 - EDGE BEARING DESIGN AND ANALYSIS PROGRAM  
 VERSION 1.0 - 1 NOVEMBER 1988

Developed by

Simpson Gumpertz & Heger Inc.  
 Arlington, Massachusetts

in Cooperation with

The Federal Highway Administration  
 and  
 The American Concrete Pipe Association

The application of this nonproprietary software is the responsibility of the user. The user must select input values suitable to his specific installation. Use of default parameters does not assure a safe design for all installations. The information presented in the computer output is for review, interpretation, application, and approval by a qualified engineer who must assume full responsibility for verifying that said output is appropriate and correct. There are no express or implied warranties. Use of this product does not constitute endorsement by FHWA or any other agents.

DATE: 01-12-1989  
 TIME: 14:23:39

TABLE 5-4d OUTPUT FOR EXAMPLE PROBLEM 4

PIPECAR - THREE EDGE BEARING - REINFORCING DESIGN  
120 INCH SPAN CIRCULAR PIPE

\*\*\*\*\*  
S P E C I F I E D D - L O A D S

DL.01 = 1000 LBS/FT/FT                      DLult = 1500 LBS/FT/FT

C A P A C I T Y R E D U C T I O N F A C T O R S

PhiF = 0.95      PhiC = 0.95      PhiD = 0.90      PhiR = 0.90

D E S I G N C O E F F I C I E N T S

Cm = 1.00      Cmo = 1.00      Cs = 0.60      Cx = 1.00      Cmp = 1.06

P I P E S P E C I F I C A T I O N S

WALL THICKNESS (IN.)-----	11.00
INSIDE REINFORCING COVER (IN.)-----	1.00
OUTSIDE REINFORCING COVER (IN.)-----	1.00
NO. OF REINFORCING LAYERS-----	1
PIPE WEIGHT (LBS/FT)-----	4755
CONCRETE STRENGTH (PSI)-----	5000
REINFORCING YIELD STRENGTH (PSI)-----	65000
REINFORCING ULTIMATE STRENGTH (PSI)-----	75000
DESIGN CRITERIA-----	ULTIMATE
SPACING OF CIRCUMFERENTIAL REINF. (IN.)-----	4
TYPE 2 REINFORCEMENT	
WELDED SMOOTH WIRE FABRIC, 8 INCH MAX. SPACING OF LONGITUDINALS	

R E I N F O R C I N G D E S I G N C R I T E R I A

FLEXURE STEEL AREA (ULTIMATE) - (SQ.IN./FT)-----	0.520
0.01 INCH CRACK STEEL AREA - (SQ.IN./FT)-----	0.697
DIAGONAL TENSION STEEL AREA - (SQ.IN./FT)-----	0.606
MAXIMUM RADIAL TENSION D-LOAD - (LBS/FT/FT)-----	2031

G O V E R N I N G R E I N F O R C I N G D E S I G N

INNER REINFORCING AREA - (SQ.IN./FT)-----	0.697
OUTER REINFORCING AREA - (SQ.IN./FT)-----	0.418
NO STIRRUPS REQUIRED	

TABLE 5-4d CONTINUED





## **PART III - PROGRAMMER MANUAL**

### **6. PROGRAM STRUCTURE**

This section presents a brief description of the subroutines that make up the computer program PIPECAR and listings of each technical subroutine. This information is not necessary to use PIPECAR but provides additional background for those interested in learning more about the internal operation of PIPECAR.

#### **6.1 Programming Languages - Hardware & Software**

PIPECAR will operate on an IBM PC, XT, AT or a similar IBM compatible computer. All subroutines are compiled, and the user need only boot the computer and have DOS active in order to use the program. Specific hardware requirements are:

- An operating system equivalent to PC DOS Version 2.0 or higher.
- An 8087 or 80287 math coprocessor.
- A minimum of 640 K bytes of memory.
- Two double density disk drives or a single double density disk drive and a hard disk drive.

PIPECAR includes subroutines that process the output for printing on 8.5 in. by 11 in. paper. It also includes the commands to send it to a printer. Some users will find it useful to exit PIPECAR and use a text editor (not included with PIPECAR) to view files before printing.

PIPECAR is written in two programming languages. Most of the menus and file manipulation subroutines are written in BASICA and compiled with the IBM BASIC Compiler Version 2.00. The structural analysis and design subroutines are written in FORTRAN, Micro Soft Version 3.3. Any user wishing to modify the code of PIPECAR will need to purchase compilers for these languages.

## 6.2 Disk Files

PIPECAR is provided to you on three disks. Each disk should contain the following files:

Program Disk 1

PIPEMAIN	SCR	3968	11-01-88	1:00a
PIPE7	SCR	3968	11-01-88	1:00a
PIPE7_1	SCR	3968	11-01-88	1:00a
PIPE1	SCR	3968	11-01-88	1:00a
PIPE3R	SCR	3968	11-01-88	1:00a
PIPE9	SCR	3968	11-01-88	1:00a
PIPE4	SCR	3968	11-01-88	1:00a
PIPE5	SCR	3968	11-01-88	1:00a
PIPE2C	SCR	3968	11-01-88	1:00a
PIPE2E	SCR	3968	11-01-88	1:00a
PIPE6	SCR	3968	11-01-88	1:00a
PIPE8	SCR	3968	11-01-88	1:00a
PIPE6H	SCR	3968	11-01-88	1:00a
PIPE6O	SCR	3968	11-01-88	1:00a
PIPE6C	SCR	3968	11-01-88	1:00a
PIPE3U	SCR	3968	11-01-88	1:00a
PIPE3M	SCR	3968	11-01-88	1:00a
PIPE7_2	SCR	3968	11-01-88	1:00a
PIPE7_3	SCR	3968	11-01-88	1:00a
PIPE7_4	SCR	3968	11-01-88	1:00a
PIPE7_5	SCR	3968	11-01-88	1:00a
PIPE7_6	SCR	3968	11-01-88	1:00a
PFILING	SCR	3968	11-01-88	1:00a
PSTIRRUP	SCR	3968	11-01-88	1:00a
BLANK	SCR	3968	11-01-88	1:00a
SCRN13	SCR	3968	11-01-88	1:00a
SCRN14	SCR	3968	11-01-88	1:00a
PHELP4M	TXT	1230	11-01-88	1:00a
PHELP1	TXT	1059	11-01-88	1:00a
PHELP6	TXT	560	11-01-88	1:00a
PHELP8	TXT	821	11-01-88	1:00a
PHELP4U	TXT	924	11-01-88	1:00a
PHELP5	TXT	963	11-01-88	1:00a
PHELP7D	TXT	938	11-01-88	1:00a
PHELP7E	TXT	342	11-01-88	1:00a
PHELP2	TXT	559	11-01-88	1:00a
PHELP4R	TXT	1095	11-01-88	1:00a
PHELP7	TXT	928	11-01-88	1:00a
PHELP3	TXT	1142	11-01-88	1:00a
PIPECAR	EXE	138314	11-01-88	1:00a
VARIABLE	LST	3687	11-01-88	1:00a
PSYSTEM	DEF	7	11-01-88	1:00a
PDCU	DEF	275	11-01-88	1:00a
PHELP9	TXT	197	11-01-88	1:00a
44 File(s)			89088 bytes	free

Program Disk 2

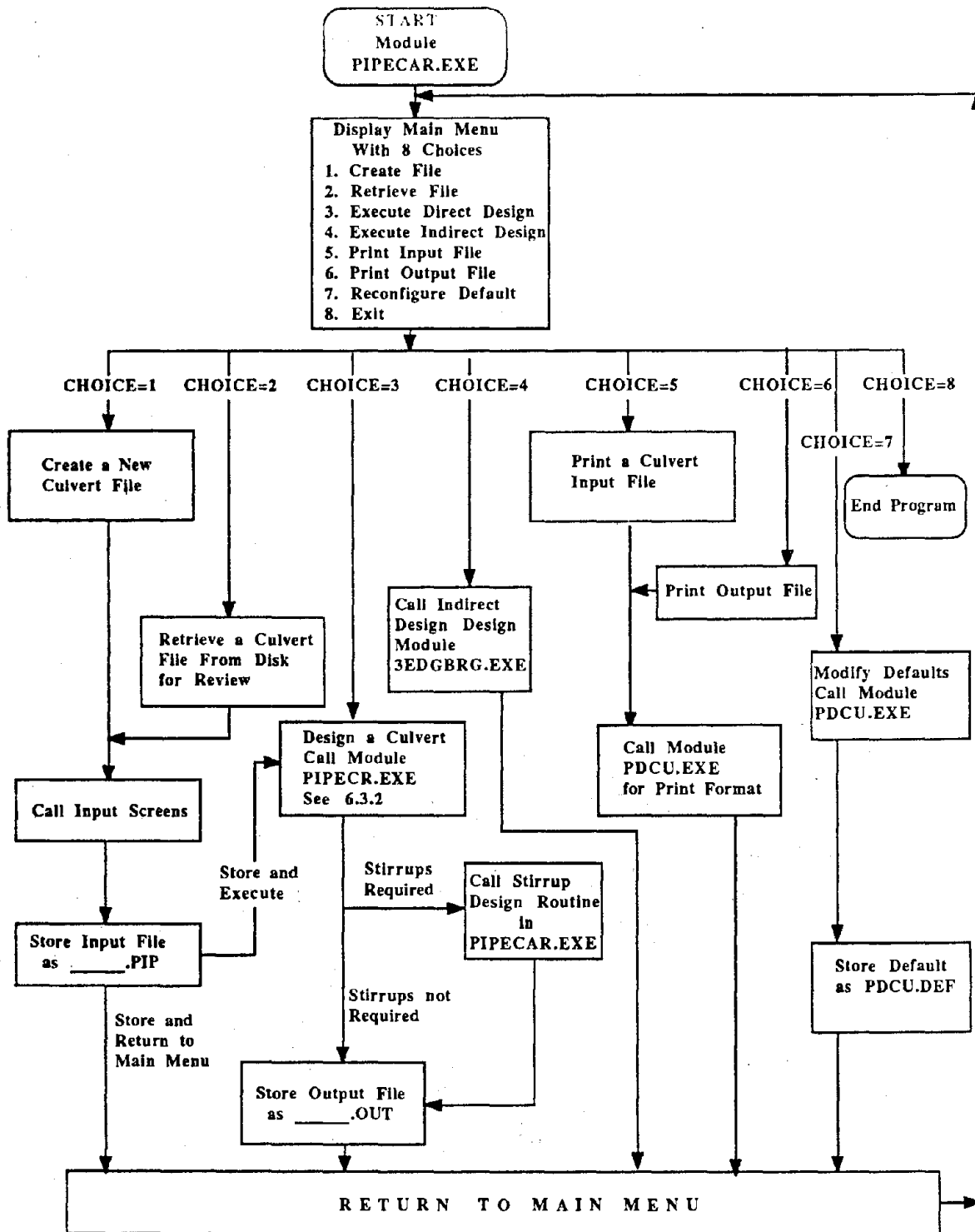
PIPECR	EXE	248128	11-01-88	1:00a
PIPEDSK2	EXE	41738	11-01-88	1:00a
PSYSTEM	DEF	7	11-01-88	1:00a
3 File(s)			41984 bytes free	

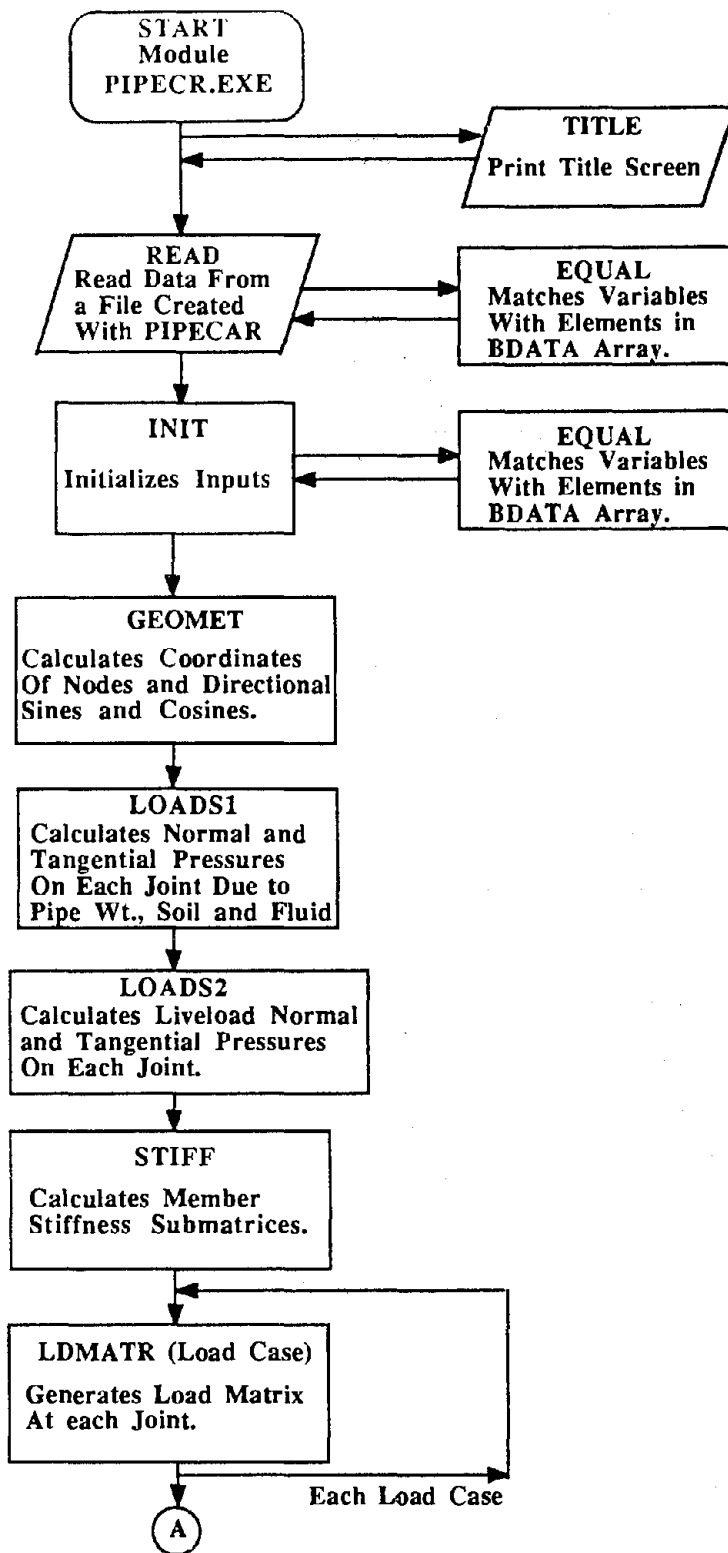
Program Disk 3

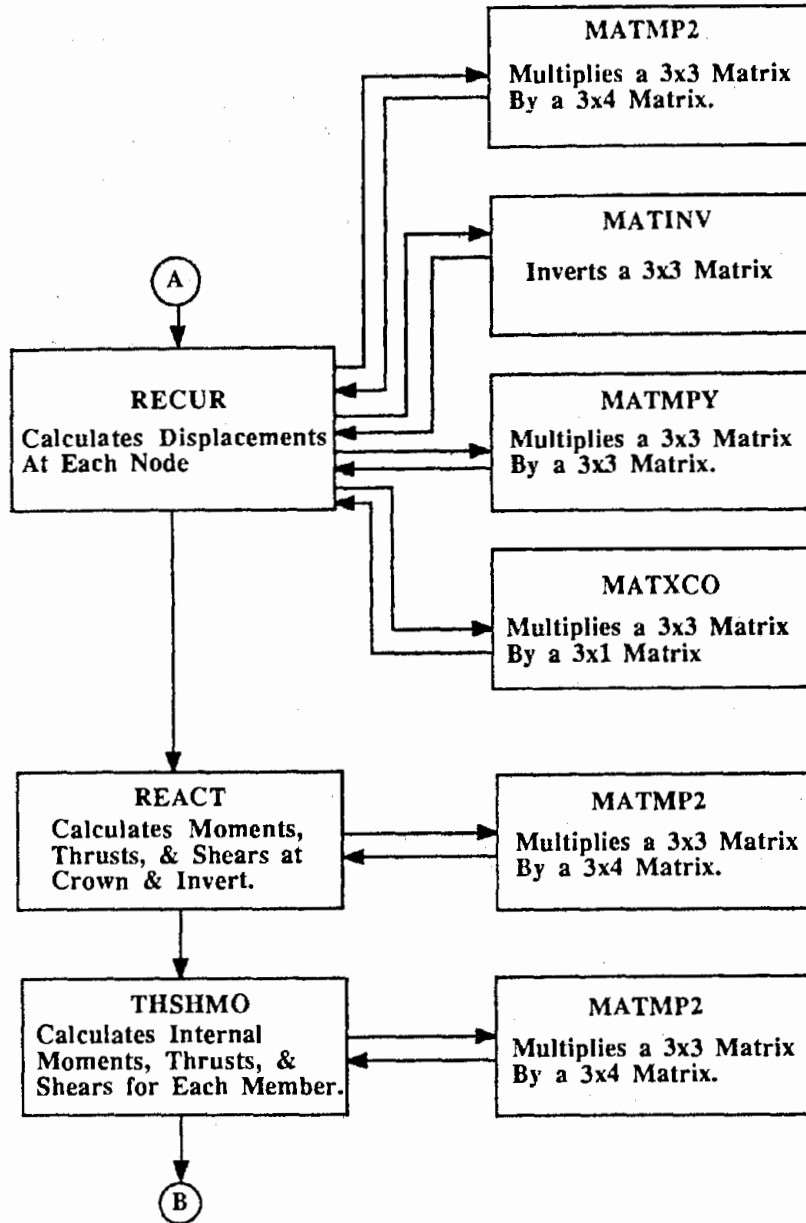
PIPE6DCU	SCR	3968	11-01-88	1:00a
PIPE1DCU	SCR	3968	11-01-88	1:00a
PIPE2DCU	SCR	3968	11-01-88	1:00a
PIPE3DCU	SCR	3968	11-01-88	1:00a
PIPE5DCU	SCR	3968	11-01-88	1:00a
PIPE4DCU	SCR	3968	11-01-88	1:00a
BLANK	SCR	3968	11-01-88	1:00a
PSYSTEM	DEF	7	11-01-88	1:00a
PINSTALL	EXE	52598	11-01-88	1:00a
3EDGBRG	EXE	84554	11-01-88	1:00a
PIPPRINT	SCR	3968	11-01-88	1:00a
PIPEDCU	EXE	94954	11-01-88	1:00a
PHELP5	TXT	963	11-01-88	1:00a
PHELP6	TXT	560	11-01-88	1:00a
PHELP7D	TXT	938	11-01-88	1:00a
PHELP7E	TXT	342	11-01-88	1:00a
PHELP8	TXT	821	11-01-88	1:00a
17 File(s)			90112 bytes free	

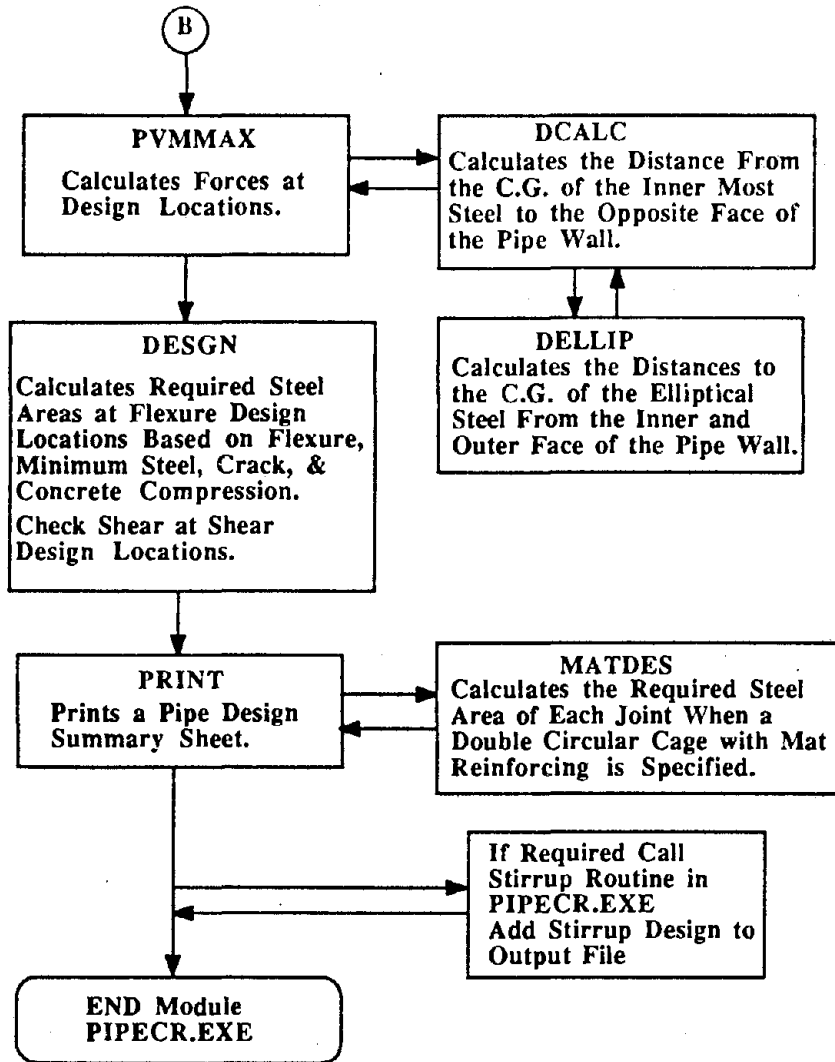
### 6.3 Flow Chart of Overall Program Structure

#### 6.3.1 Menu Flow Chart









#### **6.4 Program Structure for Each Subroutine**

**Subroutine:** PIPECAR

**Function:**

The main program sequentially calls the various subroutines needed to complete the analysis and design of the pipe.

**I/O Generated By Subroutine:**

None

**Error Messages Generated by Subroutine:**

None





```

REAL NLAY,LDF,LDFQ
REAL LATPC
INTEGER RTYPE
INTEGER PTOFAC,PBOTFAC
CHARACTER*1 SAVE
DOUBLE PRECISION K1, K2, K12, F1, F2, PVM1, PVM2,DLPR,DLPT
DOUBLE PRECISION UN,REAC,SLPR,SLPT,FLPR,FLPT,WLPR,WLPT
DOUBLE PRECISION SLPTTR,SLPRTR,FLPTTR,FLPRTR
OPEN(8,FILE=' ',STATUS='UNKNOWN')
OPEN(5,FILE=' ')
OPEN(3,FILE=' ',STATUS='UNKNOWN')

```

C

```

IP=0
IPRINT=0
III=0
ISTRP=0
IDBG=1
5556 FORMAT(A1)
1212 CALL TITLE
2000 CONTINUE
IPATH=0
CALL READ1
IF (IPATH .GT. 0) GO TO 3000
IF (IPATH .LT. 0) GO TO 1000
CALL INIT
IF (IPATH .LT. 0) GO TO 1000
IF (IPATH .GT. 0) GO TO 3000
1015 CALL GEOMET
1014 CALL LOADS1
1013 CALL LOADS2
CALL STIFF
CALL LDMATR(DLPR,DLPT,1)
CALL LDMATR(SLPR,SLPT,2)
CALL LDMATR(FLPR,FLPT,3)
CALL LDMATR(WLPR,WLPT,4)
CALL RECUR
CALL REACT
IF (IPATH .GT. 0 ) GO TO 3000
CALL THSHMO
CALL PVMMAX
IF (IPATH .GT. 0 ) GO TO 3000
CALL DESGN
IF (IPATH .GT. 0 ) GO TO 3000
1010 CALL PRINT
GO TO 3000
1000 CONTINUE
GO TO 2000
3000 CONTINUE
IF(IPRINT.EQ.1) GO TO 4000
IPRINT=1
WRITE(6,5566)
5566 FORMAT(18X,'DO YOU WISH TO SAVE AND/OR PRINT THIS OUTPUT ? (D/P/N)
1',//,18X,'D = WRITE TO DISK AND RETURN TO MAIN MENU.',/,
218X,'P = WRITE TO DISK AND PRINTER AND RETURN TO MAIN MENU.',/,
318X,'N = RETURN TO MAIN MENU WITHOUT SAVING OUTPUT.',//,
120X,'Make Selection....Then Press Enter')

```

```

        READ(6,5556) SAVE
3545 IF(SAVE.EQ.'N'.OR.SAVE.EQ.'n'.OR.SAVE.EQ.'D'.OR.SAVE.EQ.'P'.OR.SAV
    1E.EQ.'p'.OR.SAVE.EQ.'d') THEN
        GO TO 3535
        ELSE
        WRITE(6,3636)
3636 FORMAT(20X,'PLEASE RE-ENTER D, P OR N',/)
        READ(6,5556) SAVE
        GO TO 3545
        ENDIF
3535 IF(SAVE.EQ.'P'.OR.SAVE.EQ.'p'.OR.SAVE.EQ.'D'.OR.SAVE.EQ.'d') ISTRP
    1=1
        IF(SAVE.EQ.'N'.OR.SAVE.EQ.'n') GO TO 4000
501 WRITE(6,500)
        IDBG=0
500 FORMAT(////////////////////,8X,'OUTPUT SELECTIONS',//,15X,
    $'1. Print Input and Design Summary'
    1,/,15X,'2. Print Above + Total Loads, Ultimate Forces',
    2,' Design Tables',/,15X,'3. Print Above + Applied Pressures and'
    3,' Service Load Forces',/,15X,'4. Print Above + Computer Model',
    4' Geometry and Displacements',////////////////,15X,'Make Selection....Th
    5en Press Enter',/)
        READ(6,505,ERR=501) IDBG
505 FORMAT(I1)
        IF(IDBG.EQ.9) GO TO 767
        IF(IDBG.LT.1.OR.IDBG.GT.4) GO TO 501
767 WRITE(6,676)
676 FORMAT(////////////////////,
    120X,'WRITING OUTPUT TO DISK.....',/,20X,'PLEASE WAIT
    1',/////////////////)
        IF(IDBG.EQ.9) IDBG=10
        IDBUG=IDBG-1
        III=8
        IP=1
        REWIND(5)
        REWIND(3)
        REWIND(8)
        REWIND(III)
        IF (SYST .EQ. 4) GO TO 1212
        IF(IDBUG.EQ.0) GO TO 1010
        IF(IDBUG.EQ.1) GO TO 1013
        IF(IDBUG.EQ.2.AND.SYST.EQ.3.0) GO TO 1212
        IF(IDBUG.EQ.2) GO TO 1014
        GO TO 1212
4000 CONTINUE
        WRITE(3,5556) SAVE
        END

```

**Subroutine:** TITLE

**Function:**

This subroutine prints the user warning to the screen while the program is executing.

**I/O General by Subroutine:**

The user warning is printed to the screen.

**Error Messages Generated by Subroutine:**

None.

```

SUBROUTINE TITLE
C
C THIS ROUTINE PRINTS A TITLE SCREEN WHILE THE
C PROGRAM IS RUNNING
C
COMMON/PRIN/IPRINT
IF(IPRINT.EQ.1) GO TO 100
WRITE(*,97)
97 FORMAT(////////////////////,
2' P I P E C A R ',/,
3' PIPE CULVERT ANALYSIS AND REINFORCING DESIGN'
4,/,/,
4,/,/,
4050 FORMAT(/,11X,
1' The application of this non-proprietary software product is',/,
211X,' the responsibility of the user. The user must select input',
3/,11X,' values suitable to his specific installation. Use of',/,
411X,' default parameters does not assure a safe design for all',/,
511X,' installations. The information presented in the computer',/,
611X,' output is for review, interpretation, application, and',/,
711X,' approval by a qualified engineer who must assume full',/,
811X,' responsibility for verifying that said output is appropriate
9',/,11X,' and correct. There are no express or implied warranties.
$',/,11X,' Use of this product does not constitute endorsement by F
$HWA',/,11X,' or other agents.',/)
WRITE(*,4050)
WRITE(*,4051)
4051 FORMAT(' DESIGNING CULVERT..... PLEASE WAIT',
1///)
IF(IDBUG .EQ. 9) WRITE(IW,98)
98 FORMAT('1',////////////////,20X,'DESIGN INPUT',/,20X,12(1H-),/)
100 RETURN
END

```

**Subroutine:** READ1

**Function:**

This subroutine reads input data from a file created by the PIPECAR screen input routine. Data is transferred into program arrays.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

```

SUBROUTINE READ1
C
C THIS SUBROUTINE READS ALL THE INPUT IN A SPECIFIED FORMAT AND
C TRANSFERS THE DATA INTO THE BDATA ARRAY. THE EXECUTION OF READ
C IS CONTROLLED BY THE KODE VARIABLE ON THE INPUT CARDS. A KODE
C GREATER THAN 16 SIGNALS THE END OF THE INPUT DATA. READ REPRINTS
C THE INPUT CARDS AS IT READS THEM AS A CHECK FOR THE USER.
C
COMMON/IFLAG/IBDATA(52)
COMMON/BSCALE/BDATA(40)
COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,
1FY,FCP,COU,T,CIN,FLMV,FLN,DIN,DOU,T,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R
1,FPF,P0RT,THP
COMMON/ISCALE/IDBUG,IPATH
COMMON/BED/DLBED,DLUBED
COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,
1 LATPC,PTOP,SYST
COMMON/SOIL/STYPE
COMMON/ALIVE/LLTYPE,VMAG,RLEN,RWID
COMMON/CAGETYP/ ITYPE,RATIO,ELROT,DWI,DWO,TBI,TBO,DWE,
1 TBEI,TBEO,DWII,PHII,DWIC,PHIC,DWOS,PHIS,WIREI,WIREO,WIREE,
2 WIREIR,WIRECR,WIRESR
COMMON/SPSOIL/SAREA(7),SPK,SPU,SPV,SPM,SPA,SPFB,SPD,LDF,SPRADI,
1
1 INSTAL
COMMON/PRES/HP,FP
COMMON/FILE/III,IP,ISTRP
COMMON/PRN/IDBG
COMMON/FACT/FLLNP,FLMVLP
DIMENSION D(6),LAT(17),DSCPTR(6)
CHARACTER*4 ATEXT(20),TEXT(5)
CHARACTER*8 STYPE
REAL NLAY,LDF,LDFQ
REAL LATPC
INTEGER RTYPE
DATA LAT /3,2,3,3,3,3,2,4,6,2,6,5,4,6,3,2,6/
C
C
C* * * * *
C IBDATA = 0 VALUE NOT READ
C = +1 VALUE WAS READ
C = -1 VALUE WAS DEFAULTED
C
LLTYPE=0
SYST=0.0
TYPE=0.0
PTOP=0.0
PLAT1=0.0
PLAT2=0.0
BANGLE=0.0
PI=3.1415926535897
DO 5 I=1,52
IF (I .LT. 36) BDATA(I)=0.0
IBDATA(I)=0
5 CONTINUE
READ(5,1024,END=993) (ATEXT(I), I=1,20), IDBUG

```

```

1024 FORMAT ( 19A4,A3,I1)
      IF(IP.EQ.1) IDBUG=IDBG
C
C   IDBUG CONTROLS PRINT
C   IDBUG =0-----INPUT ARRAY AND TOTAL LOADS AND FINAL DESIGN
C           =1-----ABOVE + REACTIONS AND DESIGN FORCES
C           =2-----ABOVE + GEOMETRY,MOMENTS,THRUSTS AND SHEARS
C           =3-----ABOVE + STIFFNESS MATRICES AND JOINT
C                   DISPLACEMENTS
C
3   CONTINUE
1   READ (5,1000)  KODE, (TEXT(I), I=1,5), (D(I), I=1,6)
      IF (KODE .GT. 17) GO TO 995
4   K=LAT(KODE)
      GO TO (10,20,30,40,50,60,70,80,90,100,110,120,130,
1   140,150,160,170),KODE
C
C   RADIUS1, RADIUS2, DEPTH OF FILL      KODE=1
C
10  CONTINUE
      IF (D(2) .EQ. 0.0) GO TO 15
      IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1002) KODE,(D(I),I=1,K)
      BDATA(1)=D(1)
      BDATA(2)=D(2)
      BDATA(3)=D(3)
      IBDATA(1)=1
      IBDATA(2)=1
      IBDATA(3)=1
      GO TO 1
15  CONTINUE
      IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1001) KODE,D(1),D(3)
      BDATA(1)=D(1)/2
      BDATA(2)=D(1)/2
      BDATA(3)=D(3)
      IBDATA(1)=1
      IBDATA(3)=1
      IBDATA(2)=-1
      BDATA(4)=0.000001
      BDATA(5)=0.000001
      IBDATA(4)=-1
      IBDATA(5)=-1
      GO TO 1
C
C   U,V,                                KODE=2
C
20  CONTINUE
      IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1003) KODE,(D(I),I=1,K)
      IF (BDATA(1) .EQ. BDATA(2)) GO TO 1
      BDATA(4)=D(1)
      BDATA(5)=D(2)
      IBDATA(4)=1
      IBDATA(5)=1
25  CONTINUE
      GO TO 1
C
C   SLAB THICKNESS, LOAD SYSTEM, REACTION BED LENGTH FOR DEAD LOAD, KODE=3

```



```

C
30 CONTINUE
  IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1004) KODE,(D(I),I=1,K)
  BDATA(6)=D(1)
  IBDATA(6)=1
  SYST=D(2)
  IF (SYST .NE. 0.0) IBDATA(36)=1
  IF (SYST .GT. 1.0) THEN
    TYPE=2.0
  ELSE
    TYPE=1.0
  ENDIF
  DLBED=D(3)
  IF (DLBED .NE. 0.0 .AND. TYPE .EQ. 1.) IBDATA(45)=1
  GO TO 1

```

```

C
C BEDDING ANGLE, LOAD ANGLE, SOIL-STRUCTURE INTERACTION COEFFICIENT, KODE=4

```

```

C
40 CONTINUE
  IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1005) KODE,(D(I),I=1,K)
  BDATA(7)=D(1)
  IBDATA(7)=1
  BDATA(32)=D(2)
  IBDATA(32)=1
  BDATA(8)=D(3)
  IBDATA(8)=1
  GO TO 1

```

```

C
C DENSITIES; GAMAS, GAMAC, GAMAF      KODE=5

```

```

C
50 CONTINUE
  IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1006) KODE,(D(I),I=1,K)
  BDATA(9)=D(1)
  BDATA(10)=D(2)
  BDATA(11)=D(3)
  IBDATA(9)=1
  IBDATA(10)=1
  IBDATA(11)=1
  GO TO 1

```

```

C
C FLUID PARAMETERS                      KODE=6

```

```

C
60 CONTINUE
  IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1007) KODE,(D(I),I=1,K-1)
  BDATA(12)=D(1)
  IBDATA(12)=1
  PINT=D(2)
  IF (PINT .NE. 0.0) IBDATA(46)=1
  HP=PINT
  GO TO 1

```

```

C
C MATERIAL STRENGTH; F(Y),F(CP)      KODE=7

```

```

C
70 CONTINUE
  IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1008) KODE,(D(I),I=1,K)

```

```
IF (D(1) .EQ. 0.) GO TO 71
BDATA(13)=D(1)
IBDATA(13)=1
71 IF (D(2) .EQ. 0.) GO TO 1
BDATA(14)=D(2)
IBDATA(14)=1
GO TO 1
```

```
C
C CONCRETE COVER                                KODE=8
```

```
C
80 CONTINUE
IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1009) KODE,(D(I),I=1,K)
TBO=D(1)
TBI=D(2)
TBEO=D(3)
TBEI=D(4)
BDATA(15)=TBO
IBDATA(15)=1
BDATA(16)=TBI
IBDATA(16)=1
GO TO 1
```

```
C
C LOAD FACTORS, CAP. RED. FACTORS            KODE=9
```

```
C
90 CONTINUE
IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1010) KODE,(D(I),I=1,K)
BDATA(17)=D(1)
FLN=D(2)
BDATA(18)=D(2)
FLMVLL=D(3)
FLNLL=D(4)
DO 92 II=49,50
  IF (D(II-46) .NE. 0.0) IBDATA(II)=1
```

```
92 CONTINUE
BDATA(25)=D(5)
BDATA(33)=D(6)
IBDATA(17)=1
IBDATA(25)=1
IBDATA(33)=1
GO TO 1
```

```
C
C TYPE,LAYERS                                KODE=10
```

```
C
100 CONTINUE
IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1011) KODE,(D(I),I=1,K)
IF (D(1) .EQ. 0.0) GO TO 107
BDATA(21)=D(1)
IBDATA(21)=1
107 IF (D(2) .EQ. 0.0) GO TO 1
BDATA(22)=D(2)
IBDATA(22)=1
GO TO 1
```

```
C
C WIRE SPACING                                KODE=11
```

```
C
110 CONTINUE
```

```

IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1012) KODE,(D(I),I=1,K)
IF (D(1) .EQ. 0.0) GO TO 115
WIREI=D(1)
BDATA(23)=WIREI
IBDATA(23)=1
115 IF (D(2) .EQ. 0.0) GO TO 117
WIREO=D(2)
BDATA(24)=WIREO
IBDATA(24)=1
117 WIREE=D(3)
WIREIR=D(4)
WIRECR=D(5)
WIRESR=D(6)
GO TO 1

C
C DESIGN FACTORS : FCR,FRP,FVP,POR AND FLUID PRESSURE FACTOR      KODE=12
C
120 CONTINUE
IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1013) KODE,(D(I),I=1,K)
BDATA(26)=D(1)
BDATA(34)=D(2)
BDATA(35)=D(3)
POR=D(4)
FPF=D(5)
IBDATA(26)=1
IBDATA(34)=1
IBDATA(35)=1
GO TO 1

C
C LIVE LOAD      KODE=13
C
130 CONTINUE
IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1022)KODE,(D(I),I=1,K)
LLTYPE=INT(D(1))
IF (LLTYPE .NE. 0) IBDATA(48)=1
VMAG=D(2)
RLEN=D(3)
RWID=D(4)
GO TO 1

C
C PARIS DISTRIBUTION INPUT VALUES: TWIDTH, BWIDTH, BPRIME,
C APRIME,LATPC      KODE=14
C
140 CONTINUE
IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1018) KODE,(D(I),I=1,
1(K-3))
IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1019) KODE,(D(I),I=(K-2),
1K)
TWIDTH=D(1)
BWIDTH=D(2)
BPRIME=D(3)
APRIME=D(4)
LATPC=D(5)
DLUBED=D(6)
IF (DLUBED .NE. 0.0 .AND. TYPE .EQ. 2.) IBDATA(45)=1
DO 145 J=37,41

```

```

        IF (D(J-36) .NE. 0.0 .OR. J .EQ. 40) IBDATA(J)=1
145  CONTINUE
      GO TO 1
C
C  OPTIONAL PARIS INPUT: VERTICAL PRESSURE (in psf), TOP & BOTTOM
C    LATERAL PRESSURES (in psf)      KODE=15
C
150  CONTINUE
      IF (IDBUG .EQ. 9.AND.IP.EQ.1) WRITE(III,1020) KODE,(D(I),I=1,K)
      PTOP=D(1)
      PLAT1=D(2)
      PLAT2=D(3)
      DO 155 J=42,44
        IF (D(J-41) .NE. 0.0) THEN
          IBDATA(J)=1
        ELSE
          IBDATA(J)=-1
        ENDIF
155  CONTINUE
      GO TO 1
C
C    USER SPECIFIED CAGE TYPE
C
160  CONTINUE
      ITYPE=D(1)
      ELROT=D(2)
      ELROT=ELROT*PI/180.
      GO TO 1
C
C    WIRE DIAMETERS
C
170  CONTINUE
      DWI=D(1)
      DWO=D(2)
      DWE=D(3)
      DWII=D(4)
      DWIC=D(5)
      DWOS=D(6)
      BDATA(19)=DWI
      BDATA(20)=DWO
      IF (ITYPE .EQ. 6) RATIO=(DWE/DWI)**2
      GO TO 1
C
C  END OF DATA,      KODE AT 18
C
993  CONTINUE
      IPATH=1
C
C  FORMAT STATEMENTS FOR INPUT VALUES
C
1000 FORMAT (I2, 4A4, A2, 6F10.3 )
1001 FORMAT(2X,I2,3X,12HINSDDIAM(IN),1X,F10.3,
          127X,12HDPHFILL(FT),1X,F10.3)
1002 FORMAT(2X,I2,3X,12HRADIUS 1(IN),1X,F10.3,2X,
          112HRADIUS 2(IN),1X,F10.3,2X,12HDPHFILL(FT),1X,F10.3)
1003 FORMAT(5X,I2,3X,12HHORIZ OS(IN),1X,F10.3,2X,

```

```

112HVERT OS(IN),1X,F10.3)
1004 FORMAT(2X,I2,3X,12HTHICKNES(IN),1X,F10.3,2X,'LOAD SYSTEM ',1X,
1      F10.3,2X,'DL BED (%)',1X,F10.3,2X,'INSTALLATION',1X,F10.3
2)
1005 FORMAT(2X,I2,3X,12HBED. ANGLE ,1X,F10.3,2X,
112HLOAD ANGLE ,1X,F10.3,2X,12HSL-ST INT CO,1X,F10.3 )
1006 FORMAT(2X,I2,3X,12HSOIL (#/FT3),1X,F10.3,2X,
112HCONC (#/FT3),1X,F10.3,2X,12HFLUID(#/FT3),1X,F10.3)
1007 FORMAT(2X,I2,3X,12HDPHFLUD(IN),1X,F10.3,2X,'INT PRESSURE',1X,
1      F10.3)
1008 FORMAT(2X,I2,3X,12HFY (KSI),1X,F10.3,2X,
112HFCP (KSI),1X,F10.3)
1009 FORMAT(2X,I2,3X,12HOUTSDCOV(IN),1X,F10.3,2X,
112HINSDCOV (IN),1X,F10.3)
1010 FORMAT(2X,I2,3X,'DL FACTOR MV',1X,F10.3,2X,'DL FACTOR N ',
11X,F10.3,/,7X,'LL FACTOR MV',1X,F10.3,2X,'LL FACTOR N ',1X,
1F10.3,/,7X,'PHI FLEXURE ',1X,F10.3,2X,'PHI SHEAR ',1X,F10.3)
1011 FORMAT(2X,I2,3X,12HINSID WIRDIA,1X,F10.3,2X,
112HOUTSD WIRDIA,1X,F10.3,2X,12HREINFG TYPE ,1X,F10.3,/,2X,
112H# OF LAYERS ,1X,F10.3,2X,'OUT LAYER # ',1X,F10.3)
1012 FORMAT(2X,I2,3X,12HINSIDWIRSPCG,1X,F10.3,2X,
112HOUTSDWIRSPCG,1X,F10.3)
1013 FORMAT(2X,I2,3X,12HPhi FLEX ,1X,F10.3,2X,
112HFRP ,1X,F10.3,2X,12HFVP ,1X,F10.3,
2/,7X,'12HPhi RADIAL ',F10.3)
1017 FORMAT(2X,I2,3X,'SL DIST TYPE',5X,A8)
1018 FORMAT(2X,I2,3X,'TOP WIDTH(%)',1X,F10.3,2X,
1'BOT WIDTH(%)',1X,F10.3,2X,'LAT LENG(IN)',1X,F10.3)
1019 FORMAT(2X,I2,3X,'LAT STRT(IN)',1X,F10.3,2X,'LAT PR COEFF',
1      1X,F10.3,2X,'P.W.BED LEN%'1X,F10.3)
1020 FORMAT(2X,I2,3X,'VERT PRESS ',1X,F10.3,2X,
1'TP LAT PRESS',1X,F10.3,2X,'BT LAT PRESS',1X,F10.3)
1021 FORMAT(2X,I2,3X,'DL RXN ANGLE',1X,F10.3)
1022 FORMAT(2X,I2,3X,'LIVE LD TYPE',1X,F10.3,2X,'USER MAG ',1X,
1      F10.3,/,7X,'USER LENGTH ',1X,F10.3,2X,'USER WIDTH ',1X,
1      F10.3)
995 CONTINUE
CALL EQUAL
RETURN
END

```

**Subroutine:** INIT

**Function:**

This subroutine fills out the remaining program main arrays and sets up variables used throughout the program.

**I/O Generated By Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

```

SUBROUTINE INIT
C THIS SUBROUTINE FILLS OUT THE BDATA ARRAY. WHERE NEEDED, IT
C CALCULATES VALUES FROM INPUT AND INSERTS THEM INTO THE BDATA
C ARRAY.
C INIT ASSIGNS DEFAULT VALUES ON THE FOLLOWING BASIS:
C IBDATA(*)=1 -VALUE HAS BEEN INPUT, NO VALUE NEEDED
C IBDATA(*)=0 -VALUE HAS NOT BEEN INPUT,DEFAULT VALUE GIVEN
C TO BDATA(*);IBDATA(*) IS THEN SET EQUAL TO -1
C THIS ROUTINE ALSO CHECKS FOR ERROR CONDITIONS IN THE INPUT DATA
C AND PRINTS THE BDATA AND IBDATA ARRAYS FOR IDBUG VALUE GREATER
C THAN 0.
C

```

```

COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,POR
1,FPF,P0RT,THP
COMMON/BSCALE/BDATA(40)
COMMON/ISCALE/IDBUG,IPATH
COMMON/IFLAG/IBDATA(52)
COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,
1LATPC,PTOP,SYST
COMMON/BED/DLBED,DLUBED
COMMON/ALIVE/LLTYPE,VMAG,RLEN,RWID
COMMON/SPSOIL/SAREA(7),SPK,SPU,SPV,SPM,SPA,SPFB,SPD,LDF,SPRADI,
1INSTAL
COMMON/FILE/III,IP,ISTRP
COMMON/FACT/FLLNP,FLMVLP
DIMENSION ASSUME(40)
CHARACTER*8 STYPE
REAL NLAY,LDF
INTEGER RTYPE
DO 67 I=1,35
ASSUME(I)=0.0
67 CONTINUE
GO TO (1199,2299,3399,4499,5599,6699), ITYPE
1199 SPIN=WIREI
CIN=TBI
SPOUT=WIREO
COUT=TBO
GO TO 7799
2299 SPIN=WIREI
SPOUT=WIREI
CIN=TBI
COUT=TH-TBI
GO TO 7799
3399 SPIN=WIREE
SPOUT=WIREE
CIN=TBE
COUT=TBE
GO TO 7799
4499 SPIN=WIREI
SPOUT=WIREO
CIN=TBI
COUT=TBO
GO TO 7799
5599 SPIN=WIREI

```

```

        SPOUT=WIREE
        CIN=TBI
        COUT=TBE0
        GO TO 7799
6699 SPIN=WIREI
        SPOUT=WIRE0
        CIN=TBI
        COUT=TBO
7799 CONTINUE
        N=0
        PI=3.1415926535897
        LDF=BDATA(3)*BDATA(9)/1000.*2.*(BDATA(1)+BDATA(6))/12.
C
C SET DEFAULT VALUES
C INDEX OF ASSUME REFERS TO POSITION IN RSCALE COMMON
C
C CALCULATE ES, EC, MEAN RADII, EQUIVALENT DIAMETER
C
        BDATA(27)=29000.0
        BDATA(28)=(BDATA(10))**1.5*33.*SQRT(BDATA(14)*1000.)/1000.
        IF (BDATA(28) .EQ. 0.) BDATA(28)=4286.824
        UVRAT=BDATA(4)/BDATA(5)
        BDATA(31)=SQRT(2.*(BDATA(2)**2*ATAN(UVRAT)+BDATA(1)**2*(PI/2-
1ATAN(UVRAT))-BDATA(4)*BDATA(5))/PI)*2.
        IBDATA(27)=-1
        IBDATA(28)=-1
        IBDATA(29)=-1
        IBDATA(30)=-1
        IBDATA(31)=-1
        BDATA(29)=BDATA(1)+BDATA(6)/2
        BDATA(30)=BDATA(2)+BDATA(6)/2
150 CONTINUE
        CALL EQUAL
        RETURN
        END

```



**Subroutine:** GEOMET

**Function:**

This subroutine calculates the coordinates of the nodes, and the length and the directional sines and cosines of members for both circular and elliptical pipe.

**I/O Generated by Subroutine:**

When Output Option 4 is selected, the pipe geometry including a list of coordinates, member angles from vertical, member lengths, and unit sines and cosines is printed.

**Error Messages Generated by Subroutine:**

None

SUBROUTINE GEOMET

C  
C  
C  
C  
C  
C  
C  
C  
C

CALCULATES COORDINATES OF THE NODES, AND THE LENGTH AND DIRECTIONAL SINES AND COSINES OF MEMBERS FOR CIRCULAR AND ELLIPTICAL PIPE.

A PRINTOUT OF THIS INFORMATION IS AVAILABLE WITH AN IDBUG VALUE GREATER THAN 1

COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST  
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R  
1,FPP,PORT,THP

COMMON/COORD/X(37),Y(37),A(37),B,BS

COMMON/PROP/SI(37),CO(37),ALEN(37)

COMMON/ISCALE/IDBUG,IPATH

COMMON/SPSOIL/SAREA(7),SPK,SPU,SPV,SPM,SPA,SPFB,SPD,LDF,SPRADI,  
1 INSTAL

COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,  
1 LATPC,PTOP,SYST

COMMON/FILE/III,IP,ISTRP

COMMON/BED/DLBED,DLUBED

COMMON/FACT/FLLNP,FLMVLP

REAL NLAY,LDF

INTEGER RTYPE

DIMENSION DEG(37)

C

DO 68 I=1,37

X(I)=0.0

Y(I)=0.0

ALEN(I)=0.0

A(I)=0.0

SI(I)=0.0

CO(I)=0.0

68 CONTINUE

C

M=0

PI=3.1415926535897

BS=0.0

IF (BETA .NE. 180.) GO TO 200

B=179.9\*PI/180.0

BS=179.9\*PI/180.

M=2

200 CONTINUE

IF (BETAS .EQ. 180.) BS=179.9\*PI/180.

BETA=BETA\*PI/180.

BETAS=BETAS\*PI/180.

IF (BWIDTH .EQ. 100.) BWIDTH=99.99

IF (DLUBED .EQ. 100.) DLUBED=99.99

IF (DLBED .EQ. 180.) DLBED=179.9

C

C

GENERATE COORDINATES

P2 = ATAN(U/V)

SI(37)=SIN(182.5\*PI/180.)

CO(37)=COS(182.5\*PI/180.)

DO 300 I=1,37

```

DEG(I) = (I-1) * 5.00000
A(I) = (I-1)*PI/36
IF (A(I) .GT. (PI-P2)) GO TO 700
IF (A(I) .GT. P2) GO TO 600
X(I) = RADM2*SIN(A(I))
Y(I) = -RADM2*COS(A(I))+V
GO TO 500
600 CONTINUE
X(I) = RADM1*SIN(A(I)) + U
Y(I) = -RADM1*COS(A(I))
500 CONTINUE
IF (M .GE. 1) GO TO 750
IF (-ATAN(X(I)/Y(I)) .LE. (BETA+0.0017)/2.) GO TO 800
B = 2.*A(I-1)
M = 1
IF (BETAS .LE. 3.14247) M = 2
IF ((BETA+BETAS) .LT. 6.28144) GO TO 750
BS = B
M = 2
GO TO 800
750 IF (M .EQ. 2) GO TO 800
IF (-ATAN(X(I)/Y(I)) .LE. (6.2815-BETAS)/2.) GO TO 800
BS = 2.*A(I)
M = 2
GO TO 800
700 CONTINUE
X(I) = RADM2*SIN(A(I))
C
C X(I) = RADM3*SIN(A(I))
C
C Y(I) = -RADM2*COS(A(I))-V
C
C Y(I) = -RADM3*COS(A(I))-VB
C
800 CONTINUE
IF (I .EQ. 1) GO TO 300
ALEN(I-1) = ((X(I)-X(I-1))**2 + (Y(I)-Y(I-1))**2)**0.5
SI(I-1) = (Y(I)-Y(I-1))/ALEN(I-1)
CO(I-1) = (X(I)-X(I-1))/ALEN(I-1)
300 CONTINUE
IF (BS .NE. 0.0) GO TO 302
DO 301 I = 19,37
IF (A(I) .LT. (PI-BETAS/2.)) GO TO 301
BS = 2*A(I)
GO TO 302
301 CONTINUE
302 CONTINUE
IF (IDBUG .LT. 3) GO TO 1300
IF (IP.EQ.1) WRITE(III,99)
99 FORMAT(1H1)
IF (IP.EQ.1) WRITE(III,1000)
IF (IP.EQ.1) WRITE(III,1400)
IF (IP.EQ.1) WRITE(III,1200)(I,DEG(I),A(I),X(I),Y(I),
1 I = 1,37 )
1100 CONTINUE
1000 FORMAT(//,35X,8HGEOMETRY,/,30X,17HJOINT COORDINATES,/,

```

```

16X,1HI,12X,19HANGLE FROM VERTICAL,14X,18HINCHES FROM CENTER)
1200 FORMAT(37(5X,I2,11X,F4.0,12X,F5.3,10X,F9.3,3X,F9.3,/) )
1400 FORMAT(4X,5HJOINT,6X,7HDEGREES,11X,7HRADIANS,13X,4HX(I),8X,4HY(I))
      IF(IP.EQ.1) WRITE(III,100)
100  FORMAT(1H1)
      IF(IP.EQ.1) WRITE(III,1001)
      IF(IP.EQ.1) WRITE(III,1401)
      IF(IP.EQ.1) WRITE(III,1201)(I,ALEN(I),SI(I),CO(I),
1  I=1,36)
1001 FORMAT(//,35X,8HGEOMETRY,/,21X,28HMEMBER LENGTHS, UNIT SINES &,
      18H COSINES,//,12X,1HI,14X,7HLENGTH ,14X,5HSI(I),8X,5HCO(I))
1201 FORMAT(36(11X,I2,13X,F7.3,15X,F5.3,8X,F5.3,/) )
1401 FORMAT(10X,6HMEMBER,11X,6H IN. )
1300 CONTINUE
      RETURN
      END

```

**Subroutine:** LOADS1

**Function:**

This subroutine calculates the normal and tangential pressures (kips/in./ft of pipe) on each joint due to pipe, soil, and fluid loads.

**I/O Generated by Subroutine:**

When Output Option 2 or greater is selected the total pipe, soil, fluid, and live load weight applied to a one foot section of pipe are printed. When Output Option 3 or greater is selected, a list of the normal and tangential forces applied to each node are printed.

**Error Messages Generated by Subroutine:**

None

SUBROUTINE LOADS1

C  
 C CALCULATES THE NORMAL AND TAGENTIAL PRESSURE(KIPS/IN/FT) ON EACH  
 C JOINT DUE TO PIPE SOIL AND FLUID LOADS.POSITIVE RADIAL PRESSURE IS  
 C ASSUMED TO BE ACTING TOWARD THE CENTER AND POSITIVE TANGENTIAL  
 C PRESSURE IS ASSUMED TO BE CLOCKWISE.  
 C A PRINTOUT OF THIS INFORMATION ALONG WITH A SUMMARY OF  
 C THE TOTAL APPLIED PIPE, SOIL AND FLUID LOADS; IS AVAILABLE  
 C WITH AN IDBUG VALUE GREATER THAN 1.  
 C

COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
 1FY,FCP,COU,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST  
 1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,POR  
 1,FPF,P0RT,THP

COMMON/COORD/X(37),Y(37),A(37),B,BS  
 COMMON/PROP/SI(37),CO(37),ALEN(37)  
 COMMON/ISCALE/IDBUG,IPATH  
 COMMON/IFLAG/IBDATA(40)  
 COMMON/PRESS/DLPR(37,2),DLPT(37,2),SLPR(37,2),SLPT(37,2),  
 1FLPR(37,2),FLPT(37,2),WLPR(37,2),WLPT(37,2)  
 COMMON/BED/DLBED,DLUBED  
 COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,  
 1 LATPC,PTOP,SYST  
 COMMON/TRANS1/JTRANS(4,4),TRANSP(4,4,2)  
 COMMON/TRANS2/PTOPFAC,PBOTFAC,LATP,LATN,LTRANS,DIST,LLTOPI  
 COMMON/ALIVE/LLTYPE,VMAG,RLEN,RWID  
 COMMON/LD2/NBOTX  
 COMMON/WEIGHT/W,PW,B7,SPPW,FW,SPFW,LDFQ  
 COMMON/FILE/III,IP,ISTRP  
 COMMON/FACT/FLLNP,FLMVLP  
 DIMENSION DEG(37)  
 DIMENSION Q(37),PREACT(37),T(37),S(37),DQ(37),DREAC(37),DS(37)  
 DIMENSION PVERT(37),PHORZ(37)  
 REAL L,LF,NLAY,LDFQ  
 REAL NTOPX,NLATN,NLATP,LSLOPE,LATPC  
 INTEGER T JOINT  
 INTEGER PTOFAC,PBOTFAC  
 DOUBLE PRECISION XLL1,XLL2,WLTOP,WLINV,WL,NBOTX  
 DOUBLE PRECISION DLPR,DLPT,SLPT,SLPR,WLPT,WLPR,FLPT,FLPR

C  
 DO 6767 I=1,37  
 DO 7676 K=1,2  
 DLPR(I,K)=0.0  
 DLPT(I,K)=0.0  
 SLPR(I,K)=0.0  
 SLPT(I,K)=0.0  
 WLPR(I,K)=0.0  
 WLPT(I,K)=0.0  
 FLPR(I,K)=0.0  
 FLPT(I,K)=0.0  
 7676 CONTINUE  
 DREAC(I)=0.0  
 6767 CONTINUE  
 PLAT11=PLAT1  
 PLAT22=PLAT2  
 PPTOP=PTOP

```

FS=Y(37)-TH/2.
DO 1000 K=1,37
FSS=Y(38-K)+TH/2.*COS(A(38-K))
IF (FSS .LT. (DF+Y(1)+TH/2.)) GO TO 950
FS=FSS
1000 CONTINUE
950 CONTINUE
DB7=0.0
DB8=0.0
DREACT=0.0
DLX2=0.0
DLX1=0.0
DF1=0.0
B2=0.0
B4=0.0
B7=0.0
B8=0.0
PW=0.0
B5=1.0
B6=1.0
BL1=0.0
BL2=0.0
BL3=0.0
BL4=0.0
F1=1.0
PI=3.1415926535897
OD=2.0*(RADI1+U+TH)
HE=H
DIST=TYPE
LTRANS=0
DO 949 I=1,4
DO 949 J=1,4
  JTRANS(I,J)=0
  DO 949 K=1,2
    TRANSP(I,J,K)=0.0
949 CONTINUE
C
C TOTAL SOIL LOAD
C
W=GAMAS*HH*(TH+RADI1+U)*(H+(RADI2-V+TH)/56.)/6000.
IF (SYST .EQ. 3) W=PTOP/1000*TWIDTH/100.*2.*(RADI1+TH)/12.
R3=RADM1
IF (EQUID .NE. 0.0) R3=(EQUID+TH)/2.
RADO1=RADI1+TH
RADO2=RADI2+TH
IF (TYPE .EQ. 1.0) GO TO 170
C
C UNIFORM SOIL PRESSURE DISTRIBUTION
C
C
C REMOVE LOAD FROM PARTIALLY LOADED MEMBERS & ADJUST
C TO MAINTAIN THE SAME TOTAL LOAD (UNIFORM)
C
PTOPX=(TWIDTH/100.)*(U+RADO1)
PBOTX=(BWIDTH/100.)*(U+RADO1)
DO 105 I=2,19

```

```

      IF (X(I) .GT. PBOTX .AND. X(I-1) .LE. PBOTX) THEN
        NBOTX=X(I-1)
        PBOTFAC=I-1
      ELSEIF (X(I) .EQ. PBOTX) THEN
        NBOTX=PBOTX
        PBOTFAC=I
      ENDIF
105 CONTINUE
      IF (PBOTX .LT. X(2)) THEN
        NBOTX=X(2)
        PBOTFAC=2
      ENDIF
      IF (PBOTX .GT. X(19)) THEN
        NBOTX=X(19)
        PBOTFAC=19
      ENDIF
      DO 110 I=19,36
        IF (X(I) .GT. PTOPX .AND. X(I+1) .LE. PTOPX) THEN
          NTOPX=X(I+1)
          PTOFAC=I+1
        ELSEIF (X(I) .EQ. PTOPX) THEN
          NTOPX=PTOPX
          PTOFAC=I
        ENDIF
110 CONTINUE
      IF (PTOPX .GT. X(19)) THEN
        NTOPX=X(19)
        PTOFAC=19
      ENDIF
      IF(SYST.EQ.2) BPRIME=2*(RADO2-V)
      CPRIME=2*(RADO2-V)-APRIME-BPRIME
      PLATP=(RADO2-V)-CPRIME
      PLATN=-((RADO2-V)-APRIME)
      IF (Y(1) .GE. PLATN) THEN
        NLATN=Y(1)
        LATN=1
      ENDIF
      DO 120 I=2,37
        IF (Y(I) .GT. PLATN .AND. Y(I-1) .LE. PLATN) THEN
          NLATN=Y(I-1)
          LATN=I-1
        ELSEIF (Y(I) .EQ. PLATN) THEN
          LATN=I
          NLATN=PLATN
        ENDIF
120 CONTINUE
      IF (PLATN .GE. Y(37)) THEN
        NLATN=Y(37)
        LATP=37
      ENDIF
      IF (Y(1) .GE. PLATP) THEN
        NLATP=Y(1)
        LATP=1
      ENDIF
      IF (PLATP .GE. Y(37)) THEN
        NLATP=Y(37)

```



```

    LATP=37
ENDIF
DO 130 I=2,37
  IF (Y(I) .GE. PLATP .AND. Y(I-1) .LT. PLATP) THEN
    NLATP=Y(I)
    LATP=I
  ELSEIF (Y(I-1) .EQ. PLATP) THEN
    NLATP=PLATP
    LATP=I-1
  ENDIF
130 CONTINUE
IF (NLATP .EQ. NLATN) NLATN=NLATN-0.00001
IF (SYST .EQ. 3.0) THEN
  PTOP=(1./12000.)*PTOP*PTOPX/NTOPX
ELSE
  PTOP=W/(2.*NTOPX)
ENDIF
PINV=-PTOP*NTOPX/NBOTX
IF (SYST .EQ. 2.0) THEN
  PLAT1=LATPC*PTOP/HH
  PLAT2=PLAT1+LATPC*(PLATP-PLATN)*GAMAS/144000.
  PADD=0.5*(PLAT1+PLAT2)*((PLATP-PLATN)/(NLATP-NLATN)-1)
  PLAT1=(PLAT1+PADD)
  PLAT2=(PLAT2+PADD)
  GO TO 135
ENDIF
PADD=0.5*(PLAT1+PLAT2)*((PLATP-PLATN)/(NLATP-NLATN)-1)
PLAT1=(PLAT1+PADD)/12000.
PLAT2=(PLAT2+PADD)/12000.
135 CONTINUE
LSLOPE=(PLAT2-PLAT1)/(NLATP-NLATN)
C
C   CALCULATE NODAL LOADS IN RECTANGULAR COORDINATES (UNIFORM)
C
DO 140 I=1,19
  IF (I .LE. PBOTFAC) THEN
    PVERT(I)=PINV
  ELSE
    PVERT(I)=0.0
  ENDIF
  IF (I .GE. LATN .AND. I .LE. LATP) THEN
    PHORZ(I)=PLAT2-LSLOPE*(Y(I)-Y(LATN))
  ELSE
    PHORZ(I)=0.0
  ENDIF
140 CONTINUE
IF (PTOPFAC .EQ. 19) PVERT(19)=PTOP+PVERT(19)
DO 150 I=20,37
  IF (I .GE. PTOFAC) THEN
    PVERT(I)=PTOP
  ELSE
    PVERT(I)=0.0
  ENDIF
  IF (I .LE. LATP .AND. I .GE. LATN) THEN
    PHORZ(I)=PLAT2-LSLOPE*(Y(I)-Y(LATN))
  ELSE

```

```

        PHORZ(I)=0.0
    ENDIF
150 CONTINUE
C
C     CALCULATE RADIAL AND TANGENTIAL COMPONENTS OF NODAL LOADS (UNIFORM)
C
    DO 160 I=1,37
        SLPT(I,2)=PHORZ(I)*COS(A(I))*SI(I)+PVERT(I)*
1 SIN(A(I))*ABS(CO(I))
        SLPR(I,2)=PHORZ(I)*SIN(A(I))*SI(I)-PVERT(I)*COS(A(I))*
1 ABS(CO(I))
        IF (I .NE. 1) THEN
            SLPT(I,1)=PHORZ(I)*COS(A(I))*SI(I-1)+PVERT(I)*
1 SIN(A(I))*ABS(CO(I-1))
            SLPR(I,1)=PHORZ(I)*SIN(A(I))*SI(I-1)-PVERT(I)*COS(A(I))*
1 ABS(CO(I-1))
        ENDIF
160 CONTINUE
C
C     CALCULATE TRANSITION LOADS AT POINTS OF INSTANTANEOUS
C     CHANGE (UNIFORM)
C
    IF (PTOPFAC .EQ. 19 .AND. PBOTFAC .EQ. 19) THEN
        TRANSP(1,2,2)=PTOP*SIN(A(19))*ABS(CO(19))
        TRANSP(4,2,2)=PINV*SIN(A(19))*ABS(CO(19))
    ELSE
        TRANSP(1,2,2)=PHORZ(PBOTFAC)*COS(A(PBOTFAC))*SI(PBOTFAC)
        TRANSP(4,2,2)=PHORZ(PTOPFAC)*COS(A(PTOPFAC))*SI(PTOPFAC-1)
    ENDIF
    TRANSP(1,2,1)=PHORZ(PBOTFAC)*SIN(A(PBOTFAC))*SI(PBOTFAC)
    IF (LATN .NE. 1) THEN
        TRANSP(2,2,2)=PVERT(LATN)*SIN(A(LATN))*ABS(CO(LATN-1))
        TRANSP(2,2,1)=-PVERT(LATN)*COS(A(LATN))*ABS(CO(LATN-1))
    ENDIF
    TRANSP(3,2,2)=PVERT(LATP)*SIN(A(LATP))*ABS(CO(LATP))
    TRANSP(3,2,1)=-PVERT(LATP)*COS(A(LATP))*ABS(CO(LATP))
    TRANSP(4,2,1)=PHORZ(PTOPFAC)*SIN(A(PTOPFAC))*SI(PTOPFAC-1)
    JTRANS(2,1)=PBOTFAC
    JTRANS(2,2)=LATN
    JTRANS(2,3)=LATP
    JTRANS(2,4)=PTOPFAC
    IF (TYPE .EQ. 2.0) GO TO 180
C
C     RADIAL SOIL PRESSURE DISTRIBUTION
C
170 CONTINUE
    C=SIN((PI/B-1.)*B/2.)/2./(PI/B-1.)
    D=SIN((PI/B+1.)*B/2.)/2./(PI/B+1.)
    PINV=W/2./R3/(C+D)
    A9=PI-BS/2.
    E=SIN((PI/2./A9-1.)*A9)/2./(PI/2./A9-1.)
    F=SIN((PI/2./A9+1.)*A9)/2./(PI/2./A9+1.)
    PTOP=W/2./R3/(E+F)
180 CONTINUE
    DO 100 I=1,37
        DEG(I) = (I-1) * 5.00000

```

```

IF (I .EQ. 1) GO TO 225
IF (I .EQ. 37) GO TO 101
GO TO 250
225 CONTINUE
C                                     DEAD LOAD
C DLPR = DEAD LOAD - NORMAL PRESSURE
C DLPT = DEAD LOAD - TANGENTIAL PRESSURE
C
DLPR(1,1)=-TH*GAMAC/144000.0
DLPR(1,2)=DLPR(1,1)
DLPR(37,1)=-DLPR(1,1)
DLPR(37,2)=DLPR(37,1)
DLPT(1,1)=0.0
DLPT(37,1)=0.0
DREAC(I)=0.0
DLPT(1,2)=DLPT(1,1)
DLPT(37,2)=DLPT(37,1)
GO TO 101
250 CONTINUE
DLPR(I,1)=DLPR(1,1)*COS(A(I))
DLPT(I,1)=DLPR(37,1)*SIN(A(I))
DLPR(I,2)=DLPR(I,1)
DLPT(I,2)=DLPT(I,1)
101 CONTINUE
DQ(I)=DLPR(I,1)*COS(A(I))-DLPT(I,1)*SIN(A(I))
IF (I .LT. 2) THEN
  DB7=0.0000
ELSE
  DB7=DB7+(DQ(I)+DQ(I-1))/2.*ALEN(I-1)
ENDIF
PW=TH*GAMAC*ALEN(I)*2./144000.+PW
C
C   ADJUST DEAD LOAD PRESSURES TO ACCOUNT FOR REACTION PRESSURES
C
C   TRANSITION JOINT DEAD LOAD CALCULATION (IF BANGLE > 0),
C   (UNIFORM)
C
IF (TYPE .EQ. 1. .OR. DLUBED .EQ. 0.0) GO TO 108
DLX1=(DLUBED/100.)*(U+RADO1)
DO 710 II=2,19
  IF (X(II) .GT. DLX1 .AND. X(II-1) .LT. DLX1) THEN
    DLX2=X(II-1)
    LTRANS=II-1
  ELSEIF (X(II) .EQ. DLX1) THEN
    DLX2=DLX1
    LTRANS=II
  ENDIF
710 CONTINUE
IF (DLX1 .GT. X(19)) THEN
  DLX2=X(19)
  LTRANS=19
ENDIF
TRANSP(1,1,1)=DLPR(LTRANS,2)
TRANSP(1,1,2)=DLPT(LTRANS,2)
JTRANS(1,1)=LTRANS
C

```

```

C      END OF TRANSITION JOINT LOAD CALCULATION
C
108  CONTINUE
      IF (TYPE .EQ. 2.0) GO TO 20
C
C      SOIL LOAD (RADIAL)
C      SLPR = SOIL - NORMAL PRESSURE
C      SLPT = SOIL - TANGENTIAL PRESSURE
C
      SLPT(I,1)=0.0
      SLPT(I,2)=0.0
      IF (A(I) .GT. (B/2.)) GO TO 300
      SLPR(I,1)=PINV*COS(PI/B*A(I))
      SLPR(I,2)=SLPR(I,1)
      GO TO 350
300  CONTINUE
      IF ( A(I) .GT. BS/2.) GO TO 310
      SLPR(I,1)=0.0
      SLPR(I,2)=0.0
      GO TO 350
310  SLPR(I,1)=PTOP*SIN(0.5*(A(I)-BS/2.)*(PI/A9))
      SLPR(I,2)=SLPR(I,1)
350  CONTINUE
      Q(I)=SLPR(I,1)*COS(A(I))
      IF (I .EQ. 1) GO TO 200
      IF (A(I) .GT. B/2.) GO TO 400
      B2=(Q(I)+Q(I-1))/2.*ALEN(I-1)+B2
      GO TO 200
400  CONTINUE
      B4=(Q(I)+Q(I-1))/2.*ALEN(I-1)+B4
200  CONTINUE
C
C      FLUID LOAD
C      FLPR = FLUID NORMAL PRESSURE
C      FLPT = FLUID TANGENTIAL PRESSURE
C
20  CONTINUE
      FLPR(I,1)=(FS-(Y(I)+TH/2.*COS(A(I))))*GAMAF/144000.0*(-1.0)
      IF (FLPR(I,1) .GT. 0.0) FLPR(I,1)=0.0
      FLPT(I,1)=0.0
      FLPT(I,2)=0.0
      Preact(I) = 0.0
      T(I)=FLPR(I,1)*COS(A(I))
      LF = RAD12/RADM2
      IF (A(I) .GT. (PI-ATAN(U/V))) GO TO 107
      IF (A(I) .GT. ATAN(U/V)) LF=RAD11/RADM1
107  CONTINUE
      FLPR(I,1)=FLPR(I,1)*LF
      FLPR(I,2)=FLPR(I,1)
      IF (I .LT. 2) THEN
          B7=0.0000
      ELSE
          B7=(T(I)+T(I-1))/2.*ALEN(I-1)*LF+B7
      ENDIF
100  CONTINUE
C
C      ADJUST DEAD LOAD PRESSURES TO ACCOUNT FOR REACTION PRESSURES
C      FOR UNIFORM LOAD CASE

```

C

```
IF (TYPE .EQ. 1.0) GO TO 549
IF (DLUBED .EQ. 0.0) GO TO 7778
DO 7777 I=1,19
  IF (I .GT. LTRANS) GO TO 7777
  DREACT=PW/(2.*DLX2)
  IF (I .NE. 1) THEN
    DLPR(I,1)=DLPR(I,1)+DREACT*COS(A(I))*ABS(CO(I-1))
    DLPT(I,1)=DLPT(I,1)-DREACT*SIN(A(I))*ABS(CO(I-1))
  ENDIF
  DLPR(I,2)=DLPR(I,2)+DREACT*COS(A(I))*ABS(CO(I))
  DLPT(I,2)=DLPT(I,2)-DREACT*SIN(A(I))*ABS(CO(I))
7777 CONTINUE
GO TO 7778
```

C

C ADJUST DEAD LOAD FOR REACTION AND BALANCE (RADIAL)

C

```
549 CONTINUE
IF (DLBED .EQ. 0.) GO TO 7778
DO 3612 I=2,19
  THET=A(I)
  IF(RADM1.EQ.RADM2.AND.DLBED.EQ.2*A(I)*179.9/PI) THEN
    BANGLE=2*A(I)-.01
    GOTO 3399
  ELSE
    AA=RADM2*COS(THET)-V
    IF ( A(I) .GT. ATAN(U/V)) AA=RADM1*COS(THET)
    ALPH=2.*(ATAN(X(I)/AA))*180./PI+2.
  ENDIF
  IF (DLBED .LT. ALPH) GO TO 3319
3612 CONTINUE
3319 IF(I.EQ.20) THEN
  BANGLE=2*A(I-1)-.01
  ELSE
  BANGLE=2*A(I-1)
  ENDIF
3399 IF (BANGLE .EQ. 0.) GO TO 7778
C=SIN((PI/BANGLE-1.)*BANGLE/2.)/2./(PI/BANGLE-1.)
D=SIN((PI/BANGLE+1.)*BANGLE/2.)/2./(PI/BANGLE+1.)
DBOT=-DB7/R3/(C+D)/2.
DO 3010 J=1,37
  IF (A(J) .GT. (BANGLE/2.)) GO TO 3010
  DREAC(J)=DBOT*COS(A(J)*PI/BANGLE)
  DS(J)=DREAC(J)*COS(A(J))
  IF (J .EQ. 1) GO TO 3010
  DB8=(DS(J)+DS(J-1))/2.*ALEN(J-1)+DB8
3010 CONTINUE
DF1=-DB8/DB7
DO 3030 K=1,37
  DLPR(K,1)=DLPR(K,1)+DREAC(K)/DF1
  DLPR(K,2)=DLPR(K,1)
3030 CONTINUE
7778 CONTINUE
```

C

C

ADJUST FLUID PRESSURES TO ACCOUNT FOR REACTION PRESSURE (UNIFORM)

C

```

IF (TYPE .EQ. 2.0) THEN
C
C      TRANSITION JOINT FLUID LOAD CALCULATION
C
      TRANSP(1,3,1) = FLPR(PBOTFAC,2)
      TRANSP(1,3,2) = FLPT(PBOTFAC,2)
      JTRANS(3,1) = PBOTFAC
C
C      END OF TRANSITION JOINT LOAD CALCULATION
C
      DO 25 I=1,19
        IF (X(I) .LE. NBOTX) THEN
          FREACT = -B7/NBOTX
          IF (I .NE. 1) THEN
            FLPT(I,1) = FLPT(I,1) - FREACT*SIN(A(I))*ABS(CO(I-1))
            FLPR(I,1) = FLPR(I,1) + FREACT*COS(A(I))*ABS(CO(I-1))
          ENDIF
          FLPT(I,2) = FLPT(I,2) - FREACT*SIN(A(I))*ABS(CO(I))
          FLPR(I,2) = FLPR(I,2) + FREACT*COS(A(I))*ABS(CO(I))
        ENDIF
25      CONTINUE
      ENDIF
      IF (TYPE .EQ. 2.0) GO TO 1305
C
C      ADJUST SOIL AND FLUID PRESSURES FOR BALANCE (RADIAL)
C
      IF (W .EQ. 0.0) GO TO 550
      B5 = B2/W*2.
      B6 = B4*(-2.0)/W
550    PBOT = -B7/R3/(C+D)
      DO 500 J=1,37
        IF (A(J) .GT. (B/2.)) GO TO 600
        SLPR(J,1) = SLPR(J,1)/B5
        PREACT(J) = PBOT*(COS(A(J)*PI/B))
        S(J) = PREACT(J)*COS(A(J))
        GO TO 700
600    CONTINUE
        SLPR(J,1) = SLPR(J,1)/B6
700    CONTINUE
        SLPR(J,2) = SLPR(J,1)
        IF (J .EQ. 1) GO TO 500
        IF (A(J) .GT. B/2.) GO TO 500
        B8 = (S(J) + S(J-1))/2.*ALEN(J-1) + B8
500    CONTINUE
        IF (B7 .NE. 0) F1 = -B8/B7
        DO 1300 K=1,37
          FLPR(K,1) = FLPR(K,1) + PREACT(K)/F1
          FLPR(K,2) = FLPR(K,1)
1300   CONTINUE
1305   CONTINUE
        PLAT1 = PLAT11/12000.
        PLAT2 = PLAT22/12000.
        PTOP = PPTOP/12000.
        RETURN
      END

```

**Subroutine:** LOADS2

**Function:**

This subroutine calculates the normal and tangential pressures (kips/in./ft of pipe) on each joint due to live loads.

**I/O Generated by Subroutine:**

When Output Option 3 or greater is selected, a list of the normal and tangential forces applied to each node are printed.

**Error Messages Generated by Subroutine:**

None

SUBROUTINE LOADS2

C

```

COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R
1,FPF,P0RT,THP
COMMON/COORD/X(37),Y(37),A(37),B,BS
COMMON/PROP/SI(37),CO(37),ALEN(37)
COMMON/ISCALE/IDBUG,IPATH
COMMON/IFLAG/IBDATA(40)
COMMON/PRESS/DLPR(37,2),DLPT(37,2),SLPR(37,2),SLPT(37,2),
1FLPR(37,2),FLPT(37,2),WLPR(37,2),WLPT(37,2)
COMMON/BED/DLBED,DLUBED
COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,
1 LATPC,PTOP,SYST
COMMON/TRANS1/JTRANS(4,4),TRANSP(4,4,2)
COMMON/TRANS2/PTOPFAC,PBOTFAC,LATP,LATN,LTRANS,DIST,LLTOPI
COMMON/ALIVE/LLTYPE,VMAG,RLEN,RWID
COMMON/LD2/NBOTX
COMMON/WEIGHT/W,PW,B7,SPPW,FW,SPFW,LDFQ
COMMON/FILE/III,IP,ISTRP
COMMON/FACT/FLLNP,FLMVLP
DIMENSION DEG(37)
DIMENSION Q(37),PRACT(37),T(37),S(37)
DIMENSION PVERT(37),PHORZ(37)
REAL L,LF,NLAY,LDF,LDFQ,LVLD,LVLDINT,H3,H4,LVLT,LWH
REAL NTOPX,NLATN,NLATP,LSLOPE,LATPC
INTEGER T JOINT
INTEGER PTOFAC,PBOTFAC
DOUBLE PRECISION XLL1,XLL2,WLTOP,WLINV,WL,NBOTX
DOUBLE PRECISION DLPR,DLPT,SLPT,SLPR,WLPT,WLPR,FLPT,FLPR

```

C

```

IF(IP.NE.1) THEN
XXX1 = FLMVLL
XXX2 = FLMV
XXX3 = FLNLL
XXX4 = FLN
XXX5 = RLEN
FLMVLP = FLMVLL
FLLNP = FLNLL
ENDIF
IF(IP.EQ.1) THEN
FLMVLL = XXX1
FLMV = XXX2
FLNLL = XXX3
FLN = XXX4
RLEN = XXX5
ENDIF
B2 = 0.0
B4 = 0.0
B8 = 0.0
B5 = 1.0
B6 = 1.0
BL1 = 0.0
BL2 = 0.0
BL3 = 0.0

```



BL4=0.0  
PI=3.1415926535897  
AL1=0.0  
AL2=0.0  
LWH=0.0  
WWH=0.0  
XZR=0.0  
LVLD=0.0  
LVLDINT=0.0  
PL=0.0  
H1=0.0  
H2=0.0

C  
C  
C  
C  
C  
C  
C  
C  
C  
C  
C  
C

LIVE LOAD; IF LLTYPE = 1 THEN NONE  
                  = 2 THEN OTHER (USER DEFINED)  
                  = 3 THEN HS-SERIES  
                  = 4 THEN INTERSTATE  
                  = 5 THEN COOPER E-SERIES

CALCULATE WHEEL LOAD, AL1, AND AL2  
WHERE: AL1 = LENGTH ALONG DIAMETER OF PIPE (FT.)  
          AL2 = LENGTH ALONG AXIS OF PIPE (IN.)

DO 405 I=1,37  
      WLPR(I,1)=0.0  
      WLPT(I,1)=0.0  
      WLPR(I,2)=0.0  
      WLPT(I,2)=0.0

405 CONTINUE  
      SPANO=2.\*(RADI1+U+TH)/12.  
      SPANI=2.\*(RADI1+U-TH)/12.  
      ROUT=RADI1+U+TH

C  
C  
C  
C  
C  
C  
C  
C

GO TO APPROPRIATE LIVE LOAD CALCULATION  
GO TO (740,440,410,410,430),LLTYPE

COMPUTE AASHTO BETA FACTOR

410 BFCT=FLMVLL/FLMV  
      BFCTN=FLNLL/FLN

C  
C  
C

TIRE FOOTPRINT (FEET)

WWH=1.667  
LWH=8\*BFCT/12.

C  
C  
C

DETERMINE DEPTH AT WHICH CONDITION B GOVERNS LIVELOAD

HGOV=((42+WWH)\*BFCT-4\*(6+WWH))/(7-1.75\*BFCT)

C  
C  
C  
C  
C

REDUCE LIVE LOAD FACTOR FOR (H+0.75\*O.D.) FROM (2.48 TO HGOV) FEET  
BY REDUCING BETA FROM BFCT TO 1.0  
FOR (H+0.75\*O.D.) GREATER THAN HGOV LIVELOAD FACTOR IS FLMV

```

IF ((H+0.75*SPANO) .GT. 2.48) THEN
  FCT=1+(BFCT-1)*(H+0.75*SPANO-2.48)/(HGOV-2.48)
  FCTN=1+(BFCTN-1)*(H+0.75*SPANO-2.48)/(HGOV-2.48)
  FLMVLL=FLMVLL/FCT
  IF ( (H+.75*SPANO) .GT. HGOV ) FLMVLL=FLMV
  FLNLL=FLNLL/FCTN
  IF ( (H+.75*SPANO) .GT. HGOV ) FLNLL=FLN
ENDIF

C
C
C
SET AL2 - LOAD DISTRIBUTION PARALLEL TO CULVERT FLOW

AL2=WWH+1.75*H+1.3125*SPANO
IF ((H+.75*SPANO) .GT. 2.48) AL2=(42+WWH+1.3125*SPANO+1.75*H)/8.

C
C
C
HS-20 TRUCK LOAD

PL=16.0*VMAG/20.
AL1=(1.75*H+LWH)*12.
IF (H .GT. (8-LWH/1.75)) THEN
  PL=(32.-8.593*((H-(8-LWH/1.75))/(2.+LWH/1.75)))*VMAG/20.
  AL1=336.+(0.875*(H-(8-LWH/1.75))+LWH)*12.
ENDIF
IF (H .GT. 10.0) THEN
  PL=36.0*VMAG/20.
  AL1=336.+(1.75*H+LWH)*12.
ENDIF
LVLD=PL/AL1/AL2*SPANO*12.
IF ( AL1/12. .LT. SPANO ) LVLD=PL/AL2

C
C
C
C
C
C
H1=DEPTH TO WHERE LOAD SPREAD IS TANGENT TO PIPE (IN.)
H2=DEPTH TO WHERE LOAD SPREAD AT CROWN EQUALS PIPE O.D. (IN.)
XZR=WIDTH OF TIRE PRINT AT GROUND SURFACE/2.0
XH1=HORZ DIST FROM PIPE CENTERLINE TO LOAD/PIPE TANGENT POINT

XZR=12.*LWH/2.
H2=(ROUT-XZR)/0.875
H1=0.5186*ROUT-(XZR/.875)
IF (LLTYPE .EQ. 3) GO TO 425

C
C
C
INTERSTATE TRUCK LOAD

PLINT=24.0
AL1INT=48.+(1.75*H+LWH)*12.
IF (H .GT. (8-(2+LWH)/1.75) ) THEN
  PLINT=24.
  AL1INT=192.+(0.875*(H-(8-(2+LWH)/1.75))+LWH)*12.
ENDIF
IF (H .GT. (8-LWH/1.75)) THEN
  PLINT=24.-6.526*((H-(8-LWH/1.75))/(2+LWH/1.75))
  AL1INT=204.+(0.875*(H-(8-LWH/1.75))+LWH)*12.
ENDIF
IF (H .GT. 10.0) THEN
  PLINT=44.0
  AL1INT=360.+(1.75*H+LWH)*12.
ENDIF
LVLDINT=PLINT/AL1INT/AL2*SPANO*12.

```

```

IF (AL1INT/12. .LT. SPANO ) LVLDINT=PLINT/AL2
C
C   DETERMINE IF HS-20 OR INTERSTATE GOVERNS
C
IF ( LVLDINT .GT. LVLD) THEN
  PL=PLINT
  AL1=AL1INT
  XZR=24.+LWH*12./2
  H2=(ROUT-XZR)/0.875
  H1=.5186*ROUT-XZR/.875
ENDIF
425 CONTINUE
  AIMP=1.3
  IF (H .GT. 1.0) AIMP=1.2
  IF (H .GT. 2.0) AIMP=1.1
  IF (H .GE. 3.0) AIMP=1.0
  PL=AIMP*PL
  GO TO 460
C
C   COOPER E-80 TRAIN LOAD
C
430 CONTINUE
  PL=VMAG
  AL2=5.0
  AIMP=1.4-0.04*H
  AL1=(4.44+1.34*H)*12.
  IF(H.LT.10.0) GO TO 432
431 AIMP=1.
  AL1=(-3.64+2.14*H)*12.
432 PL=AIMP*PL/(AL1*AL2)
  WL=PL
  BLL=PI
  GO TO 470
C
C   USER DEFINED LIVE LOAD - NO IMPACT FACTOR IS APPLIED
C
440 CONTINUE
  PL=VMAG
  AL1=RLEN
  AL2=RWID/12.0
  XZR=0.0
  H2=ROUT/0.875
  H1=0.5186*ROUT
460 CONTINUE
  PL=PL/(AL1*AL2)
  HIN=H*12.
  IF (LLTYPE .EQ. 2) HIN=RLEN/1.75
C
C   CALCULATE LOAD DISTRIBUTION ON CIRCULAR PIPE
C
IF (RADM2.EQ.RADM1) THEN
  IF (H1 .EQ. 0.) H1=0.000009
  IF (H2 .EQ. 0.) H2=0.00001
  WL=PL
  BLL=PI
  IF (HIN .LT. H2) THEN

```

```

      BLL=(97.628+82.372*(HIN-H1)/(H2-H1))*PI/180.
    ENDIF
    IF (HIN .LT. H1) THEN
      ANGZR=ASIN(XZR/ROUT)
      BLL=2*((.85196-ANGZR)*HIN/H1+ANGZR)
    ENDIF
    GO TO 470
  ENDIF

```

C  
C  
C

FOR ELLIPTICAL PIPE:

```

    RADO1=RADI1+TH
    RADO2=RADI2+TH
    IF (ATAN(U/V)*180./PI .GE. 48.814) THEN
      H1=0.5186*RADO2-XZR/0.875
    ELSE
      VERTT=(0.7526*RADO1+U)/0.875
      H1=VERTT+0.6585*RADO1-(RADO2-V)-XZR/0.875
    ENDIF
    WL=PL
    BLL=PI
    IF (HIN .LT. H2) THEN
      BLL=97.628+82.372*(HIN-H1)/(H2-H1)
    ENDIF
    IF (HIN .LT. H1) THEN
      ANGZR=ASIN(XZR/RADO2)
      BLL=2*((.85196-ANGZR)*HIN/H1+ANGZR)
    ENDIF
  470 CONTINUE

```

C  
C  
C

RADIAL LIVE LOAD PRESSURE DISTRIBUTION

```

  IF (TYPE .EQ. 1.0) THEN
    IF (BLL .LT. PI) THEN
      MFLAG=0
      DO 481 I=20,37
        IF (MFLAG .GT. 0) GO TO 480
        IF (BLL .GE. 2.*(ATAN(ABS(X(I)/Y(I)))) THEN
          MFLAG=1
          IF (I .NE. 37) THEN
            BLL=2.*(ATAN(ABS(X(I)/Y(I))))
            WL=WL*AL1/(2.*X(I))
            WLL=WL*2.*X(I)
          ELSE
            IF (IP.EQ.1) WRITE(III,474)
            474 FORMAT(/,14X,50(1H*),/,14X,1H*,48X,1H*,/,14X,1H*,18X,
1              7HWARNING,23X,1H*,/,14X,1H*,48X,1H*,/,14X,1H*,5X,
2              38HCALCULATED LIVE LOAD APPLICATION ANGLE,5X,1H*,/,
3              14X,1H*,4X,
4              40HIS LESS THAN 10 DEG. DESIGN IS PERFORMED,4X,1H*,/,
5              14X,1H*,4X,41HFOR LIVE LOAD APPLICATION EQUAL TO 10 DEG
6              ,3X,1H*,/,14X,50(1H*))
            BLL=0.08727
            IF (LLTYPE .EQ. 2) RLEN=1E10
            WL=WL*AL1/(2.*X(36))
            WLL=WL*2.*X(36)
          ENDIF
        ENDIF
      END DO
    ENDIF
  ENDIF

```

```

        ENDIF
        ENDIF
480    CONTINUE
481    CONTINUE
    ELSE
        WL=WL*(U+RADI1+TH)/(U+RADM1)
        WLL=WL*2.*(U+RADM1)
    ENDIF
    IF (BLL .EQ. PI) BLL=179.999*PI/180.
    C=SIN((PI/B-1.)*B/2.)/2./(PI/B-1.)
    D=SIN((PI/B+1.)*B/2.)/2./(PI/B+1.)
    WLINV=WLL/2./R3/(C+D)
    E=SIN((PI/BLL-1.)*BLL/2.)/2./(PI/BLL-1.)
    F=SIN((PI/BLL+1.)*BLL/2.)/2./(PI/BLL+1.)
    WLTOP=WLL/2./R3/(E+F)
    DO 488 I=1,37
        IF (A(I) .GT. (B/2.)) GO TO 482
        WLPR(I,1)=WLINV*COS(PI/B*A(I))
        WLPR(I,2)=WLPR(I,1)
        GO TO 486
482    CONTINUE
        IF (A(I) .GE. (PI-BLL/2.)) GO TO 484
        WLPR(I,1)=0.0
        WLPR(I,2)=0.0
        GO TO 486
484    ABLL=PI-BLL/2.
        WLPR(I,1)=WLTOP*SIN(0.5*(A(I)-ABLL)*(2.*PI/BLL))
        WLPR(I,2)=WLPR(I,1)
486    CONTINUE
        Q(I)=WLPR(I,1)*COS(A(I))
        IF (I .EQ. 1) GO TO 489
        IF (A(I) .GT. B/2.) GO TO 487
        B2=(Q(I)+Q(I-1))/2.*ALEN(I-1)+B2
        GO TO 489
487    CONTINUE
        B4=(Q(I)+Q(I-1))/2.*ALEN(I-1)+B4
489    CONTINUE
488    CONTINUE
    ENDIF

```

```

C
C UNIFORM LIVE LOAD PRESSURE DISTRIBUTION
C

```

```

    IF (TYPE .EQ. 2.0) THEN
        IF (BLL .EQ. PI) THEN
            XLL1=ROUT
            XLL2=X(19)
            WLTOP=WL*XLL1/XLL2
            WLL=WL*XLL1*2.
            LLTOPI=19
        ELSE
            M=0
            DO 492 I=20,37
                IF (M .GT. 0) GO TO 490
                IF (BLL .GE. (2*ATAN(ABS(X(I)/Y(I)))) THEN
                    M=1
                    IF (I .NE. 37) THEN

```

```

        XLL1=AL1/2.
        XLL2=X(I)
        WLTOP=WL*XLL1/XLL2
        WLL=WL*XLL1*2.
        LLTOPI=I
        BLL=2.*(ATAN(ABS(X(I)/Y(I))))
    ELSE
        IF(IP.EQ.1) WRITE(III,474)
        BLL=0.08727
        IF (LLTYPE .EQ. 2) RLEN=1E10
        XLL1=AL1/2.
        XLL2=X(36)
        WLTOP=WL*XLL1/XLL2
        WLL=WL*XLL1*2.
        LLTOPI=36
    ENDIF
ENDIF
490 CONTINUE
492 CONTINUE
ENDIF
WLINV=WL*XLL1/NBOTX
DO 610 I=1,19
    IF (I .LE. PBOTFAC) THEN
        IF (I .NE. 1) THEN
            WLPT(I,1)=-WLINV*SIN(A(I))*CO(I-1)
            WLPR(I,1)=WLINV*COS(A(I))*ABS(CO(I-1))
        ENDIF
        WLPT(I,2)=-WLINV*SIN(A(I))*CO(I)
        WLPR(I,2)=WLINV*COS(A(I))*ABS(CO(I))
    ELSE
        WLPT(I,1)=0.0
        WLPR(I,1)=0.0
        WLPT(I,2)=0.0
        WLPR(I,2)=0.0
    ENDIF
610 CONTINUE
    IF (LLTOPI .EQ. 19) THEN
        WLPT(19,1)=WLPT(19,1)+WLTOP*ABS(CO(18))
        WLPT(19,2)=WLPT(19,2)+WLTOP*ABS(CO(19))
    ENDIF
DO 620 I=20,37
    IF (I .GE. LLTOPI) THEN
        WLPT(I,1)=WLTOP*SIN(A(I))*ABS(CO(I-1))
        WLPR(I,1)=WLTOP*ABS(COS(A(I)))*ABS(CO(I-1))
        WLPT(I,2)=WLTOP*SIN(A(I))*ABS(CO(I))
        WLPR(I,2)=WLTOP*ABS(COS(A(I)))*ABS(CO(I))
    ELSE
        WLPT(I,1)=0.0
        WLPR(I,1)=0.0
        WLPT(I,2)=0.0
        WLPR(I,2)=0.0
    ENDIF
620 CONTINUE
ENDIF
499 CONTINUE
JTRANS(4,1)=PBOTFAC

```

```

JTRANS(4,4) = LLTOPI
  IF (PBOFAC .EQ. 19 .AND. LLTOPI .EQ. 19) THEN
    TRANSP(1,4,2) = WLTOP*SIN(A(19))*ABS(CO(19))
    TRANSP(4,4,2) = -WLINV*SIN(A(19))*ABS(CO(19))
  ELSE
    TRANSP(1,4,1) = 0.0
    TRANSP(1,4,2) = 0.0
    TRANSP(4,4,1) = 0.0
    TRANSP(4,4,2) = 0.0
  ENDIF
C
C ADJUST WHEEL PRESSURES FOR BALANCE (RADIAL)
C
  IF (TYPE .EQ. 2.0) GO TO 740
  IF (WLL .EQ. 0.0) GO TO 740
  B5 = B2/WLL*2.
  B6 = B4*(-2.0)/WLL
  DO 710 J = 1,37
    IF (A(J) .GT. (B/2.)) GO TO 720
    WLPR(J,1) = WLPR(J,1)/B5
    WLPR(J,2) = WLPR(J,1)
    GO TO 730
720  CONTINUE
    WLPR(J,1) = WLPR(J,1)/B6
    WLPR(J,2) = WLPR(J,1)
730  CONTINUE
710  CONTINUE
740  CONTINUE
    IF (IDBUG .LT. 2) GO TO 3000
C
C PRINT LOADS TABLE
C
  IF (IP.EQ.1) WRITE(III,5000)
  IF (IP.EQ.1) WRITE(III,1400)
1400 FORMAT(///,22X,'PRESSURES AT EACH JOINT, KIPS/IN/FT',/)
  IF (IP.EQ.1) WRITE(III,1500)
1500 FORMAT(25X,4HDEAD,22X,4HSOIL)
  IF (IP.EQ.1) WRITE(III,1550)
1550 FORMAT(2X,'I',3X,8HDEG FROM,4X,2(19(1H-),8X))
  IF (IP.EQ.1) WRITE(III,1600)
1600 FORMAT(1X,'JT.',2X,8HVERTICAL,7X,6HRADIAL,4X,4HTANG,13X,6HRADIAL,
1 4X,4HTANG)
  IF (IP.EQ.1) WRITE(III,1700)(I,A(I)*180./PI,DLPR(I,2),DLPT(I,2),
1 SLPR(I,2),SLPT(I,2),I=1,18)
1700 FORMAT(1X,I2,5X,F4.0,6X,F9.4,1X,F9.4,8X,F9.4,1X,F9.4)
  I = 19
1710 FORMAT(1X,I2,5X,F4.0,6X,F9.4,1X,F9.4,8X,F9.4,1X,F9.4)
  IF (IP.EQ.1) WRITE(III,1710)I,A(I)*180./PI,(DLPR(I,2)+DLPR(I,1))/
12.,(DLPT(I,2)+DLPT(I,1))/2.,(SLPR(I,2)+SLPR(I,1))/2.,
1(SLPT(I,2)+SLPT(I,1))/2.
  IF (IP.EQ.1) WRITE(III,1720)(I,A(I)*180./PI,DLPR(I,1),DLPT(I,1),
1 SLPR(I,1),SLPT(I,1),I=20,37)
1720 FORMAT(1X,I2,5X,F4.0,6X,F9.4,1X,F9.4,8X,F9.4,1X,F9.4)
C
C
  IF (IP.EQ.1) WRITE(III,5000)

```

```

5000 FORMAT(1H1)
      IF(IP.EQ.1) WRITE(III,5100)
5100 FORMAT(///,22X,'PRESSURES AT EACH JOINT, KIPS/IN/FT',/)
      IF(IP.EQ.1) WRITE(III,5200)
5200 FORMAT(25X,'FLUID',22X,'LIVE')
      IF(IP.EQ.1) WRITE(III,5300)
5300 FORMAT(2X,'I',3X,'DEG FROM',4X,2(19(1H-),8X))
      IF(IP.EQ.1) WRITE(III,5400)
5400 FORMAT(1X,'JT.',2X,'VERTICAL',7X,'RADIAL',4X,'TANG',13X,'RADIAL'
1      ,4X,'TANG')
      IF(IP.EQ.1) WRITE(III,5500)(I,A(I)*180/PI,FLPR(I,2),FLPT(I,2),
1WLPR(I,2),WLPT(I,2),I=1,18)
5500 FORMAT(1X,I2,5X,F4.0,6X,F9.4,1X,F9.4,8X,F9.4,1X,F9.4)
      I=19
      IF(IP.EQ.1) WRITE(III,5510)I,A(I)*180./PI,(FLPR(I,2)+FLPR(I,1))/
12.,(FLPT(I,2)+FLPT(I,1))/2.,(WLPR(I,2)+WLPR(I,1))/2.,
1(WLPT(I,2)+WLPT(I,1))/2.
5510 FORMAT(1X,I2,5X,F4.0,6X,F9.4,1X,F9.4,8X,F9.4,1X,F9.4)
      IF(IP.EQ.1) WRITE(III,5520)(I,A(I)*180/PI,FLPR(I,1),FLPT(I,1),
1WLPR(I,1),WLPT(I,1),I=20,37)
5520 FORMAT(1X,I2,5X,F4.0,6X,F9.4,1X,F9.4,8X,F9.4,1X,F9.4)

```

C  
C

```

3000 CONTINUE
      IF (IDBUG .LT. 1 ) GO TO 4000
      IF(IP.EQ.1) WRITE(III,1800) PW
1800 FORMAT(//,15X,'*****TOTAL APPLIED LOADS ON PIPE*****',
1 //,22X,'PIPE WEIGHT  =',F9.3,' KIPS/FT')
      IF(IP.EQ.1) WRITE(III,1900) W
1900 FORMAT(/,22X,'SOIL WEIGHT  =',F9.3,' KIPS/FT')
      B7TMP = -2.0*B7
      IF(IP.EQ.1) WRITE(III,2000) B7TMP
2000 FORMAT(/,22X,'FLUID WEIGHT  =',F9.3,' KIPS/FT')
      IF(IP.EQ.1) WRITE(III,2005) WLL
2005 FORMAT(/,22X,'LIVE LOAD  =',F9.3,' KIPS/FT' )
4000 CONTINUE
      RETURN
      END

```



**Subroutine:** STIFF

**Function:**

This subroutine calculates the member stiffness matrices.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

SUBROUTINE STIFF

C  
C  
C CALCULATES MEMBER STIFFNESS SUBMATRICES

COMMON/PROP/SI(37),CO(37),ALEN(37)  
COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST  
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R  
1,FPF,P0RT,THP  
COMMON/ISCALE/IDBUG,IPATH  
COMMON/CONST/K1(3,3,36),K2(3,3,36),K12(3,3,36)  
COMMON/FILE/III,IP,ISTRP  
COMMON/FACT/FLLNP,FLMVLP  
DOUBLE PRECISION K1, K2, K12, MI

C  
AREA=12.\*TH  
MI=TH\*\*3  
DO 1120 I=1,36  
DO 1122 K=1,3  
DO 1123 L=1,3  
K12(L,K,I)=0.0  
K2(L,K,I)=0.0  
K1(L,K,I)=0.0  
1123 CONTINUE  
1122 CONTINUE  
1120 CONTINUE  
DO 100 I=1,36  
C1=ECON/ALEN(I)  
C2=MI/ALEN(I)\*\*2  
A1=C1\*(CO(I)\*\*2\*AREA+12.\*SI(I)\*\*2\*C2)  
A2=C1\*(SI(I)\*\*2\*AREA+12.\*CO(I)\*\*2\*C2)  
A3=C1\*SI(I)\*CO(I)\*(AREA-12.\*C2)  
A4=6.\*SI(I)\*ECON\*C2  
A5=A4/SI(I)\*CO(I)  
A6=4.\*MI\*C1  
K1(1,1,I)=A1  
K2(1,1,I)=A1  
K12(1,1,I)=-A1  
K1(1,2,I)=A3  
K1(2,1,I)=A3  
K2(1,2,I)=A3  
K2(2,1,I)=A3  
K12(1,2,I)=-A3  
K12(2,1,I)=-A3  
K1(1,3,I)=-A4  
K1(3,1,I)=-A4  
K12(1,3,I)=-A4  
K1(2,2,I)=A2  
K2(2,2,I)=A2  
K12(2,2,I)=-A2  
K1(2,3,I)=A5  
K1(3,2,I)=A5  
K12(2,3,I)=A5  
K2(2,3,I)=-A5  
K2(3,2,I)=-A5  
K12(3,2,I)=-A5

**Subroutine:** STIFF

**Function:**

This subroutine calculates the member stiffness matrices.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

SUBROUTINE STIFF

C  
C  
C CALCULATES MEMBER STIFFNESS SUBMATRICES

COMMON/PROP/SI(37),CO(37),ALEN(37)  
COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST  
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,PQR  
1,FPF,P0RT,THP  
COMMON/ISCALE/IDBUG,IPATH  
COMMON/CONST/K1(3,3,36),K2(3,3,36),K12(3,3,36)  
COMMON/FILE/III,IP,ISTRP  
COMMON/FACT/FLLNP,FLMVLP  
DOUBLE PRECISION K1, K2, K12, MI

C  
AREA=12.\*TH  
MI=TH\*\*3  
DO 1120 I=1,36  
DO 1122 K=1,3  
DO 1123 L=1,3  
K12(L,K,I)=0.0  
K2(L,K,I)=0.0  
K1(L,K,I)=0.0  
1123 CONTINUE  
1122 CONTINUE  
1120 CONTINUE  
DO 100 I=1,36  
C1=ECON/ALEN(I)  
C2=MI/ALEN(I)\*\*2  
A1=C1\*(CO(I)\*\*2\*AREA+12.\*SI(I)\*\*2\*C2)  
A2=C1\*(SI(I)\*\*2\*AREA+12.\*CO(I)\*\*2\*C2)  
A3=C1\*SI(I)\*CO(I)\*(AREA-12.\*C2)  
A4=6.\*SI(I)\*ECON\*C2  
A5=A4/SI(I)\*CO(I)  
A6=4.\*MI\*C1  
K1(1,1,I)=A1  
K2(1,1,I)=A1  
K12(1,1,I)=-A1  
K1(1,2,I)=A3  
K1(2,1,I)=A3  
K2(1,2,I)=A3  
K2(2,1,I)=A3  
K12(1,2,I)=-A3  
K12(2,1,I)=-A3  
K1(1,3,I)=-A4  
K1(3,1,I)=-A4  
K12(1,3,I)=-A4  
K1(2,2,I)=A2  
K2(2,2,I)=A2  
K12(2,2,I)=-A2  
K1(2,3,I)=A5  
K1(3,2,I)=A5  
K12(2,3,I)=A5  
K2(2,3,I)=-A5  
K2(3,2,I)=-A5  
K12(3,2,I)=-A5

```
K1(3,3,I) = A6  
K2(3,3,I) = A6  
K12(3,3,I) = 0.5*A6  
K2(1,3,I) = A4  
K2(3,1,I) = A4  
K12(3,1,I) = A4  
100 CONTINUE  
200 CONTINUE  
RETURN  
END
```

**Subroutine:** LDMATR

**Function:**

For each loading condition, this subroutine generates the load matrices for each joint from the member geometry and radial and tangential pressures.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

SUBROUTINE LDMATR(P,PT,K)

C  
C  
C  
C  
C  
C  
C  
C  
C

FOR EACH LOADING CONDITION, LDMATR GENERATES THE LOAD MATRICES  
FOR EACH JOINT FROM THE MEMBER PROPERTIES AND THE RADIAL AND  
TANGENTIAL PRESSURES. THE LDMATR VALUES, REPRESENT THE REACTIONS.  
AT EACH END OF A MEMBER DUE TO THE APPLIED LOADS

DIMENSION P(37,2),PT(37,2),INDEX(4)  
COMMON/COORD/X(37),Y(37),A(37),B,BS  
COMMON/PROP/SI(37),CO(37),ALEN(37)  
COMMON/LOAD/F1(3,4,36),F2(3,4,36)  
COMMON/TRANS1/JTRANS(4,4),TRANSP(4,4,2)  
COMMON/TRANS2/PTOPFAC,PBOTFAC,LATP,LATN,LTRANS,DIST,LLTOPI  
COMMON/ALIVE/LLTYPE,VMAG,RLEN,RWID  
COMMON/FILE/III,IP,ISTRP  
COMMON/FACT/FLLNP,FLMVLP  
INTEGER PTOPFAC,PBOTFAC  
DOUBLE PRECISION F1,F2,C1,C2,P,PT  
DOUBLE PRECISION PRB,PTB,PRE,PTE,PRTB,PTTB,PRTE,PTTE

C

PI=3.1415926535897  
CSN=COS(2.5\*PI/180.)  
SN=SIN(2.5\*PI/180.)  
DO 100 I=1,36  
  C1=SI(I)\*ALEN(I)  
  C2=CO(I)\*ALEN(I)  
  PRB=P(I,2)  
  PTB=PT(I,2)  
  PRE=P(I+1,1)  
  PTE=PT(I+1,1)  
  IF (DIST .EQ. 1.0) GO TO 200  
  IF (K .EQ. 1 .OR. K .EQ. 3) THEN  
    IF (I .EQ. JTRANS(K,1)) THEN  
      PRB=TRANSP(1,K,1)  
      PTB=TRANSP(1,K,2)  
    ENDIF  
  ENDIF  
  IF (K .EQ. 2) THEN  
    DO 110 J=1,3,2  
      IF (I .EQ. JTRANS(K,J)) THEN  
        PRB=TRANSP(J,K,1)  
        PTB=TRANSP(J,K,2)  
      ENDIF  
110  CONTINUE  
    DO 120 J=2,4,2  
      IF ((I+1) .EQ. JTRANS(K,J)) THEN  
        PRE=TRANSP(J,K,1)  
        PTE=TRANSP(J,K,2)  
      ENDIF  
120  CONTINUE  
  ENDIF  
  IF (K .EQ. 4) THEN  
    IF (I .EQ. JTRANS(K,1)) THEN  
      PRB=TRANSP(1,K,1)  
      PTB=TRANSP(1,K,2)

```

ENDIF
IF ((I+1) .EQ. JTRANS(K,4)) THEN
  PRE=TRANSP(4,K,1)
  PTE=TRANSP(4,K,2)
ENDIF
ENDIF
200 CONTINUE
PRTB=PRB*CSN+PTB*SN
PTTB=-PRB*SN+PTB*CSN
PRTE=PRE*CSN-PTE*SN
PTTE=+PRE*SN+PTE*CSN
F1(1,K,I)=C1/(-20.)*(7.*PRTB+3.*PRTE)-C2/8.*(3.*PTTB+
1 PTTE)
F1(2,K,I)=C2/20.*(7.*PRTB+3.*PRTE)-C1/8.*(3.*PTTB+PTTE)
F1(3,K,I)=ALEN(I)**2/60.*(3.*PRTB+2.*PRTE)
F2(1,K,I)=C1/(-20.)*(3.*PRTB+7.*PRTE)-C2/8.*(PTTB+
1 3.*PTTE)
F2(2,K,I)=C2/20.*(3.*PRTB+7.*PRTE)-C1/8.*(PTTB+3.*PTTE)
F2(3,K,I)=ALEN(I)**2/60.0*(2.*PRTB+3.*PRTE)*(-1.0)
100 CONTINUE
RETURN
END

```



**Subroutine:** RECUR

**Function:**

This subroutine solves for joint deflections and rotations recursively by assuming symmetric boundary conditions at the crown and invert and determining the deflection at the crown using the member load and stiffness matrices.

**I/O Generated by Subroutine:**

When Option 4 is selected joint displacements and rotations are printed for each load case.

**Error Messages Generated by Subroutine:**

None

SUBROUTINE RECUR

```

C
C ASSUMES THAT JOINT 1(INVERT) IS FIXED AND JOINT 37(CROWN) ONLY
C DEFLECTS IN THE Y-DIRECTION. GIVEN THESE BOUNDARY CONDITIONS AND
C THE LOAD AND STIFFNESS MATRICES THE DEFLECTION AT JOINT 37 IS
C CALCULATED AND ALL OTHER JOINT X,Y DEFLECTIONS AND ROTATIONS
C ARE SOLVED RECURSIVELY.
C A PRINTOUT OF THIS INFORMATION IS AVAILABLE WITH AN IDBUG VALUE
C EQUAL TO 3
COMMON/ISCALE/IDBUG,IPATH
COMMON/CONST/K1(3,3,36),K2(3,3,36) ,K12(3,3,36)
COMMON/LOAD/F1(3,4,36),F2(3,4,36)
COMMON/DISP/UN(3,4,37)
COMMON/FILE/III,IP,ISTRP
COMMON/FACT/FLLNP,FLMVLP
DOUBLE PRECISION K1, K2, K12, F1, F2, K12T(3,3)
DOUBLE PRECISION UN, P(3,3,37),Q(3,4,37),D(3),A(3,3),B(3,3)
DOUBLE PRECISION C(3,4),AA(3,4)
C
DO 100 I=1,3
DO 100 J=1,3
A(I,J)=K2(I,J,1)+K1(I,J,2)
C(I,J)=F2(I,J,1)+F1(I,J,2)
C(I,4)=F2(I,4,1)+F1(I,4,2)
100 CONTINUE
CALL MATINV(A,B)
CALL MATMPY(B,K12(1,1,2),P(1,1,2))
CALL MATMP2(B,C,Q(1,1,2),4)
DO 200 L=3,36
DO 300 I=1,3
DO 300 J=1,3
K12T(J,I)=K12(I,J,L-1)
300 CONTINUE
CALL MATMPY(K12T,P(1,1,L-1),A)
DO 400 I=1,3
DO 400 J=1,3
A(I,J) = K2(I,J,L-1) - A(I,J) + K1(I,J,L)
400 CONTINUE
CALL MATINV(A,B)
CALL MATMP2(K12T,Q(1,1,L-1),C,4)
DO 500 I=1,3
DO 500 J=1,4
C(I,J) = F2(I,J,L-1) - C(I,J) + F1(I,J,L)
500 CONTINUE
CALL MATMP2(B,C,Q(1,1,L),4)
IF (L .EQ. 36) GO TO 600
CALL MATMPY(B,K12(1,1,L),P(1,1,L))
GO TO 200
600 CONTINUE
D(1)=K12(1,2,L)
D(2)=K12(2,2,L)
D(3)=K12(3,2,L)
CALL MATXCO(D,B,P(1,1,36))
200 CONTINUE
DO 700 K=1,4
UN(1,K,37)=0.0D0

```

```

UN(3,K,37)=0.0D0
UN(2,K,37)=(K2(2,1,36)*Q(1,K,36) - K2(2,3,36)*Q(3,K,36) +
1      K2(2,2,36)*Q(2,K,36) + F2(2,K,36) ) /
2      (K2(2,1,36)*P(1,1,36) - K2(2,3,36)*P(3,1,36) +
3      K2(2,2,36)*(1.0D0 + P(2,1,36) ) )
UN(1,K,1)=0.00D0
UN(2,K,1)=0.00D0
UN(3,K,1)=0.0D0
UN(1,K,36)=-P(1,1,36)*UN(2,K,37)+Q(1,K,36)
UN(2,K,36)=-P(2,1,36)*UN(2,K,37)+Q(2,K,36)
UN(3,K,36)=-P(3,1,36)*UN(2,K,37)+Q(3,K,36)
700 CONTINUE
L=35
1000 CONTINUE
CALL MATMP2(P(1,1,L),UN(1,1,L+1),AA,4)
DO 800 I=1,3
DO 800 J=1,4
UN(I,J,L)=Q(I,J,L)-AA(I,J)
800 CONTINUE
L=L-1
IF (L .GE. 2) GO TO 1000
IF (IDBUG .LT. 3) GO TO 2500
C
C WRITES DISPLACEMENTS
C
IF(IP.EQ.1) WRITE(III,99)
99  FORMAT(1H1)
IF(IP.EQ.1) WRITE(III,2000)
IF(IP.EQ.1) WRITE(III,2001)
IF(IP.EQ.1) WRITE(III,2002)
DO 1200 L=1,37
IF(IP.EQ.1) WRITE(III,2100)L
DO 1200 I=1,3
GO TO (11,12,13),I
11  IF(IP.EQ.1) WRITE(III,1) (UN(I,J,L),J=1,4)
GO TO 1200
12  IF(IP.EQ.1) WRITE(III,2)(UN(I,J,L),J=1,4)
GO TO 1200
13  IF(IP.EQ.1) WRITE(III,3)(UN(I,J,L),J=1,4)
1200 CONTINUE
2000 FORMAT(//,30X,'DISPLACEMENTS, IN',/)
2001 FORMAT(34X,7HLOADING)
2002 FORMAT(14X,'1',15X,'2',15X,'3',15X,'4',/)
2100 FORMAT(6X,5HJOINT,2X,I2)
1  FORMAT(2X,'X',5X,4(E12.5,4X))
2  FORMAT(2X,'Y',5X,4(E12.5,4X))
3  FORMAT(1X,'ROT',4X,4(E12.5,4X))
2500 CONTINUE
RETURN
END

```

**Subroutine:** REACT

**Function:**

This subroutine calculates the moments, thrusts, and shears at the crown and invert joints.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

**WARNING** - Design not possible due to opposite sign moments at the crown, invert or springline.  
PIPECAR design capabilities are exceeded.

SUBROUTINE REACT

C  
C  
C  
C  
C

CALCULATES THE MOMENTS, THRUSTS AND SHEARS AT JOINT 1(INVERT) AND JOINT 37(CROWN)

COMMON/REACTI/REAC(3,4,2)  
COMMON/DESIGN/DMU(5),DPU(5),DVU(5),VLOC(5),DMS(5),DPS(5),DDES(5)  
COMMON/CONST/K1(3,3,36),K2(3,3,36),K12(3,3,36)  
COMMON/DISP/UN(3,4,37)  
COMMON/LOAD/F1(3,4,36),F2(3,4,36)  
COMMON/ISCALE/IDBUG,IPATH  
COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,  
1EST,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R  
1,FPF,P0RT,THP  
COMMON/SPSOIL/SAREA(7),SPK,SPU,SPV,SPM,SPA,SPFB,SPD,LDF,SPRADI,  
1  
1 INSTAL  
COMMON/WEIGHT/W,PW,B7,SPPW,FW,SPFW,LDFQ  
COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,  
1 LATPC,PTOP,SYST  
COMMON/PRES/HP,FP  
COMMON/FILE/III,IP,ISTRP  
COMMON/FACT/FLLNP,FLMVLP  
DOUBLE PRECISION K1, K2, K12, F1, F2, UN  
DOUBLE PRECISION REAC,T(3,3),B(3,4),C(3,4),LFS(4)  
REAL LDF,LDFQ

C

\*\*\*\*\* TGH \*\*\*\*\*

FP=-HP\*0.4335\*RADI1\*12.0/1000.0  
TENSTR=HP\*0.4335\*RADI1/TH  
IF(TENSTR.GT.4.5\*SQRT(FCP\*1000.)) THEN  
IF(IP.EQ.1) WRITE(III,1234) TENSTR  
WRITE(\*,1234) TENSTR  
1234 FORMAT(3X,'TENSILE STRESS OF ',F8.2,' psi DUE TO PRESSURE EXCEEDS  
14.5 x SQRT(Fc)',//)  
IPATH=1  
GOTO 999  
ELSE

GOTO 888

ENDIF

888 DO 17 I=1,5

DVU(I)=0.0

DPS(I)=0.0

DMS(I)=0.0

DPU(I)=0.0

DMU(I)=0.0

17 CONTINUE

C

CALL MATMP2(K12(1,1,1),UN(1,1,2),B,4)

DO 100 I=1,3

DO 100 J=1,4

REAC(I,J,1)=B(I,J)-F1(I,J,1)

100 CONTINUE

DO 200 I=1,3,2

T(1,1)=K12(1,1,36)

T(1,2)=K12(2,1,36)

```

T(1,3)=K12(3,1,36)
T(2,1)=0.00
T(2,2)=0.00
T(2,3)=0.00
T(3,1)=0.00
T(3,2)=0.00
T(3,3)=0.00
CALL MATMP2(T,UN(1,1,36),C,4)
DO 300 J=1,4
    REAC(I,J,2) = C(1,J) - F2(I,J,36) + K2(I,2,36)*UN(2,J,37)
300 CONTINUE
200 CONTINUE
DMS(1)=REAC(3,1,1)+REAC(3,2,1)
DPS(1)=REAC(1,1,1)+REAC(1,2,1)
DMU(1)=FLMV*DMS(1)
C ***** TGH ***** FP
DPU(1)=FLN*DPS(1)+FP*FPF
IF (DABS(DMS(1)+REAC(3,3,1)) .LT. ABS(DMS(1))) GO TO 700
DMS(1)=DMS(1)+REAC(3,3,1)
DPS(1)=DPS(1)+REAC(1,3,1)
DMU(1)=FLMV*DMS(1)
DPU(1)=FLN*DPS(1)+FP*FPF
700 IF (DABS(DMS(1)+REAC(3,4,1)) .LT. ABS(DMS(1))) GO TO 400
DMS(1)=DMS(1)+REAC(3,4,1)
DPS(1)=DPS(1)+REAC(1,4,1)
DMU(1)=DMU(1)+REAC(3,4,1)*FLMVLL
DPU(1)=DPU(1)+REAC(1,4,1)*FLNLL
400 DMS(5)=-REAC(3,1,2)-REAC(3,2,2)
DPS(5)=REAC(1,1,2)+REAC(1,2,2)
DMU(5)=DMS(5)*FLMV
C ***** TGH ***** FP
DPU(5)=DPS(5)*FLN+FP*FPF
IF (DABS(DMS(5)-REAC(3,3,2)) .LT. ABS(DMS(5))) GO TO 800
DMS(5)=DMS(5)-REAC(3,3,2)
DPS(5)=DPS(5)+REAC(1,3,2)
DMU(5)=DMS(5)*FLMV
DPU(5)=DPS(5)*FLN+FP*FPF
800 CONTINUE
IF (DABS(DMS(5)-REAC(3,4,2)) .LT. ABS(DMS(5))) GO TO 450
DMS(5)=DMS(5)-REAC(3,4,2)
DPS(5)=DPS(5)+REAC(1,4,2)
DMU(5)=DMU(5)-REAC(3,4,2)*FLMVLL
DPU(5)=DPU(5)+REAC(1,4,2)*FLNLL
450 CONTINUE
DO 801 J=1,4
    REAC(3,J,2) = -REAC(3,J,2)
801 CONTINUE
DO 907 K=1,4
    REAC(2,K,2)=0.0
907 CONTINUE
IF (DMU(1) .LE. 0. .OR. DMU(5) .LE. 0.)
    1 GO TO 6012
    GO TO 999
6012 IF(IP.EQ.1) WRITE(III,6015)
    WRITE(*,6015)
6015 FORMAT(8(/),14X,50(1H*),/,14X,1H*,48X,1H*,/,14X,1H*,18X,

```

17HWARNING,23X,1H\*,/,14X,1H\*,48X,1H\*,/,14X,1H\*,4X,  
240HDESIGN NOT POSSIBLE DUE TO OPPOSITE SIGN,4X,1H\*,/,14X,1H\*,3X,  
342HMOMENTS AT THE CROWN OR INVERT. ,3X,1H\*,/,14X,1H\*,  
448X,1H\*,/,14X,1H\*,4X,40HPIPECAR DESIGN CAPABILITIES ARE EXCEEDED  
5,4X,1H\*,/,14X,1H\*,48X,1H\*,/,14X,50(1H\*),/////)  
PAUSE , Press [Enter] to Continue'  
IPATH=1  
999 RETURN  
END

**Subroutine:** THSHMO

**Function:**

This subroutine calculates the thrusts, moments, and shears at each end of each member

**I/O Generated by Subroutine:**

When Output Option 2 or greater is selected, service load moments, thrusts, and shears are printed for each joint and load case.

**Error Messages Generated by Subroutine:**

None





```

9459 CONTINUE
      IF (IDBUG .LT. 2) GO TO 2
      IF(IP.EQ.1) WRITE(III,99)
99  FORMAT(1H1)
      IF(IP.EQ.1) WRITE(III,600)
2   CONTINUE
      DEG = 0.0
      DO 200 I=1,36
      T(1,1)=CO(I)
      T(1,2)=SI(I)
      T(1,3)=0.00
      T(2,1) = -SI(I)
      T(2,2)=CO(I)
      T(2,3)=0.00
      T(3,1)=0.00
      T(3,2)=0.00
      T(3,3)=1.00
      DO 300 L=1,3
      DO 300 M=1,3
      K12T(M,L) = K12(L,M,I)
300 CONTINUE
      CALL MATMP2(K1(1,1,I),UN(1,1,I),D,4)
      CALL MATMP2(K12(1,1,I),UN(1,1,I+1),E,4)
      CALL MATMP2(K12T(1,1),UN(1,1,I),R,4)
      CALL MATMP2(K2(1,1,I),UN(1,1,I+1),S,4)
      DO 400 J=1,3
      DO 400 K=1,4
      G(J,K) = D(J,K) - F1(J,K,I) + E(J,K)
      WW(J,K) = R(J,K) - F2(J,K,I) + S(J,K)
400 CONTINUE
      CALL MATMP2(T,G,PVM1(1,1,I),4)
      CALL MATMP2(T,WW,PVM2(1,1,I),4)
C
C   WRITE THRUSTS SHEARS AND MOMENTS
C
      IF (I .EQ. 1) GO TO 201
      J3 = 0
      DO 203 J1 = 1,4
      DO 203 J2 = 1,3
      J3 = J3 + 1
      A(J3) = (PVM1(J2,J1,I)-PVM2(J2,J1,I-1))/2.0000000
203 CONTINUE
      DEG=(I-1)*5.00000
      IF (IDBUG .GE. 2.AND.IP.EQ.1) WRITE(III,204) I,DEG,(A(J5),J5=1,6)
      GO TO 200
201 IF (IDBUG .GE. 2.AND.IP.EQ.1)
1  WRITE(III,204) I,DEG,(REAC(J6,1,1),J6=1,3),(REAC(J6,2,1),J6=1,3)
200 CONTINUE
      IF (IDBUG .LT. 2) GO TO 1200
      I=37
      DEG = 180.0
      IF(IP.EQ.1) WRITE(III,204) I,DEG,(REAC(J6,1,2),J6=1,3),
1  (REAC(J6,2,2),J6=1,3)
600 FORMAT(//,30X,'SERVICE LOAD FORCES',/,12X,'N=THRUST(KIPS/FT)', ',
1'V=SHEAR(KIPS/FT), M=MOMENT(IN.KIPS/FT)',//,27X,'DEAD LOAD',23X,
2 'SOIL LOAD',/,7X,'DEG FROM',1X,30(1H-),2X,30(1H-),

```

```

3 /,' JOINT',1X,'VERTICAL',7X,'N',9X,'V',9X,'M',11X,'N',9X,
4 'V',9X,'M')
204 FORMAT(2X,I2,5X,F4.0,3X,3F10.2,2X,3F10.2 )
1200 CONTINUE
C
C
IF (IDBUG .LT. 2) GO TO 3
IF(IP.EQ.1) WRITE(III,100)
100 FORMAT(1H1)
IF(IP.EQ.1) WRITE(III,601)
3 CONTINUE
DEG = 0.0
DO 210 I=1,36
T(1,1)=CO(I)
T(1,2)=SI(I)
T(1,3)=0.00
T(2,1)=-SI(I)
T(2,2)=CO(I)
T(2,3)=0.00
T(3,1)=0.00
T(3,2)=0.00
T(3,3)=1.00
DO 301 L=1,3
DO 301 M=1,3
K12T(M,L)=K12(L,M,I)
301 CONTINUE
CALL MATMP2(K1(1,1,I),UN(1,1,I),D,4)
CALL MATMP2(K12(1,1,I),UN(1,1,I+1),E,4)
CALL MATMP2(K12T(1,1),UN(1,1,I),R,4)
CALL MATMP2(K2(1,1,I),UN(1,1,I+1),S,4)
DO 401 J=1,3
DO 401 K=1,4
G(J,K)=D(J,K)-F1(J,K,I)+E(J,K)
WW(J,K)=R(J,K)-F2(J,K,I)+S(J,K)
401 CONTINUE
CALL MATMP2(T,G,PVM1(1,1,I),4)
CALL MATMP2(T,WW,PVM2(1,1,I),4)
C
C WRITE THRUSTS SHEARS AND MOMENTS
C
IF (I .EQ. 1) GO TO 202
J3=0
DO 211 J1=1,4
DO 211 J2=1,3
J3=J3+1
A(J3)=(PVM1(J2,J1,I)-PVM2(J2,J1,I-1))/2.0000000
211 CONTINUE
DEG=(I-1)*5.00000
IF (IDBUG .GE. 2.AND.IP.EQ.1) WRITE(III,205) I,DEG,(A(J5),J5=7,12)
GO TO 210
202 IF (IDBUG .GE. 2.AND.IP.EQ.1)
1 WRITE(III,205) I,DEG,(REAC(J6,3,1),J6=1,3),(REAC(J6,4,1),J6=1,3)
210 CONTINUE
IF (IDBUG .LT. 2) GO TO 1201
I=37
DEG=180.0

```

```

IF(IP.EQ.1) WRITE(III,205) I,DEG,(REAC(J6,3,2),J6=1,3),
1(REAC(J6,4,2),J6=1,3)
C      **** BY TGH ***
      IF (IDBUG .GE. 2) THEN
      FP=-HP*0.4335*RADI1*12.0/1000.0
IF(IP.EQ.1) WRITE(III,207) FP
207  FORMAT(//////,12X,'THRUST (KIP/FT) AT EACH JOINT DUE TO FLUID PRE
1SSURE = ',F7.2)
      ENDIF
C      *****
601  FORMAT(//,30X,'SERVICE LOAD FORCES',/,12X,'N=THRUST(KIPS/FT)',
1' V=SHEAR(KIPS/FT), M=MOMENT(IN.KIPS/FT)',//,26X,'FLUID LOAD',
2 23X,'LIVE LOAD',/,7X,'DEG FROM',1X,30(1H-),2X,30(1H-),
3 /,' JOINT VERTICAL',7X,'N',9X,'V',9X,'M',11X,'N',9X,'V',9X,'M')
205  FORMAT(2X,I2,5X,F4.0,3X,3F10.2,2X,3F10.2)
1201 CONTINUE
      IF (IDBUG .GE. 1.AND.IP.EQ.1) WRITE(III,1991)
1991 FORMAT(1H1)
      RETURN
      END

```

**Subroutine:** MATINV

**Function:**

This subroutine inverts a 3 x 3 matrix.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

```

SUBROUTINE MATINV(A,B)
C
C C INVERTS 3 X 3 MATRIX
C
C DOUBLE PRECISION A(3,3),B(3,3),DELTA
C
DELTA=A(1,1)*A(2,2)*A(3,3)+A(1,2)*A(2,3)*A(3,1)+A(1,3)*A(2,1)*
1A(3,2)-A(3,1)*A(2,2)*A(1,3)-A(3,2)*A(2,3)*A(1,1)-A(3,3)*A(2,1)*
1A(1,2)
C
B(1,1)=(A(2,2)*A(3,3)-A(2,3)*A(3,2))/DELTA
B(1,2)=- (A(1,2)*A(3,3)-A(3,2)*A(1,3))/DELTA
B(1,3)=(A(1,2)*A(2,3)-A(2,2)*A(1,3))/DELTA
B(2,1)=- (A(2,1)*A(3,3)-A(3,1)*A(2,3))/DELTA
B(2,2)=(A(1,1)*A(3,3)-A(1,3)*A(3,1))/DELTA
B(2,3)=- (A(1,1)*A(2,3)-A(2,1)*A(1,3))/DELTA
B(3,1)=(A(2,1)*A(3,2)-A(3,1)*A(2,2))/DELTA
B(3,2)=- (A(1,1)*A(3,2)-A(3,1)*A(1,2))/DELTA
B(3,3)=(A(1,1)*A(2,2)-A(2,1)*A(1,2))/DELTA
RETURN
END

```

**Subroutine:** MATMPY

**Function:**

This subroutine multiplies a 3 x 3 matrix by a 3 x 3 matrix.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

```
      SUBROUTINE MATMPY(A,B,C)
C
C  GENERATES MATRIX MULTIPLICATION
C
C  DOUBLE PRECISION A(3,3), B(3,3), C(3,3)
C
      DO 10 I=1,3
      DO 10 J=1,3
      C(I,J)=0.0D0
      DO 10 K=1,3
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
10    CONTINUE
      RETURN
      END
```



**Subroutine:** MATMP2

**Function:**

This subroutine multiplies a 3 x 3 matrix by a 3 x 4 matrix.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

```
      SUBROUTINE MATMP2(A,B,C,M)
C
C  GENERATES MATRIX MULTIPLICATION
C
C  DOUBLE PRECISION A(3,3), B(3,M), C(3,M)
C
      DO 10 I=1,3
      DO 10 J=1,M
      C(I,J)=0.0D0
      DO 10 K=1,3
      C(I,J)=C(I,J)+A(I,K)*B(K,J)
10  CONTINUE
      RETURN
      END
```

**Subroutine:** MATXCO

**Function:**

This subroutine multiplies a 3 x 3 matrix by a 3 x 1 matrix.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

```
      SUBROUTINE MATXCO(X,A,Y)
C
C  MULTIPLIES 3X3 MATRIX BY 3X1 MATRIX
C
C  DOUBLE PRECISION X(3),A(3,3) , Y(3)
C
      DO 10 I=1,3
      Y(I) = 0.0D0
      DO 10 K=1,3
      Y(I)=Y(I)+A(I,K)*X(K)
10  CONTINUE
      RETURN
      END
```

**Subroutine:** PVMMAX

**Function:**

This subroutine calculates the thrusts, shears, and moments at the five critical design sections. These forces are multiplied by load factors to obtain ultimate forces.

**I/O Generated by Subroutine:**

When Option 2 or greater is selected a table of ultimate design forces is printed.

**Error Messages Generated by Subroutine:**

None

SUBROUTINE PVMMAX

C  
 C LOCATES AND CALCULATES THE THRUSTS, SHEARS AND MOMENTS AT THE 5  
 C CRITICAL DESIGN SECTIONS. THE PROCEDURE FOR FINDING THE EXACT  
 C LOCATION OF M/PHIVD=3.0 ASSUMES LINEAR SHEAR AND QUADRATIC  
 C MOMENT DISTRIBUTION ON A MEMBER.  
 C LOAD FACTORS ARE THEN USED TO CONVERT DESIGN FORCES TO ULTIMATE  
 C FORCES.

C  
 C COMMON/PRES/HP,FP  
 C COMMON/PVM/PVM1(3,4,36),PVM2(3,4,36)  
 C COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
 C 1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,  
 C 1EST,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,POR  
 C 1,FPF,P0RT,THP  
 C COMMON/PROP/SI(37),CO(37),ALEN(37)  
 C COMMON/COORD/X(37),Y(37),A(37),B,BS  
 C COMMON/DESIGN/DMU(5),DPU(5),DVU(5),VLOC(5),DMS(5),DPS(5),DDES(5)  
 C COMMON/ISCALE/IDBUG,IPATH  
 C COMMON /MATPVM/ DMMAT(37),DPMAT(37),DVMAT(37),DPRMAT(37)  
 C COMMON /CAGETYP/ ITYPE,RATIO,ELROT,DWI,DWO,TBI,TBO,DWE,  
 C 1TBEI,TBEO,DWII,PHII,DWIC,PHIC,DWOS,PHIS,WIREI,WIREO,WIREE,  
 C 2WIREIR,WIRECR,WIRESR  
 C COMMON/DD/DDIN(37),DDOUT(37)  
 C COMMON/SPSOIL/SAREA(7),SPK,SPU,SPV,SPM,SPA,SPFB,SPD,LDF,SPRADI,  
 C 1 INSTAL  
 C COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,  
 C 1 LATPC,PTOP,SYST  
 C COMMON/FILE/III,IP,ISTRP  
 C COMMON/FACT/FLLNP,FLMVLP  
 C DOUBLE PRECISION PVM1, PVM2  
 C REAL MMAX,LDF

C  
 C L IS INDEX FOR LOCATIONS AT WHICH DESIGN WILL BE CHECKED  
 C

FP=-HP\*0.4335\*RADI1\*12.0/1000.0  
 L=2

C  
 C SEARCH FOR MEMBER NEAR INVERT WHERE M/VD=3  
 C

C  
 C CALL DCALC  
 C VMAX=0.  
 C IMAX=1  
 C CLEN=1.0  
 C G1=DMU(1)  
 C C1=DVU(1)  
 C F1=DPU(1)  
 C N=0  
 C DO 300 I=2,36  
 C ICHK=1  
 C G=(PVM1(3,1,I)+PVM1(3,2,I))\*FLMV  
 C C=((PVM1(2,1,I)+PVM1(2,2,I)-PVM2(2,1,I-1)-PVM2(2,2,I-1))/2.)\*FLMV  
 C F=(0.5\*(PVM1(1,1,I)+PVM1(1,2,I)-PVM2(1,1,I-1)-PVM2(1,2,I-1)))\*FLN  
 C \*\*\*\*\* \* FP BY TGH  
 C F=F+FP\*FPF  
 C IF (DABS(C+(PVM1(2,3,I)-PVM2(2,3,I-1))/2.) .LT. ABS(C)) GO TO 400

```

C=C+((PVM1(2,3,I)-PVM2(2,3,I-1))/2.)*FLMV
G=G+(PVM1(3,3,I))*FLMV
F=F+(0.5*(PVM1(1,3,I)-PVM1(1,3,I-1)))*FLN
400 CONTINUE
IF (DABS(C+(PVM1(2,4,I)-PVM2(2,4,I-1))/2.) .LT. ABS(C)) GO TO 2960
C=C+((PVM1(2,4,I)-PVM2(2,4,I-1))/2.)*FLMVLL
G=G+PVM1(3,4,I)*FLMVLL
F=F+(0.5*(PVM1(1,4,I)-PVM1(1,4,I-1)))*FLNLL
2960 IF(C.LT.VMAX) GO TO 410
VMAX=C
IMAX=I
296 G22=G
C22=C
F22=F
G11=G1
C11=C1
F11=F1
410 CONTINUE
D=POD*DDIN(I)
IF (G .GT. 0.0) GO TO 350
D=POD*DDOUT(I)
350 IF (ABS(G/C/D) .LE. 3.0) GO TO 200
G1=G
C1=C
F1=F
300 CONTINUE
200 CONTINUE

```

```

IF (VMAX .LE. C) GO TO 405
DVU(L)=VMAX
VUNIT=(C22-C11)/ALEN(IMAX-1)
DMU(L)=G11-C11*0.5*ALEN(IMAX-1)-0.5*VUNIT*(0.5*ALEN(IMAX-1))**2
DPU(L)=F11+(F22-F11)*0.5
DDES(L)=POD*(DDIN(IMAX-1)+(DDIN(IMAX)-DDIN(IMAX-1))*0.5)
IF (DMU(L) .LE. 0.) DDES(L)=POD*(DDOUT(IMAX-1)+(DDOUT(IMAX)
1-DDOUT(IMAX-1))*0.5)
IF (ABS(DMU(L)/(DVU(L)*DDES(L))) .GT. 3) GO TO 1557
CLEN=0.5
C=VMAX
GO TO 405
1557 VLOC(L)=A(IMAX-1)+0.087266*0.5
GO TO 500
405 J=I-1
J1 = 1
J2 = J
2000 CONTINUE
VUNIT=(C-C1)/(ALEN(J)*CLEN)
DDIF=POD*(DDIN(J+1)-DDIN(J))/ALEN(J)
AA=DDIF*VUNIT+VUNIT/6.
BB=C1/3.+VUNIT*DDIN(J)*POD+C1*DDIF
CC=C1*DDIN(J)*POD-G1/3.
IF(G.GT.0.0) GO TO 374
DDIF=POD*(DDOUT(J+1)-DDOUT(J))/ALEN(J)
AA=DDIF*VUNIT+VUNIT/6.
BB=C1/3.+VUNIT*DDOUT(J)*POD+C1*DDIF
CC=C1*DDOUT(J)*POD-G1/3.

```

```

374 XL=(-BB+SQRT(BB*BB-4*AA*CC))/(2*AA)
   DDES(L)=DDIN(J)*P0D+DDIF*XL
   IF (G .LE. 0.) DDES(L)=DDOUT(J)*P0D+DDIF*XL
   DMU(L) = G1 - C1*XL - 0.5*VUNIT*XL*XL
   DPU(L) = F1 + (F-F1)*XL/ALEN(J)
   DVU(L) = C1 + VUNIT*XL
875 VLOC(L) = A(J2) + 0.087266*XL/ALEN(J)*J1
500 CONTINUE
C
C   SEARCH FOR JOINT WITH MAX. NEGATIVE MOMENT NEAR SPRINGLINE
C
C   IF (L .EQ. 4) GO TO 2100
C
C   SEARCH FOR LOCATION OF MAX NEG MOMENT
C
   S=0.0
   S1=0.0
   S2=0.0
   S3=0.0
   S4=0.0
   MMAX=0.0
   DO 1000 I=10,28
   S1=PVM1(3,1,I)+PVM1(3,2,I)
   S2=PVM1(3,1,I)+PVM1(3,2,I)+PVM1(3,3,I)
   S3=PVM1(3,1,I)+PVM1(3,2,I)+PVM1(3,3,I)+PVM1(3,4,I)
   S4=PVM1(3,1,I)+PVM1(3,2,I)+PVM1(3,4,I)
   S=DMIN1(S1,S2,S3,S4)
   S=DABS(S)
   IF(S.LT.MMAX) THEN
   VLOC(3)=A(I-1)
   IF(S.EQ.DABS(S1)) ICOMB=1
   IF(S.EQ.DABS(S2)) ICOMB=2
   IF(S.EQ.DABS(S3)) ICOMB=3
   IF(S.EQ.DABS(S4)) ICOMB=4
   GO TO (1101,1102,1103,1104) ICOMB
   ELSE
   MMAX=S
   GO TO 1000
   ENDIF
1101 DMS(3)=(PVM1(3,1,I-1)+PVM1(3,2,I-1))
   DMU(3)=(PVM1(3,1,I-1)+PVM1(3,2,I-1))*FLMV
   DVU(3)=((PVM1(2,1,I-1)+PVM1(2,2,I-1)-PVM2(2,1,I-2)-PVM2(2,2,I-2))/
12.)*FLMV
   DPS(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/
12.)+FP
   DPU(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/
12.)*FLN+FP*FPF
   DDES(3)=DDOUT(I-1)*P0
   GO TO 1107
1102 DMS(3)=PVM1(3,1,I-1)+PVM1(3,2,I-1)+PVM1(3,3,I-1)
   DMU(3)=(PVM1(3,1,I-1)+PVM1(3,2,I-1))*FLMV+PVM1(3,3,I-1)*FLMV
   DVU(3)=((PVM1(2,1,I-1)+PVM1(2,2,I-1)-PVM2(2,1,I-2)-PVM2(2,2,I-2))/
12.)*FLMV+((PVM1(2,3,I-1)-PVM2(2,3,I-2))/2.)*FLMV
   DPS(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/
12.)+((PVM1(1,3,I-1)-PVM2(1,3,I-2))/2.)+FP
   DPU(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/

```



```

12.)*FLN+((PVM1(1,3,I-1)-PVM2(1,3,I-2))/2.)*FLN+FP*FPF
DDES(3)=DDOUT(I-1)*P0
GO TO 1107
1103 DMS(3)=(PVM1(3,1,I-1)+PVM1(3,2,I-1))+PVM1(3,3,I-1)+PVM1(3,4,I-1)
DMU(3)=(PVM1(3,1,I-1)+PVM1(3,2,I-1))*FLMV+PVM1(3,3,I-1)*FLMV+PVM1(
13,4,I-1)*FLMVLL
DVU(3)=((PVM1(2,1,I-1)+PVM1(2,2,I-1)-PVM2(2,1,I-2)-PVM2(2,2,I-2))/
12.)*FLMV+((PVM1(2,3,I-1)-PVM2(2,3,I-2))/2.)*FLMV+((PVM1(2,4,I-2)-P
2VM2(2,4,I-2))/2.)*FLMVLL
DPS(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/
12.)+(PVM1(1,3,I-1)-PVM2(1,3,I-2))/2.+(PVM1(1,4,I-1)-PVM2(1,4,I-
22))/2.+FP
DPU(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/
12.)*FLN+((PVM1(1,3,I-1)-PVM2(1,3,I-2))/2.)*FLN+((PVM1(1,4,I-1)-PVM
22(1,4,I-2))/2.)*FLNLL+FP*FPF
DDES(3)=DDOUT(I-1)*P0
GO TO 1107
1104 DMS(3)=(PVM1(3,1,I-1)+PVM1(3,2,I-1))+PVM1(3,4,I-1)
DMU(3)=(PVM1(3,1,I-1)+PVM1(3,2,I-1))*FLMV+PVM1(3,4,I-1)*FLMVLL
DVU(3)=((PVM1(2,1,I-1)+PVM1(2,2,I-1)-PVM2(2,1,I-2)-PVM2(2,2,I-2))/
12.)*FLMV+((PVM1(2,4,I-1)-PVM2(2,4,I-2))/2.)*FLMVLL
DPS(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/
12.)+(PVM1(1,4,I-1)-PVM2(1,4,I-2))/2.+FP
DPU(3)=((PVM1(1,1,I-1)+PVM1(1,2,I-1)-PVM2(1,1,I-2)-PVM2(1,2,I-2))/
12.)*FLN+((PVM1(1,4,I-1)-PVM2(1,4,I-2))/2.)*FLNLL+FP*FPF
DDES(3)=DDOUT(I-1)*P0
GO TO 1107
1000 CONTINUE
1107 CONTINUE
C CHECK SIGN OF SPRINGLINE MOMENT
IF (DMU(3) .GE. 0. ) GO TO 6012
GO TO 999
6012 IF(IP.EQ.1) WRITE(III,6015)
WRITE(*,6015)
6015 FORMAT(8(/),14X,50(1H*),/,14X,1H*,48X,1H*,/,14X,1H*,18X,
17HWARNING,23X,1H*,/,14X,1H*,48X,1H*,/,14X,1H*,4X,
240HDESIGN NOT POSSIBLE DUE TO OPPOSITE SIGN,4X,1H*,/,14X,1H*,3X,
342H MOMENTS AT THE CROWN OR INVERT. ,3X,1H*,/,14X,1H*,
448X,1H*,/,14X,1H*,4X,40HPIPECAR DESIGN CAPABILITIES ARE EXCEEDED
5,4X,1H*,/,14X,1H*,48X,1H*,/,14X,50(1H*),/////
PAUSE ' Press [Enter] to Continue'
IPATH=1
RETURN
999 CONTINUE
C
C SEARCH FOR MEMBER NEAR CROWN WHERE M/VD=3
C
I=36
VMAX=0.
IMAX=N
CLEN=1.0
G1=DMU(5)
C1=DVU(5)
F1=DPU(5)
1400 CONTINUE
G=(PVM1(3,1,I)+PVM1(3,2,I))*FLMV

```

```

      C = ((PVM1(2,1,I) + PVM1(2,2,I) - PVM2(2,1,I-1) - PVM2(2,2,I-1))/2.) * FLMV
      F = (0.5 * (PVM1(1,1,I) + PVM1(1,2,I) - PVM2(1,1,I-1) - PVM2(1,2,I-1))) * FLN
C *****
      F = F + FP * FPF
      IF (DABS(C + (PVM1(2,3,I) - PVM2(2,3,I-1))/2.) .LT. ABS(C)) GO
1 TO 1420
      C = C + ((PVM1(2,3,I) - PVM2(2,3,I-1))/2.) * FLMV
      G = G + PVM1(3,3,I) * FLMV
      F = F + (0.5 * (PVM1(1,3,I) - PVM2(1,3,I-1))) * FLN
1420 CONTINUE
      IF (DABS(C + (PVM1(2,4,I) - PVM2(2,4,I-1))/2.) .LT. ABS(C)) GO
1 TO 1493
      C = C + ((PVM1(2,4,I) - PVM2(2,4,I-1))/2.) * FLMVLL
      G = G + PVM1(3,4,I) * FLMVLL
      F = F + (0.5 * (PVM1(1,4,I) - PVM2(1,4,I-1))) * FLNLL
1493 IF(C .LT. VMAX) GO TO 1492
      VMAX = C
      IMAX = I
      G22 = G
      C22 = C
      F22 = F
      G11 = G1
      C11 = C1
      F11 = F1
1492 CONTINUE
      D = P0D * DDIN(I)
      IF (G .GT. 0.0) GO TO 1450
      D = P0D * DDOUT(I)
1450 CONTINUE
      C = ABS(C)
      IF (ABS(G/C/D) .LE. 3.0) GO TO 1600
      G1 = G
      C1 = C
      F1 = F
      I = I - 1
      GO TO 1400
1600 CONTINUE
      L = 4
      IF (VMAX .LE. C) GO TO 1603
      DVU(L) = VMAX
      VUNIT = (C22 - C11) / ALEN(IMAX)
      DMU(L) = G11 - C11 * 0.5 * ALEN(IMAX) - 0.5 * VUNIT * (0.5 * ALEN(IMAX)) ** 2
      DPU(L) = F11 + (F22 - F11) * 0.5
      DDES(L) = P0D * (DDIN(IMAX) + (DDIN(IMAX + 1) - DDIN(IMAX)) * 0.5)
      IF (DMU(L) .LE. 0.) DDES(L) = P0D * (DDOUT(IMAX) + (DDOUT(IMAX + 1)
1 - DDOUT(IMAX)) * 0.5)
      IF (ABS(DMU(L) / (DVU(L) * DDES(L))) .GT. 3) GO TO 1558
      CLEN = 0.5
      C = VMAX
      GO TO 1603
1558 VLOC(L) = A(IMAX) + 0.087266 * 0.5
      GO TO 2100
1603 J = I
      J1 = -1
      J2 = J + 1
      GO TO 2000

```

```

2100 CONTINUE
  DDES(1) = DDIN(1)*P0
  DDES(5) = DDIN(37)*P0
  VLOC(1) = 0.0
  VLOC(5) = 3.1415926535897
C   IF(I*TYPE.NE.4) GO TO 3540
  DO 2511 I=2,36
    DMMAT(I) = (PVM1(3,1,I) + PVM1(3,2,I))*FLMV
    DPMAT(I) = (0.5*(PVM1(1,1,I) + PVM1(1,2,I) - PVM2(1,1,I) -
1   PVM2(1,2,I-1)))*FLN
C ***** * FP BY TGH
    DPMAT(I) = DPMAT(I) + FP*FPF
    DVMAT(I) = (0.5*(PVM1(2,1,I) + PVM1(2,2,I) - PVM2(2,1,I) -
1   PVM2(2,2,I-1)))*FLMV
    IF(ABS(DMMAT(I) + PVM1(3,3,I))*FLMV) .LT. ABS(DMMAT(I))) GO TO 3333
    DMMAT(I) = DMMAT(I) + PVM1(3,3,I)*FLMV
    DVMAT(I) = DVMAT(I) + ((PVM1(2,3,I) - PVM2(2,3,I-1))/2.)*FLMV
    DPMAT(I) = DPMAT(I) + ((PVM1(1,3,I) - PVM2(1,3,I-1))/2.)*FLN
3333 CONTINUE
    IF(ABS(DMMAT(I) + PVM1(3,4,I))*FLMVLL) .LT. ABS(DMMAT(I))) GO TO 2511
    DMMAT(I) = DMMAT(I) + PVM1(3,4,I)*FLMVLL
    DVMAT(I) = DVMAT(I) + ((PVM1(2,4,I) - PVM2(2,4,I-1))/2.)*FLMVLL
    DPMAT(I) = DPMAT(I) + ((PVM1(1,4,I) - PVM2(1,4,I-1))/2.)*FLNLL
2511 CONTINUE
    DMMAT(1) = (PVM1(3,1,1) + PVM1(3,2,1))*FLMV
    DMMAT(37) = (-PVM2(3,1,36) - PVM2(3,2,36))*FLMV
    DPMAT(1) = (PVM1(1,1,1) + PVM1(1,2,1))*FLN
C ***** * FP BY TGH
    DPMAT(1) = DPMAT(1) + FP*FPF
    DPMAT(37) = (-PVM2(1,1,36) - PVM2(1,2,36))*FLN
C ***** * FP BY TGH
    DPMAT(37) = DPMAT(37) + FP*FPF
    IF(ABS(DMMAT(1) + PVM1(3,3,1))*FLMV) .LT. ABS(DMMAT(1))) GOTO 2054
    DMMAT(1) = DMMAT(1) + PVM1(3,3,1)*FLMV
    DPMAT(1) = DPMAT(1) + PVM1(1,3,1)*FLN
2054 IF(ABS(DMMAT(1) + PVM1(3,4,1))*FLMVLL) .LT. ABS(DMMAT(1))) GOTO 2055
    DMMAT(1) = DMMAT(1) + PVM1(3,4,1)*FLMVLL
    DPMAT(1) = DPMAT(1) + PVM1(1,4,1)*FLNLL
2055 IF(ABS(DMMAT(37) - PVM2(3,3,36))*FLMV) .LT. ABS(DMMAT(37))) GOTO 2056
    DMMAT(37) = DMMAT(37) - PVM2(3,3,36)*FLMV
    DPMAT(37) = DPMAT(37) - PVM2(1,3,36)*FLN
2056 IF(ABS(DMMAT(37) - PVM2(3,4,36))*FLMVLL) .LT. ABS(DMMAT(37))) GOTO 2057
    DMMAT(37) = DMMAT(37) - PVM2(3,4,36)*FLMVLL
    DPMAT(37) = DPMAT(37) - PVM2(1,4,36)*FLNLL
2057 DVMAT(1) = 0.0
    DVMAT(37) = 0.0
3540 CONTINUE

```

```
C ***** BY TGH
C CHECK EACH NODE FOR MAX POS MOMENT
  DO 6000 I=1,19
  IF(DMMAT(I) .GT. DMMAT(1)) DMU(1)=DMMAT(I)
6000 CONTINUE
  DO 6005 I=21,36
  IF(DMMAT(I) .GT. DMMAT(37)) DMU(5)=DMMAT(I)
6005 CONTINUE
  RETURN
  END
```

**Subroutine:** DESGN

**Function:**

This subroutine calculates the required steel areas at design locations 1, 3, and 5 based on the design provisions of Section 17 of AASHTO. Radial tension strength is checked at the crown and invert. Diagonal tension strength is checked at design locations 2 and 4 where  $M/V\phi d$  equals 3.

**I/O Generated by Subroutine:**

When Output Option 1 or greater is selected, summary tables for flexure and shear design are printed. The tables present all the information required to design steel reinforcing based on flexure, minimum steel, maximum steel, crack control, radial tension strength and diagonal tension strength, and the governing design criteria for each section.

**Error Messages Generated by Subroutine:**

- o DESIGN NOT POSSIBLE AT POINT \_\_\_\_\_ DUE TO EXCESSIVE CONCRETE COMPRESSION  
MI = \_\_\_\_\_ IN.KIPS/FT  
NI = \_\_\_\_\_ KIPS/FT  
REQUIRED STEEL AREA = \_\_\_\_\_ SQ IN./FT  
MAXIMUM STEEL AREA = \_\_\_\_\_ SQ IN./FT
- o WARNING -- STIRRUPS REQUIRED AT \_\_\_\_\_ TO RESIST (DIAGONAL/RADIAL) TENSION

SUBROUTINE DESGN

C  
C CALCULATES THE REQUIRED STEEL AREAS AT DESIGN LOCATIONS 1, 3 AND 5  
C BASED ON THE FOLLOWING: FLEXURE  
C                   MINIMUM STEEL FOR FLEXURE  
C                   LIMITING CONCRETE COMPRESSION  
C                   0.01" CRACK AT SERVICE LOADS  
C IT CHECKS FOR RADIAL TENSION AT DESIGN LOCATIONS 1 AND 5 AND  
C IF REQUIRED CALCULATES THE CIRCUMFERENTIAL EXTENT AND MAXIMUM  
C SPACING OF STIRRUPS.  
C IT ALSO CHECKS THE DIAGONAL TENSION SHEAR AT DESIGN LOCATIONS 2  
C AND 4 AND IF REQUIRED, CALCULATES THE CIRCUMFERENTIAL EXTENT AND  
C MAXIMUM SPACING OF STIRRUPS.  
C ALL THE CALCULATED STEEL AREAS ARE PASSED TO THE PRINT SUBROUTINE  
C THROUGH THE COMMON BLOCK STLAR  
C A PRINTOUT OF THE ULTIMATE FORCES AT EACH DESIGN SECTION, ALONG  
C WITH FLEXURE AND SHEAR DESIGN TABLES ARE AVAILABLE WITH AN IDBUG  
C VALUE GREATER THAN 0.

COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
1FY,FCP,COU,CIN,FLMV,FLN,DIN,DOU,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST  
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R  
1,FPF,P0RT,THP

COMMON/ISCALE/IDBUG,IPATH

COMMON/PVM/PVM1(3,4,36),PVM2(3,4,36)

COMMON/DESIGN/DMU(5),DPU(5),DVU(5),VLOC(5),DMS(5),DPS(5),DDES(5)

COMMON/STLAR/AREA1(5),SRATIO(5),SGOV(5),AREADT(5),STEXT(5),  
1STSPA(5),DUM2(12)

COMMON /CAGETYP/ ITYPE,RATIO,ELROT,DWI,DWO,TBI,TBO,DWE,  
1TBEI,TBEO,DWII,PHII,DWIC,PHIC,DWOS,PHIS,WIREI,WIREO,WIREE,  
2WIREIR,WIRECR,WIRESR

COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,  
1 LATPC,PTOP,SYST

COMMON/PRES/HP,FP

COMMON/FILE/III,IP,ISTRP

COMMON/FACT/FLLNP,FLMVLP

C  
C DOUBLE PRECISION PVM1, PVM2

C AREA1(1) = INSIDE STEEL AT INVERT

C AREA1(2) = M/VD=3 NEAR INVERT

C TAKE MAX OF (1) AND (2) FOR INSIDE STEEL AT INVERT.

C AREA1(3) = OUTSIDE STEEL

C AREA1(4) = M/VD=3 NEAR CROWN

C AREA1(5) = INSIDE STEEL AT CROWN

C TAKE MAX OF (4) AND (5) FOR INSIDE STEEL AT CROWN

C  
C COMMON/COORD/X(37),Y(37),A(37),B,BS

REAL J,M0,N0,M1,N1,M1PSI,N1PSI,NLAY,MRAD,NRAD,MSPSI,NSPSI,N1PSIRT

REAL N1RT

INTEGER RTYPE

DIMENSION AREA1(5),AREAC(5),RDT(5),CRIND(5)

CHARACTER\*4 RLOC(9),RAD(2),DAG(2)

CHARACTER\*3 ADESG,PSTIR

CHARACTER\*25 GOVERN(8)

CHARACTER\*1 STAR

C

```
DATA RAD/'RADI','AL '/,DAG/'DIAG','ONAL'/,RLOC/'INVE','RT ',
1' ','SPRI','NGLI','NE','CROW','N ' ; ' /
DATA GOVERN/' FLEXURE ' ; MINIMUM REINFORCING '
2, ' 0.01 INCH CRACK ' ; RAD. TEN. + FLEXURE '
3, 'RAD. TEN. + 0.01 IN. CR.', 'DIAG. TEN. - NO STIRRUPS '
4, 'DIAG. TEN. WITH STIRRUPS', 'MAX CONCRETE COMPRESSION '
5/
```

```
IFLAG4 = 0
DO 901 I=1,5
AREA1(I)=0.0
AREAF(I)=0.0
AREAC(I)=0.0
RDT(I)=0.0
SRATIO(I)=0.0
AREADT(I)=0.0
STEXT(I)=0.0
SGOV(I)=0.0
```

901 CONTINUE

```
W = ATAN(U/V)
B1=0.85-0.05*(FCP-4.)
IF (B1 .GT. 0.85) B1=0.85
IF (B1 .LT. 0.65) B1=0.65
FCPPSI=FCP*1000.
FYPSI=FY*1000.
PI=3.1415926535897
SPMN=(RADM1+U)*2.
SPAN=(RADI1+U)*2.
IF (DIN .EQ. 0.) DIN=0.08*TH
IF (DOUT .EQ. 0.) DOUT=0.08*TH
```

C

C

C

DESIGN STEEL AT THREE MOMENT SECTIONS

```
DO 1 L=1,5,2
CASMN=1.0
C01=0.
FLAY=0.
M1=ABS(DMU(L))
N1=DPU(L)
N1RT=DPU(L)-FP*FPF
M1PSI=M1*1000.
N1PSI=N1*1000.
N1PSIRT=N1RT*1000.
MSPSI=1000.*ABS(DMS(L))
NSPSI=1000.*DPS(L)
Q=10.2*FCPPSI
D=DDES(L)
```

C

C

C

REQUIRED STEEL FOR FLEXURE

```
IF (Q*(Q*D*D-N1PSI*(2.*D-TH)-2.*M1PSI) .LT. 0.) GO TO 1111
AREA1(L)=(Q*D-N1PSI-SQRT(Q*(Q*D*D-N1PSI*(2.*D-TH)-2.*M1PSI))
1)/FYPSI
AREAF(L)=AREA1(L)
SRATIO(L)=(AREA1(L)/(12.*D))*P0
SGOV(L)=1.
```

C  
C  
C

MINIMUM STEEL AREA FOR FLEXURE

IF (L .EQ. 3) CASMN=0.75  
IF(ITYPE.EQ.2.OR.ITYPE.EQ.3) CASMN=2.0  
IF(ITYPE.EQ.5) CASMN=2.0  
IF(AREA1(L).GT.CASMN\*SPMN\*\*2./65000..AND.AREA1(L).GT.0.07) GO TO 2

IF(AREA1(L).LT.0.07) AREA1(L)=0.07  
AREAF(L)=AREA1(L)  
SRATIO(L) = (AREA1(L)/(12.\*D))\*P0  
SGOV(L)=2.

C  
C  
C

CHECK CONCRETE COMPRESSION

2 AREAMF=5.5E4\*12.\*B1\*FCPPSI\*D/  
1(FYPSI\*(87000.+FYPSI))-0.75\*N1PSI/FYPSI  
IF (AREA1(L) .LT. AREAMF) GO TO 3  
1111 LL=1  
IF (L .EQ. 3) LL=4  
IF (L .EQ. 5) LL=7  
IF(IP.EQ.1) WRITE(III,10)(RLOC(JJ),JJ=LL,LL+2),DMU(L),DPU(L),  
1AREA1(L),AREAMF  
AREA1(L)=1.0E26  
AREAF(L)=AREA1(L)  
RDT(L)=1.0E26  
SRATIO(L)=1.0E26  
SGOV(L) =8.0  
GO TO 1

C  
C  
C  
C

CHECK RADIAL TENSION AT CROWN AND INVERT  
DESIGN RADIAL TENSION STIRRUPS IF REQUIRED

3 IF (L .EQ. 3) GO TO 990  
CIM=TBI  
IF(ITYPE .EQ. 3) CIM = TBEI  
D=D\*P0R/P0  
FRT=0.8  
IF(SPAN.LT.144.0) FRT=(144.0-SPAN)\*\*2/26000+0.8  
IF(SPAN.LE.72.0) FRT=1.0+0.00833\*(72.0-SPAN)  
IF(SPAN.LE.12.0) FRT=1.5  
RADTEN=(M1PSI-0.45\*N1PSIRT\*D)/12./D/(RADI2+CIM)/1.2/SQRT(FCPPSI)  
1\*FRP/FRT  
RDT(L)=RADTEN  
IF (RADTEN .LE. 1.) GO TO 990  
SGOV(L)=4.  
K=L/2.+0.75  
IF(IP.EQ.1) WRITE(III,850) RLOC(3\*K-2),RLOC(3\*K-1),RLOC(3\*K),  
1RAD(1),RAD(2)

C

IF(ITYPE.EQ.1) GO TO 842  
IFLAG4 = 1  
847 FORMAT(//,T15,50(1H\*),/,T15,1H\*,48X,1H\*,/,T15,1H\*,10X,  
13(7HWARNING,2X),11X,1H\*,/,T15,1H\*,48X,1H\*,/,T15,1H\*,1X,  
246HDESIGN FOR SPECIFIED CAGE TYPE IS NOT POSSIBLE,1X,1H\*,/,  
3T15,1H\*,9X,31HSTIRRUP DESIGN IS ONLY POSSIBLE,8X,1H\*,/,T15,



```

      41H*,11X,26HWITH DOUBLE CIRCULAR CAGES,11X,1H*,/,T15,50(1H*))
      GO TO 990
842 CONTINUE
C
C SIZE RADIAL TENSION STIRRUPS
C
      AREADT(L) = 1.1*(M1PSI-0.45*N1PSIRT*D)/(D*(RADI2+CIM))
C
C EXTENT OF RADIAL TENSION STIRRUPS
C
      K=2
      IF (L .EQ. 5) K=36
872 CONTINUE
      MRAD=(PVM1(3,1,K)+PVM1(3,2,K))*FLMV*1000.
      NRAD=0.5*(PVM1(1,1,K)+PVM1(1,2,K)-PVM2(1,1,K-1)-PVM2(1,2,K-1))*
1FLN*1000.
      IF (PVM1(3,3,K) .LT. 0.0) GO TO 871
      MRAD=(MRAD+PVM1(3,3,K))*FLMV*1000.
      NRAD=NRAD+(0.5*(PVM1(1,3,K)-PVM2(1,3,K-1)))*FLN*1000.
871 IF (PVM1(3,4,K) .LT. 0.0) GO TO 740
      MRAD=(MRAD+PVM1(3,4,K))*FLMVLL*1000.
      NRAD=NRAD+(0.5*(PVM1(1,4,K)-PVM2(1,4,K-1)))*FLNLL*1000.
740 CONTINUE
      RADST=RADI2+TBI
      IF (A(K) .GT. W) RADST=RADI1+TBI
      RADTEN=(MRAD-0.45*NRAD*D)/(12.*D*(RADST)*1.2*SQRT(FCPPSI))*FRP
      IF (RADTEN .LT. 1.) GO TO 873
      K=K+1
      IF (L .EQ. 5) K=K-2
      GO TO 872
873 CONTINUE
      IF (L .EQ. 5) K=38-K
      STSPA(L)=0.75*D
      IF (A(K) .LT. W) GO TO 874
      STEXT(L)=(RADM2*W+RADM1*(A(K)-W))*2.
      GO TO 990
874 CONTINUE
      STEXT(L)=2.*RADM2*A(K)
C
C
C STEEL AREA BASED ON 0.01 INCH CRACK
C
990 CONTINUE
      IF (L .NE. 3) D=D*P0/P0R
      AREA01=0.0
      ARE012=0.0
      GO TO(111,222,333,444,555,677),ITYPE
111 SIM=WIREI
      CIM=TBI
      IF(L.EQ.3) CIM=TBO
      IF(L.EQ.3) SIM=WIREO
      GO TO 777
222 SIM=WIREI
      CIM=TBI
      IF(L.EQ.3) CIM=TBI
      GO TO 777
333 SIM=WIREE

```

```

CIM=TBEI
IF(L.EQ.3) CIM=TBEO
GO TO 777
444 SIM=WIREI
CIM=TBI
IF(L.EQ.3) CIM=TBO
IF(L.EQ.3) SIM=WIREO
GO TO 777
555 SIM=WIREI
CIM=TBI
IF(L.EQ.3) CIM=TBEO
GO TO 777
677 SIM=WIREI
CIM=TBI
IF(L.EQ.3) CIM=TBO
777 ITMP=IFIX(RTYPE)
GO TO (1000,2000,3000),ITMP
1000 C0=1.0
B2=(0.5*CIM**2*SIM/NLAY)**(1./3.)
GO TO 140
2000 C0=1.5
B2=(0.5*CIM**2*SIM/NLAY)**(1./3.)
FLAY=CIM**2.*SIM/NLAY
GO TO 140
3000 C0=1.9
B2=(0.5*CIM**2*SIM/NLAY)**(1./3.)
140 M0=MSPSI
N0=NSPSI
D=D/P0
E=M0/N0+D-TH/2.
IF ((E/D) .LT. 1.15) GO TO 1
619 J=0.74+0.1*E/D
IF (J .GT. 0.90) J=0.90
P=1./(1.-J*D/E)
620 CONTINUE
Q1=(M0+N0*(D-TH/2.))*B2/(30000.*J*P*P0*D*FCR)
R1=C0*B2**12.*TH**2*SQRT(FCPPSI)/(30000.*FCR*D*P0)
AREA01=Q1-R1
IF (C01 .EQ. 1.) GO TO 625
IF (FLAY .LT. 3.) GO TO 650
C01=1.
C0=1.9
B2=(0.5*FLAY)**(1./3.)
ARE012=AREA01
GO TO 620
625 IF (ARE012 .GT. AREA01) AREA01=ARE012
650 CONTINUE
CRACK=AREA01/AREA1(L)
CRIND(L)=CRACK
AREAC(L)=AREA01

```

C  
C  
C

SERVICE LOAD CRACK CONTROL INDEX LIMIT

```

IF (CRACK .LE. 1.) GO TO 1
IF (SGOV(L) .EQ. 4.) GO TO 666
SGOV(L)=3.

```

```

        GO TO 667
666  CONTINUE
        SGOV(L)=5.
667  CONTINUE
C
C  STEEL AREA IS DETERMINED BY CRACK CONTROL
C
        AREA1(L)=AREA01
        SRATIO(L)=AREA1(L)/(12.*D*P0)
1  CONTINUE
C  *****

C  CHECK FOR MINIMUM PRESSURE REINFORCEMENT
C
        IF(HP .EQ. 0.0) GO TO 7077
        AMPR = HP*62.4/12.*RADI2/22500.
        IF(ITYPE.EQ.2 .OR. ITYPE.EQ.3) GO TO 2022
1011 AGINV = AREA1(1)+AREA1(3)
        AGCRN = AREA1(5)+AREA1(3)
        A13=0.
        A53=0.
        IF (AMPR .LE. AGINV) GO TO 1014
        ADIF = AMPR-AGINV
        AREA1(1) = 0.6*ADIF+AREA1(1)
        A13 = 0.4*ADIF+AREA1(3)
        SGV=9
        IF(SGOV(1) .EQ. 4 .OR. SGOV(1) .EQ. 5) SGV=10
        SGOV(1)=SGV
        SGOV(3)=9.
1014 IF (AMPR .LE. AGCRN) GO TO 1017
        ADIF = AMPR-AGCRN
        AREA1(5) = 0.6*ADIF+AREA1(5)
        A53 = 0.4*ADIF+AREA1(3)
        SGV=9
        IF(SGOV(5) .EQ. 4 .OR. SGOV(5) .EQ. 5) SGV=10
        SGOV(5)=SGV
        SGOV(3)=9.
1017 IF (SGOV(3) .EQ. 9.) AREA1(3) = AMAX1(A13,A53)
        GO TO 7077
2022 DO 2027 I=1,5,2
        IF (AMPR .LE. AREA1(I)) GO TO 2027
        AREA1(I) = AMPR
        SGV=9
        IF(SGOV(I) .EQ. 4 .OR. SGOV(I) .EQ. 5) SGV=10
        SGOV(I)=SGV
2027 CONTINUE
7077 CONTINUE
C  ***** TGH 6/15/88

C
C  EVALUATE DIAGONAL TENSION SHEAR
C
        DO 810 K=2,4,2
        STIND=0.0
        AREVRT=0.0
        AREVDT=0.0
        M1=ABS(DMU(K))

```

```

N1=DPU(K)
VU=ABS(DVU(K))
IF (K .EQ. 4) GO TO 1051
SRAT=SRATIO(1)*P0
IF (SGOV(1) .LT. 8.) GO TO 1052
SGOV(K)=8.0
AREA1(K)=1.0E26
SRATIO(K)=1.0E26
GO TO 810
1051 SRAT=SRATIO(5)*P0
IF (SGOV(5) .LT. 8.0) GO TO 1052
SGOV(K)=8.0
AREA1(K)=1.0E26
SRATIO(K)=1.0E26
1052 CONTINUE
IF(ITYPE.EQ.2 .OR. ITYPE.EQ.3 )SRAT=(AMAX1(AREA1(1),AREA1(3),
1AREA1(5)))/(12.*DDES(K))*P0D
IF(ITYPE.EQ.5) SRAT=AREA1(3)/(12.*DDES(K))*P0D
IF(ITYPE.EQ.6) SRAT=(AMAX1(AREA1(1),AREA1(5))*RATIO/(1.+RATIO))/(1
12.*DDES(K))*P0D
IF (SRAT .GT. 0.02) SRAT=0.02
M1PSI=M1*1000.
N1PSI=N1*1000.
VUPSI=VU*1000.
D=DDES(K)/P0D
FD=0.8+1.6/(D)
IF (FD .GT. 1.25) FD=1.25
FN=0.5-(N1/6./VU)+SQRT(0.25+(N1/6./VU)**2)
IF (FN .LT. 0.75) FN=0.75
R=RADM1
IF (VLOC(K) .LT. W) R=RADM2
IF (VLOC(K) .GT. PI-W) R=RADM2
RADST=R+CIN-TH/2.
IF (FCPPSI .GT. 7000.) FCPPSI=7000.
FC=1.0+D*P0D/2./R
VC=(1.1+63.0*SRAT)*SQRT(FCPPSI)*P0D*12.0*D*FD*FVP/(FC*FN)
ADTEN=(0.01587*FC*FN*VUPSI)/(FD*FVP*SQRT(FCPPSI))-0.20952*P0D*D)
1 /P0D
IF (ADTEN .LT. 0.) ADTEN=0.
RDTIN=VUPSI/VC
RDT(K)=ADTEN/(SRAT*12.0*D)
IF (RDT(K) .LE. 1.) GO TO 8
AREA1(K)=ADTEN
SGOV(K)=6.
SRATIO(K)=AREA1(K)/(12.*D)
IF (SRATIO(K) .LT. 0.02) GO TO 9050
SGOV(K)=7.0
AREA1(K)=1.0E26
SRATIO(K)=1.0E26
9050 CONTINUE
IF (K .EQ. 4) GO TO 9
IF(IP.EQ.1) WRITE(III,850)RLOC(1),RLOC(2),RLOC(3),DAG(1),DAG(2)
GO TO 6
9 IF(IP.EQ.1) WRITE(III,850)RLOC(7),RLOC(8),RLOC(9),DAG(1),DAG(2)
6 STIND=2.
8 CONTINUE

```

```

C
C
C
C          STIRRUP DESIGN
C
C          IF (STIND .EQ. 0.0) GO TO 830
C          IF (ITYPE.EQ.1) GO TO 9059
C          IF (IP.EQ.1) WRITE(III,847)
C          GO TO 830
C
C          STIRRUP DESIGN FOR RADIAL TENSION
C          9059 CONTINUE
C
C          AREVRT=1.1*(M1PSI-0.45*N1PSIRT*D*P0R)/(P0R*D*RADST)
C
C          STIRRUP DESIGN FOR DIAGONAL TENSION
C
C          IF (VC .GT. 2*SQRT(FCPPSI)*12.*P0D*D) VC=2.*SQRT(FCPPSI)
C          1*12.*P0D*D
C          AREVDT=1.1/(P0D*D)*(VUPSI*FC-P0D*VC)+AREVRT
C          880 CONTINUE
C          AREADT(K)=AREVDT
C          N=VLOC(K)/0.087266+0.5
C          IF (N .LE. 1) N=2
C          5000 CONTINUE
C          V1=0.5*(PVM1(2,1,N)+PVM1(2,2,N)-PVM2(2,1,N-1)-PVM2(2,2,N-1))*FLMV
C          M1=(PVM1(3,1,N)+PVM1(3,2,N))*FLMV
C          N1=0.5*(PVM1(1,1,N)+PVM1(1,2,N)-PVM2(1,1,N-1)-PVM2(1,2,N-1))*FLN
C          N1=N1+FP*FPF
C          IF (DABS(V1+(0.5*(PVM1(2,3,N)-PVM2(2,3,N-1)))*FLMV) .LT. ABS(V1))
C          1 GO TO 4000
C          V1=V1+0.5*(PVM1(2,3,N)-PVM2(2,3,N-1))*FLMV
C          M1=M1+PVM1(3,3,N)*FLMV
C          N1=N1+0.5*(PVM1(1,3,N)-PVM2(1,3,N-1))*FLN
C          4000 IF (DABS(V1+(0.5*(PVM1(2,4,N)-PVM2(2,4,N-1)))*FLMVLL) .LT.
C          1 ABS(V1)) GO TO 4001
C          V1=V1+0.5*(PVM1(2,4,N)-PVM2(2,4,N-1))*FLMVLL
C          M1=M1+PVM1(3,4,N)*FLMVLL
C          N1=N1+0.5*(PVM1(1,4,N)-PVM2(1,4,N-1))*FLNLL
C          4001 CONTINUE
C          DH=DOUT
C          CIM=COUT
C          IF (M1 .LT. 0.0) GO TO 6600
C          CIM=CIN
C          DH=DIN
C          6600 CONTINUE
C          V1=ABS(V1)
C          M1PSI=ABS(M1*1000.)
C          N1PSI=N1*1000.
C          V1PSI=V1*1000.
C          IF (DH .EQ. 0.0) DH=0.08*TH
C          D=TH-CIM-DH/2
C          FD=0.80+1.6/(D*P0D)
C          IF (FD .GT. 1.25) FD=1.25
C          FN=0.5-(N1/V1/6.)+SQRT(0.25+(N1/V1/6.)**2)
C          IF (FN .LT. 0.75) FN=0.75
C          R=RADM1
C          IF (A(N) .LT. W) R=RADM2

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IF (A(N) .GT. (PI-W)) R=RADM2
FC=1.0+D*P0D/2./R
SRAT=SRATIO(1)*P0
IF (L .EQ. 4) SRAT=SRATIO(5)*P0
IF (M1 .GT. 0.0) GO TO 6601
FC=1.0-D*P0D/(2.*R)
SRAT=SRATIO(3)*P0
6601 CONTINUE
VC=(1.1+63.0*SRAT)*SQRT(FCPPSI)*P0D*D*12.*FD*FVP/(FC*FN)
1*4./(M1PSI/(V1PSI*P0D*D)+1)
IF ( VC .GT. 4.5*SQRT(FCPPSI)*P0D*D*12./FN) VC=4.5*SQRT(FCPPSI)
1*P0D*D*12./FN
IF (VC .GE. V1PSI) GO TO 6000
N=N+1
IF (K .EQ. 4) N=N-2
GO TO 5000
6000 CONTINUE
IF (K .EQ. 4) GO TO 7000
STEXT(K)=RADM2*(A(N)+0.1745)*2.0
IF (A(N) .GT. W) STEXT(K)=(RADM2*W+(A(N)+0.1745-W)*RADM1)*2.
STSPA(K)=0.75*P0D*D
GO TO 810
7000 CONTINUE
STEXT(K)=(PI-A(N)+0.1745)*RADM2*2.
IF (A(N) .LT. (PI-W)) STEXT(K)=(W*RADM2+(PI-A(N)-W+0.1745)*
1 RADM1)*2.
STSPA(K)=0.75*P0D*D
GO TO 810
830 AREADT(K)=0.0
810 CONTINUE
IF (IDBUG .LT. 1) GO TO 950
IF (IP.EQ.1) WRITE(III,849)
IF (IP.EQ.1) WRITE(III,851)
DO 848 L=1,5
KF = (SGOV(L)+1.)*3.
JF =KF-2
VLCTM=VLOC(L)*180./PI
IF (IP.EQ.1) WRITE(III,852)VLCTM,DMU(L),DPU(L),DVU(L)
848 CONTINUE
IF (IP.EQ.1) WRITE(III,857)
857 FORMAT(11X,57('-'))
849 FORMAT(////,26X,24HTABLE OF ULTIMATE FORCES,/,11X,57(1H-))
850 FORMAT(//,14X,50(1H*),/,14X,1H*,48X,1H*,/,14X,1H*,18X,
17HWARNING.23X,1H*,/,14X,1H*,9X,21HSTIRRUPS REQUIRED AT ,2A4.A2,8X,
11H*,
1/,14X,1H*,9X,10HTO RESIST ,2A4,8H TENSION,13X,1H*,/,14X,50(1H*))
10 FORMAT(//,14X,50(1H*),/,14X,1H*,48X,1H*,/,14X,1H*,18X,
17HWARNING,23X,1H*,/,14X,1H*,5X,23HDESIGN NOT POSSIBLE AT ,3A4,8X,
11H*,/,14X,1H*,5X,38HDUE TO EXCESSIVE CONCRETE COMPRESSION,5X,1H*,
1/,14X,1H*,48X,1H*,/,14X,1H*,2X,3HMu=,F8.2,11H IN.KIPS/FT,5X,3HNu=
1,F6.2,8H KIPS/FT,2X,1H*,/,14X,1H*,7X,20HREQUIRED STEEL AREA=,
1F6.3,9H SQ.IN/FT,6X,1H*,/,14X,1H*,7X,20H MAXIMUM STEEL AREA=,
1F6.3,9H SQ.IN/FT,6X,1H*,/,14X,50(1H*))
851 FORMAT(/,11X,7H DESIGN,/,11X,8HLOCATION,10X,6HMOMENT,9X,6HTHRUST,
19X,5HSHEAR,/,11X,57(1H-),/,11X,8HDEG FROM,7X,12H IN.KIPS/FT ,5X,
29H KIPS/FT ,5X,9H KIPS/FT ,/,12X,6HINVERT)

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852 FORMAT(/,12X,F6.2,6X,F12.3,4X,F10.3,4X,F10.3)
   IF(IP.EQ.1) WRITE(III,710)
710 FORMAT(1H1,/,T3,21('*'),'REINFORCING DESIGN TABLE',30('*'),/,
1 T4,'DESIGN',T12,'REINF.',T22,'DEPTH',T33,'FLEXURAL',T43,'|',T53,
2 'DESIGN INDICES',/,T3,'LOCATION',T12,'DESIG.',T20,'TO REINF.',
3 T31,'REINFORCING |',8X,'NOT REINF. AREAS',
4 /,T3,'-----',T12,'-----',T20,'-----',
5 T31,'-----',T43,'|',
6 T44,34('-'),/,T3,'DEG FROM',T23,'IN.',T32,'SQ.IN./FT |',T44,
7 '0.01 INCH',T56,'RAD. TENS.',T67,'DIAG.TENS.',/,T5,'INVERT',T43,
8 '|',/,T3,40('-'),'|',34('-'))
   DO 701 L=1,5
   VLCTM=VLOC(L)*180./PI
   D=DDES(L)/P0
   ADESG='ASI'
   IF (L .GE. 4) ADESG='ASC'
   IF (L .EQ. 3) ADESG='ASO'
   IF (L .EQ. 2 .OR. L .EQ. 4) GO TO 721
   IF (AREAC(L) .GE. 0.) GO TO 718
   AREAC(L)=0.0
   CRIND(L)=0.0
718 CONTINUE
719 IF(IP.EQ.1) WRITE(III,720)VLCTM,ADESG,D,AREAF(L),CRIND(L),RDT(L)
720 FORMAT(T3,F6.2,T13,A3,T20,F6.2,T34,F6.3,T43,'|',T45,F6.3,T57,F6.3
1 /,T43,'|')
   GO TO 701
721 D=DDES(L)/P0D
   STAR=' '
   IF(RDT(L).GT.1.0 .AND. SRATIO(L).GT.0.02) STAR='*'
   IF(IP.EQ.1) WRITE(III,723)VLCTM,ADESG,D,RDT(L),STAR
723 FORMAT(T3,F6.2,T13,A3,T20,F6.2,T43,'|',T68,F6.3,A1,/,T43,'|')
701 CONTINUE
   IF(IP.EQ.1) WRITE(III,746)
746 FORMAT(T3,75('-'),/,T6,'NOTES:',T15,
1'1. REINFORCING REQUIRED FOR 0.01 INCH CRACK OR DIAGONAL TENSION',
2/,T18,'IS DETERMINED BY MULTIPLYING THE DESIGN INDICE BY THE FLEXU
3RAL',/,T18,'REINFORCEMENT.',/,T15,
4'2. STIRRUPS MUST BE USED FOR DIAGONAL TENSION IF THE REINFORCEMEN
5T',/,T18,'RATIO IS GREATER THAN 0.02. THIS IS INDICATED BY A "*"
6AFTER',/,T18,'THE DIAGONAL TENSION INDEX',/,T15,
7'3. IF THE RADIAL TENSION INDEX IS GREATER THAN 1, STIRRUPS MUST B
8E',/,T18,'USED.')
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C  
C

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   IF(IP.EQ.1) WRITE(III,8000)
8000 FORMAT(///,T5,'REINF.',T15,'DEPTH',T43,'GOVERNING DESIGN',/,
1 T5,'DESIG.',T13,'TO REINF.',/,T5,'-----',T24,54('-'),
2 /,T25,'REQUIRED',T35,'REINF.',T43,'STIRRUPS',T62,'GOVERNING',/,
3 T27,'AREA',T35,'RATIO',T43,'REQUIRED?',T64,'MODE',/,T16,'IN.',
4 T24,'SQ.IN./FT',/,T5,73('-'))
   DO 8001 L=1,5,2
   FDES=2
   IF (L .EQ. 5) FDES=4
   D=DDES(L)/P0
   ADESG='ASI'
   IF (L .GE. 4) ADESG='ASC'
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IF (L .EQ. 3) ADESG='ASO'
PSTIR=' NO'
IF (L .EQ. 3) GO TO 8073
IF (SGOV(L) .GT. 3 .AND. SGOV(L) .LT. 8) PSTIR='YES'
IF (SGOV(FDES) .EQ. 6 .OR. SGOV(FDES) .EQ. 7 ) PSTIR='YES'
8073 IF(IP.EQ.1) WRITE(III,8020)ADESG,D,AREA1(L),SRATIO(L),PSTIR,
1GOVERN(SGOV(L))
8020 FORMAT(T6,A3,T14,F5.2,T24,F6.3,T34,F6.4,T44,A3,T53.A25,/)
8001 CONTINUE
IF(IP.EQ.1) WRITE(III,8004)
8004 FORMAT(T5,73('-'))
IF (SGOV(2) .NE. 6 .AND. SGOV(4) .NE. 6) GO TO 950
DO 931 L=2,4,2
FDES=1
IF (L .EQ. 4) FDES=5
IF (SGOV(L) .NE. 6 .OR. SGOV(FDES) .EQ. 4 .OR.
1 SGOV(FDES) .EQ. 5) GO TO 931
ADESG='ASI'
IF (L .EQ. 4) ADESG='ASC'
D=DDES(L)/P0D
IF(IP.EQ.1) WRITE(III,927) ADESG,D,AREA1(L),SRATIO(L),GOVERN
1(SGOV(L))
927 FORMAT(T6,A3,'*',T14,F5.2,T24.F6.3,T34,F6.4,T44,' NO',T53,A25,/)
931 CONTINUE
IF(IP.EQ.1) WRITE(III,938)
938 FORMAT(T5,73('-'),/,T6,'AS_* DENOTES ALTERNATIVE REINFORCEMENT WIT
1HOUT STIRRUPS')
950 CONTINUE
RETURN
END

```



**Subroutine:** PRINT

**Function:**

This subroutine prints the design summary sheet for all output options.

**I/O Generated by Subroutine:**

A design summary table is printed, listing all the important design parameters for the pipe section. Output includes installation data, material properties, loading data, pipe data, and reinforcing steel data.

**Error Messages Generated by Subroutine:**

None

SUBROUTINE PRINT

C  
 C ORGANIZES AND PRINTS OUT A PIPE DESIGN SUMMARY SHEET FROM DATA  
 C ACCUMULATED IN THE COMMON BLOCKS STLAR(CALCULATED STEEL AREAS FROM  
 C SUBROUTINE DESIGN) AND RSCALE(BDATA ARRAY GENERATED IN SUBROUTINES  
 C READ AND INIT)  
 C THE PRINTOUT INCLUDES THE FOLLOWING:  
 C INSTALLATION DATA  
 C MATERIAL PROPERTIES  
 C LOADING DATA  
 C PIPE DATA  
 C FLUID DATA  
 C REINFORCING DATA  
 C THE OUTPUT IS AVAILABLE WITH ALL IDBUG VALUES.  
 C

COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,  
 1FY,FCP,COU,CIN,FLMV,FLN,DIN,DOU,RTYPE,NLAY,SPIN,SPOUT,P0.FCR,EST  
 1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R  
 1,FPF,P0RT,THP

COMMON/STLAR/AREA1(5),SRATIO(5),SGOV(5),AREADT(5),STEXT(5)  
 1,STSPA(5),DUM2(12)

COMMON/PARIS/TYPE,TWIDTH,BWIDTH,BPRIME,APRIME,PLAT1,PLAT2,  
 1 LATPC,PTOP,SYST

COMMON/ALIVE/LLTYPE,VMAG,RLEN,RWID

COMMON/BED/DLBED,DLUBED

COMMON /CAGETYP/ ITYPE,RATIO,ELROT,DWI,DWO,TBI,TBO,DWE,  
 1TBEI,TBEO,DWII,PHII,DWIC,PHIC,DWOS,PHIS,WIREI,WIREO.WIREE,  
 2WIREIR,WIRECR,WIRESR

COMMON/SPOIL/SAREA(7),SPK,SPU,SPV,SPM,SPA,SPFB,SPD,LDF,SPRADI,  
 1 INSTAL

COMMON/PRES/HP,FP

COMMON/FILE/III,IP,ISTRP

COMMON/PRIN/IPRINT

COMMON/FACT/FLLNP,FLMVLP

CHARACTER\*25 CLOAD,REINT(3)

CHARACTER\*26 CSYST

REAL NLAY,LATPC

INTEGER RTYPE,P,ISYST

DATA REINT/' SMOOTH WIRE',  
 1 'SMOOTH WELDED WIRE FABRIC',  
 2 ' DEFORMED WIRE OR BAR'/

IRTYPE=INT(RTYPE)

ISYST=INT(SYST)

JLAY=IFIX(NLAY)

STFLAG=0.0

C  
 C  
 C SETUP DESIGN TABLES

IF(IPRINT.EQ.0) WRITE(\*,93)  
 93 FORMAT(////////////////////)  
 IF(IP.EQ.1) WRITE(III,99)  
 IF(IPRINT.EQ.0) WRITE(\*,99)  
 99 FORMAT(1H1)  
 IF(IP.EQ.1) WRITE(III,50)  
 IF(IPRINT.EQ.0) WRITE(\*,50)  
 50 FORMAT(//,22X,'PIPECAR PIPE CULVERT DESIGN SUMMARY')

```

IF (RADI1 .EQ. RADI2) GO TO 10
SPAN=2.0*(U+RADI1)
RISE=2.0*(RADI2-V)
IF(IP.EQ.1) WRITE(III,1000)SPAN,RISE
IF(IPRINT.EQ.0) WRITE(*,1000)SPAN,RISE
1000 FORMAT(5X,F5.1,1X,12HINCH SPAN X ,F5.1,47H INCH RISE REINFORCED EL
1LIPTICAL CONCRETE PIPE ,/,5X,71(1H*))
GO TO 20
10 R1TMP=RADI1*2.
IF(IP.EQ.1) WRITE(III,2000)R1TMP
IF(IPRINT.EQ.0) WRITE(*,2000)R1TMP
2000 FORMAT(13X,F5.1,49H INCH DIAMETER REINFORCED CONCRETE CIRCULAR PIP
1E ,/,5X,71(1H*))
20 CONTINUE
IF(IP.EQ.1) WRITE(III,6000)
6000 FORMAT(/,5X,34H I N S T A L L A T I O N D A T A ,/,5X,71(1H-))
BTMP=BETA*180./3.1415926536
BTMPS=BETAS*180.0/3.1415926536
IF(IP.EQ.1) WRITE(III,7000)H,GAMAS,HH
C IF (TYPE .EQ. 1.0.AND.IP.EQ.1) WRITE(III,7200)BTMP,
C 1BTMPS CHANGED 11/6/87 MJM
7000 FORMAT(7X,31HHEIGHT OF FILL ABOVE CROWN, FT,29X,F6.2,/,7X,22H SOIL
1 UNIT WEIGHT, PCF,38X,F6.2,/,7X,
2 38H SOIL-STRUCTURE INTERACTION COEFFICIENT ,22X,F6.2)
7200 FORMAT(7X,22H BEDDING ANGLE, DEGREES ,38X,F6.2,
2 /,5X,20H LOAD ANGLE, DEGREES ,40X,F6.2)
C
C DETERMINE TYPE OF LOAD SYSTEM
C
GO TO (301,302,303),ISYST
301 CSYST=' RADIAL LOAD SYSTEM'
GO TO 304
302 CSYST=' UNIFORM LOAD SYSTEM'
GO TO 304
303 CSYST='UNIFORM/MANUAL LOAD SYSTEM'
GO TO 304
304 CONTINUE
IF(IP.EQ.1) WRITE(III,52) CSYST
52 FORMAT(7X,'LOAD SYSTEM',29X,A26)
C
C FORMAT STATEMENTS FOR LOAD SYSTEMS
C
401 FORMAT(15X,'LOAD ANGLE, DEGREES',32X,F7.0,/,15X,'BEDDING ANGLE',
1 ', DEGREES',29X,F7.0,/,15X,'PIPE WEIGHT REACTION BED ANGLE',
2 ', DEGREES.'12X,F6.0)
402 FORMAT(15X,'LATERAL PRESSURE COEFFICIENT',24X,F6.3,/,
2 15X,'BOTTOM LOAD WIDTH, (SOIL,WATER,LIVE) %',14X,F6.0,
4 /,15X,'BOTTOM LOAD WIDTH (PIPE WT.) %',22X,F6.0)
403 FORMAT(15X,'VERTICAL PRESSURE, PSF',28X,F8.1,/,15X,'LATERAL ',
1 'PRESSURE AT TOP, PSF',22X,F8.1,/,15X,'LATERAL PRESSURE AT ',
2 'BOTTOM, PSF',19X,F8.1,/,15X,'TOP LOAD WIDTH, %',35X,F6.2,/,
3 15X,'BOTTOM LOAD WIDTH, %',32X,F6.2,/,15X,'DISTANCE FROM INVERT ',
4 ',TO BOTTOM OF SIDE LOAD, IN.',4X,F6.2,/,15X,'HEIGHT OF SIDE LOAD
5',', IN.',28X,F6.2,/,15X,'BOTTOM LOAD WIDTH (PIPE WT.) %',20X,
6F6.0)
414 FORMAT(15X,'INSTALLATION TYPE ',28X,I8)

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415 FORMAT(7X,'ELLIPTICAL CAGE MISORIENTATION ANGLE, DEG.',18X,F6.2)
C
C   PRINT LOAD SYSTEM PARAMETERS
C
      GO TO (501,502,503),ISYST
501 IF(IP.EQ.1) WRITE(III,401) BTMPS,BTMP,DLBED
      GO TO 504
502 IF(IP.EQ.1) WRITE(III,402) LATPC,BWIDTH,DLUBED
      GO TO 504
503 IF(IP.EQ.1) WRITE(III,403) PTOP*12000.,PLAT1*12000.,
      1PLAT2*12000.,TWIDTH,BWIDTH,APRIME,BPRIME,DLUBED
      GO TO 504
504 CONTINUE
      PI=3.1415926535897
      IF(ITYPE.EQ.3.OR.ITYPE.EQ.5.OR.ITYPE.EQ.6) THEN
      IF(IP.EQ.1) WRITE(III,415) ELROT*180/PI
      ENDIF
C
      IF(IP.EQ.1) WRITE(III,3000)
3000 FORMAT(/,5X,38H M A T E R I A L P R O P E R T I E S ,/,5X
      1 ,71(1H-))
      IF(IP.EQ.1) WRITE(III,4000) FY,REINT(IRTYPE),JLAY,FCP
4000 FORMAT(7X,52HREINFORCING - MINIMUM SPECIFIED YIELD STRENGTH, KSI ,
      1 8X,F6.0,/,15X,16HREINFORCING TYPE ,17X,A25,
      2 /,15X,28HNO. OF LAYERS OF REINFORCING ,25X,I5,
      3 /,7X,47HCONCRETE - SPECIFIED COMPRESSIVE STRENGTH, KSI ,
      4 13X,F6.0)
      IF(IP.EQ.1) WRITE(III,9000)
9000 FORMAT(/,5X,24H L O A D I N G D A T A ,/,5X,71(1H-))
      IF(IP.EQ.1) WRITE(III,1001) FLMV,FLN,FLMVLP,FLLNP,FPF,
      1P0,P0D,P0R,FCR,FRP,FVP
1001 FORMAT(7X,35HDEAD LOAD FACTOR - MOMENT AND SHEAR,25X,F6.2,/
      1 ,7X,25HDEAD LOAD FACTOR - THRUST ,35X,F6.2,/,
      2 7X,35HLIVE LOAD FACTOR - MOMENT AND SHEAR,25X,F6.2,/
      3 ,7X,25HLIVE LOAD FACTOR - THRUST ,35X,F6.2,
      $ /,7X,33HINTERNAL PRESSURE FACTOR - THRUST,27X,F6.2,
      4 /,7X,33HSTRENGTH REDUCTION FACTOR-FLEXURE,27X,F6.2,/,
      5 7X,42HSTRENGTH REDUCTION FACTOR-DIAGONAL TENSION,18X,F6.2,/,7X,
      $'STRENGTH REDUCTION FACTOR-RADIAL TENSION',20X,F6.2,/,7X,
      6 28HLIMITING CRACK WIDTH FACTOR ,32X,F6.2,/,7X,
      7 30HRADIAL TENSION PROCESS FACTOR ,30X,F6.2,/,7X,
      8 32HDIAGONAL TENSION PROCESS FACTOR ,28X,F6.2.)
C
C   DETERMINE TYPE OF LIVELOAD           COPIED FROM BOXCAR - MJM
C
      GO TO (201,202,203,204,205),LLTYPE
201 CLOAD='          NONE'
      GO TO 206
202 CLOAD='          OTHER'
      GO TO 206
203 CLOAD='          AASHTO HS-'
      GO TO 206
204 CLOAD=' AASHTO INTERSTATE/HS-20'
      GO TO 206
205 CLOAD='          COOPER E-'
206 CONTINUE

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C

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IF (CLOAD .NE. ' AASHTO HS-' .AND.
1 CLOAD .NE. ' COOPER E-') GO TO 207
GO TO 208
207 IF(IP.EQ.1) WRITE(III,54) CLOAD
208 IF (CLOAD .EQ. ' AASHTO HS-' .OR.
1 CLOAD .EQ. ' COOPER E-') GO TO 209
GO TO 211
209 IF(IP.EQ.1) WRITE(III,58) CLOAD,VMAG
54 FORMAT(7X,'LIVE LOAD TYPE',27X,A25)
58 FORMAT(7X,'LIVE LOAD TYPE',24X,A25,F3.0)
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C

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211 IF(IP.EQ.1) WRITE(III,2001)
2001 FORMAT(/,5X,18HP I P E D A T A ,/,5X,71(1H-))
IF (RADI1 .NE. RADI2.AND.IP.EQ.1) WRITE(III,3002) RADI1,RADI2,U,V
GO TO (111,222,333,444,555,666),ITYPE
111 CIN=TBI
COUT=TBO
GO TO 777
222 CIN=TBI
COUT=TH-TBI
GO TO 777
333 CIN=TBEI
COUT=TBE0
GO TO 777
444 CIN=TBI
COUT=TBO
GO TO 777
555 CIN=TBI
COUT=TBE0
GO TO 777
666 CIN=TBI
COUT=TBO
777 IF(IP.EQ.1) WRITE(III,3001) TH,CIN,COUT
3002 FORMAT(7X,13HRADIUS 1, IN., 47X,F6.2,/,7X,13HRADIUS 2,IN.,
1 47X,F6.2,/,7X,'HORIZONTAL OFFSET, IN.',38X,F6.2,/,7X,
2'VERTICAL OFFSET, IN.',40X,F6.2)
3001 FORMAT(7X,19HWALL THICKNESS, IN. ,41X,F6.2,/,
1 7X,44HINSIDE CONCRETE COVER OVER REINFORCING, IN. ,16X,F6.2,
1 /,7X,44HOUTSIDE CONCRETE COVER OVER REINFORCING, IN. ,16X,F6.2)
IF(IP.EQ.1) WRITE(III,4001) GAMAF,DF,HP
4001 FORMAT(/,5X,20HF L U I D D A T A ,/,5X,71(1H-),/,
1 7X,19HFLUID DENSITY, PCF. ,41X,F6.2,/,7X,
1 34HDEPTH OF FLUID,INCHES ABOVE INVERT ,26X,F6.2,/,7X,
1 17HPRESSURE HEAD, FT,43X,F6.2)
IF ((SGOV(1) .LT. 4 .OR. SGOV(1) .EQ. 8) .AND. (SGOV(5) .LT. 4
1 .OR. SGOV(5) .EQ. 8)) GO TO 5073
5073 IF(IP.EQ.1) WRITE(III,5074)
5074 FORMAT(1H1,5(/))
IF(IP.EQ.1) WRITE(III,5001)
IF(IPRINT.EQ.0) WRITE(*,5001)
5001 FORMAT(/,5X,34HR E I N F O R C I N G D A T A ,
1 /,5X,71(1H-))
GO TO (1011,2022,3033,4044,5055,6066),ITYPE
1011 IF(IP.EQ.1) WRITE(III,1014)
IF(IPRINT.EQ.0) WRITE(*,1014)
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1014 FORMAT(5X,21HREINFORCING CAGE TYPE,30X,15HDOUBLE CIRCULAR)
  ASINV=AREA1(1)
  ASSPR=AREA1(3)
  ASCRN=AREA1(5)
  AINV=ASINV
  ASPR=ASSPR
  ACRN=ASCRN
  STEXTM = AMAX1(STEXT(1),STEXT(2))
  AREDTX = AMAX1(AREADT(1),AREADT(2))
  IF (STSPA(2) .NE. 0.) STSPAM = STSPA(2)
  IF (STSPA(1) .NE. 0.) STSPAM=STSPA(1)
  IF (STSPA(1) .NE. 0. .AND. STSPA(2).NE.0.) STSPAM=AMIN1(STSPA(1),S
1TSPA(2))
  IF (STSPAM .LT. 0.5) STSPAM=0.5
  IF (SGOV(1) .LT. 4.) GO TO 101
  IF(IP.EQ.1) WRITE(III,6001) ASINV,ASSPR,ASCRN
  IF(IPRINT.EQ.0) WRITE(*,6001) ASINV,ASSPR,ASCRN
6001 FORMAT(7X,38HINVERT- INSIDE REINFORCING, SQ.IN./FT. ,22X,
1 F6.3,/,7X,43HSPRINGLINE- OUTSIDE REINFORCING, SQ.IN./FT.,17X,
1 F6.3,/,7X,37HCROWN- INSIDE REINFORCING, SQ.IN./FT.,23X,F6.3)
  IF (SGOV(1) .EQ. 8.) GO TO 103
  WRITE(3,7979) STEXTM,AREADTX,STSPAM,ISTRP
7979 FORMAT('1',3F10.3,I2)
  GO TO 103
101 IF (SGOV(2) .LT. 7.) GO TO 102
  IF(IP.EQ.1) WRITE(III,6001) ASINV,ASSPR,ASCRN
  IF(IPRINT.EQ.0) WRITE(*,6001) ASINV,ASSPR,ASCRN
  WRITE(3,7979) STEXTM,AREADTX,STSPAM,ISTRP
  GO TO 103
102 IF (SGOV(2) .NE. 6.) GO TO 108
  IF(IP.EQ.1) WRITE(III,6001)ASINV,ASSPR,ASCRN
  IF(IPRINT.EQ.0) WRITE(*,6001)ASINV,ASSPR,ASCRN
  WRITE(3,7979) STEXTM,AREADTX,STSPAM,ISTRP
  ASINV=AMAX1(ASINV,AREA1(2))
  ATINV=ASINV
  ATCRN=ASCRN
  ATSPR=ASSPR
103 CREXTM= AMAX1(STEXT(4),STEXT(5))
  CRASTM= AMAX1(AREADT(4),AREADT(5))
  IF (STSPA(4) .NE. 0.) CRSTSP= STSPA(4)
  IF (STSPA(5) .NE. 0.) CRSTSP=AMIN1(STSPA(4),STSPA(5))
  IF (CRSTSP .LT. 0.5) CRSTSP=0.5
  IF (SGOV(5) .LT. 4.) GO TO 104
  IF (SGOV(5) .EQ. 8.) GO TO 110
  WRITE(3,8989) CREXTM,CRASTM,CRSTSP,ISTRP
8989 FORMAT('2',3F10.3,I2)
  GO TO 110
104 IF (SGOV(4) .LT. 7.) GO TO 105
  WRITE(3,8989) CREXTM,CRASTM,CRSTSP,ISTRP
  GO TO 110
105 IF (SGOV(4) .NE. 6.) GO TO 106
  WRITE(3,8989) CREXTM,CRASTM,CRSTSP,ISTRP
  ASCRN=AMAX1(ASCRN,AREA1(4))
  ATINV=ASINV
  ATSPR=ASSPR
  ATCRN=ASCRN

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DO 1919 L=1,5
  IF (SGOV(L) .GT. 3 .AND. SGOV(L) .LT. 8) GO TO 1717
1919 CONTINUE
  GO TO 2233
1717 IF(IPRINT.EQ.0) WRITE(*,1616)
  IF(IP.EQ.1) WRITE(III,1616)
  STFLAG=1.0
1616 FORMAT(/,7X,'*** STIRRUP REINFORCING IS REQUIRED ***')
2233 IF (SGOV(1) .GE. 4.0) GO TO 109
  IF (SGOV(2) .NE. 6.0) GO TO 109
  IF(IP.EQ.1) WRITE(III,9001)
  IF(IP.EQ.1) WRITE(III,6001) ASINV,ASSPR,ASCRN
  IF(IPRINT.EQ.0) WRITE(*,6001) ASINV,ASSPR,ASCRN
  GO TO 110
109 IF(IP.EQ.1) WRITE(III,9002)
  IF(IPRINT.EQ.0) WRITE(*,9202)
9002 FORMAT(/,7X,'SEE TABLE BELOW FOR STIRRUP REINFORCEMENT',//,7X,
1 45HALTERNATE REINFORCING WITHOUT CROWN STIRRUPS ,/)
9202 FORMAT(/,7X,
1 45HALTERNATE REINFORCING WITHOUT CROWN STIRRUPS ,/)
  IF(IP.EQ.1) WRITE(III,6001)ASINV,ASSPR,ASCRN
  IF(IPRINT.EQ.0) WRITE(*,6001)ASINV,ASSPR,ASCRN
  IF (SGOV(2) .EQ. 8.0) GO TO 110
  WRITE(3,7979) STEXTM,AREDTX,STSPAM,ISTRP
  GO TO 110
106 DO 9191 L=1,5
  IF (SGOV(L) .GT. 3 .AND. SGOV(L) .LT. 8) GO TO 7171
9191 CONTINUE
  GO TO 2244
7171 IF(IPRINT.EQ.0) WRITE(*,6161)
  IF(IP.EQ.1) WRITE(III,6161)
  STFLAG=1.0
6161 FORMAT(/,7X,'*** STIRRUP REINFORCING IS REQUIRED ***')
2244 IF (SGOV(1) .GE. 4.) GO TO 110
  IF (SGOV(2) .NE. 6.) GO TO 110
107 IF(IP.EQ.1) WRITE(III,9001)
  IF(IPRINT.EQ.0) WRITE(*,9101)
9001 FORMAT(/,7X,'SEE TABLE BELOW FOR STIRRUP REINFORCEMENT',//,7X,
1 'ALTERNATE REINFORCING WITHOUT STIRRUPS',/)
9101 FORMAT(/,7X,
1 'ALTERNATE REINFORCING WITHOUT STIRRUPS',/)
  IF(IP.EQ.1) WRITE(III,6001) ASINV,ASSPR,ASCRN
  IF(IPRINT.EQ.0) WRITE(*,6001) ASINV,ASSPR,ASCRN
  GO TO 110
108 CONTINUE
  IF(IP.EQ.1) WRITE(III,6001) ASINV,ASSPR,ASCRN
  IF(IPRINT.EQ.0) WRITE(*,6001) ASINV,ASSPR,ASCRN
110 CONTINUE
  GO TO 7077
2022 IF(IP.EQ.1) WRITE(III,2023)
  IF(IPRINT.EQ.0) WRITE(*,2023)
2023 FORMAT(5X,21HREINFORCING CAGE TYPE,30X,15HSINGLE CIRCULAR)
  ASDES=AMAX1(AREA1(1),AREA1(2),AREA1(3),AREA1(4),AREA1(5))
  IF(IP.EQ.1) WRITE(III,2027) ASDES
  IF(IPRINT.EQ.0) WRITE(*,2027) ASDES
2027 FORMAT(5X,23HREINFORCING, SQ.IN./FT.,37X,F6.3)

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NPR=0
DO 2031 I=1,5
IF(SGOV(I).LE.3..OR.SGOV(I).EQ.6.) GO TO 2031
IF(SGOV(I) .EQ. 9) GO TO 2031
IF(NPR.EQ.1) GO TO 2031
NPR=1
IF(SGOV(I) .EQ. 8) GO TO 2437
IF(IP.EQ.1) WRITE(III,2249)
IF(IPRINT.EQ.0) WRITE(*,2249)
2249 FORMAT(/,5X,
155HPIPECAR DESIGNS STIRRUPS ONLY FOR DOUBLE CIRCULAR CAGES)
GO TO 2031
2437 IF(IP.EQ.1) WRITE(III,2037)
IF(IPRINT.EQ.0) WRITE(*,2037)
2037 FORMAT(/,5X,65H*** DESIGN NOT POSSIBLE DUE TO EXCESSIVE CONCRETE C
1OMPRESSION ***)
2031 CONTINUE
GO TO 7077
3033 IF(IP.EQ.1) WRITE(III,3041)
IF(IPRINT.EQ.0) WRITE(*,3041)
3041 FORMAT(5X,21HREINFORCING CAGE TYPE,28X,17HSINGLE ELLIPTICAL)
ASDES=AMAX1(AREA1(1),AREA1(2),AREA1(3),AREA1(4),AREA1(5))
IF(IP.EQ.1) WRITE(III,3047) ASDES
IF(IPRINT.EQ.0) WRITE(*,3047) ASDES
3047 FORMAT(5X,23HREINFORCING, SQ.IN./FT.,37X,F6.3)
NPR=0
DO 3052 I=1,5
IF(SGOV(I).LE.3..OR.SGOV(I).EQ.6.) GO TO 3052
IF(SGOV(I) .EQ. 9) GO TO 3052
IF(NPR.EQ.1) GO TO 3052
NPR=1
IF(SGOV(I) .EQ. 8) GO TO 3417
IF(IP.EQ.1) WRITE(III,2249)
IF(IPRINT.EQ.0) WRITE(*,2249)
GO TO 3052
3417 IF(IP.EQ.1) WRITE(III,2037)
IF(IPRINT.EQ.0) WRITE(*,2037)
3052 CONTINUE
GO TO 7077
4044 IF(IP.EQ.1) WRITE(III,4047)
IF(IPRINT.EQ.0) WRITE(*,4047)
4047 FORMAT(5X,21HREINFORCING CAGE TYPE,20X,25HDOUBLE CIRCULAR WITH MAT
1S)
ASINV=AMAX1(AREA1(1),AREA1(2))
ASSPR=AREA1(3)
ASCRN=AMAX1(AREA1(5),AREA1(4))
IF(ASINV .LT. 1.0E26 .AND. ASCRN .LT. 1.0E26) GO TO 4172
ASINV=1.0E26
ASSPR=1.0E26
ASCRN=1.0E26
4172 CONTINUE
IF(IP.EQ.1) WRITE(III,6001) ASINV,ASSPR,ASCRN
IF(IPRINT.EQ.0) WRITE(*,6001) ASINV,ASSPR,ASCRN
C
DO 4057 I=1,5
IF(SGOV(I).LE.3..OR.SGOV(I).EQ.6.) GO TO 4057

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IF(SGOV(I) .EQ. 9) GO TO 4057
C
IF(SGOV(I) .EQ. 8) GO TO 4474
IF(IP.EQ.1) WRITE(III,2249)
IF(IPRINT.EQ.0) WRITE(*,2249)
GO TO 4068
4474 IF(IP.EQ.1) WRITE(III,2037)
IF(IPRINT.EQ.0) WRITE(*,2037)
GO TO 4068
4057 CONTINUE
IF(IP.EQ.1) WRITE(III,9430)
CALL MATDES
IF(IP.EQ.1) WRITE(III,4052)
4052 FORMAT(/,5X,85(1H-),/,10X,
156HREINFORCING AREAS SHOWN ARE REQUIRED AREAS AT THE CROWN,,/,5X,
260HINVERT,AND SPRINGLINE. THIS MAY BE SUPPLIED BY FULL CIRCULAR,/,
35X,62HCAGES OR WITH MATS. IF MAT REINFORCING IS USED,IT MUST PROVI
4DE,/,5X,60HTHE MINIMUM REINFORCING REQUIREMENTS AT EACH LOCATION A
5ROUND,/,5X,61HTHE PIPE AS GIVEN ABOVE. MAT REINFORCING MUST EXTEND
6 AT LEAST,/,5X,63HITS DEVELOPMENT LENGTH BEYOND THE POINT AT WHICH
7 IT IS REQUIRED,/,5X,64HPLUS TOLERANCE FOR LOCATION OF PIPE INVERT
8 IN THE FIELD INSTALL-,/,5X,6HATION.)
4068 CONTINUE
GO TO 7077
5055 IF(IP.EQ.1) WRITE(III,5059)
IF(IPRINT.EQ.0) WRITE(*,5059)
5059 FORMAT(5X,21HREINFORCING CAGE TYPE,15X,30HSINGLE CIRCULAR AND ELLI
1PTICAL)
ASCIR=AMAX1(AREA1(1),AREA1(5))
ASELL=AMAX1(AREA1(3),AREA1(2),AREA1(4))
ASCIR=ASCIR-ASELL
IF(ASCIR.LT.0.) ASCIR=0.
IF(ASELL .EQ. 1.0E26) ASCIR=1.0E26
IF(IP.EQ.1) WRITE(III,5063) ASCIR,ASELL
IF(IPRINT.EQ.0) WRITE(*,5063) ASCIR,ASELL
5063 FORMAT(5X,39HINSIDE CIRCULAR REINFORCING, SQ.IN./FT.,21X,F6.3,
1/,5X,34HELLIPTICAL REINFORCING, SQ.IN./FT.,26X,F6.3)
IF(ASCIR .EQ. 0.0.AND.IP.EQ.1) WRITE(III,5291)
5291 FORMAT(/,5X,36HINSIDE CIRCULAR CAGE IS NOT REQUIRED)
NPR=0
DO 5072 I=1,5
IF(SGOV(I).LE.3..OR.SGOV(I).EQ.6.) GO TO 5072
IF(SGOV(I) .EQ. 9) GO TO 5072
IF(NPR.EQ.1) GO TO 5072
NPR=1
IF(SGOV(I) .EQ. 8) GO TO 5339
IF(IP.EQ.1) WRITE(III,2249)
IF(IPRINT.EQ.0) WRITE(*,2249)
GO TO 5072
5339 IF(IP.EQ.1) WRITE(III,2037)
IF(IPRINT.EQ.0) WRITE(*,2037)
5072 CONTINUE
GO TO 7077
6066 IF(IP.EQ.1) WRITE(III,6069)
IF(IPRINT.EQ.0) WRITE(*,6069)
6069 FORMAT(5X,21HREINFORCING CAGE TYPE,15X,30HDOUBLE CIRCULAR AND ELLI

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1PTICAL)
ASINV=AMAX1(AREA1(1),AREA1(2),AREA1(4),AREA1(5))
ASSPR=AREA1(3)
ASINN=ASINV/(RATIO+1.)
ASELL=RATIO*ASINN
ASSPR=ASSPR-ASELL
IF(ASSPR.LT.0.) ASSPR=0.
IF(ASINV .LT. 1.0E26) GO TO 6419
ASINN=1.0E26
ASELL=1.0E26
ASSPR=1.0E26
6419 CONTINUE
IF(IP.EQ.1) WRITE(III,6072) ASINN,ASELL,ASSPR
IF(IPRINT.EQ.0) WRITE(*,6072) ASINN,ASELL,ASSPR
6072 FORMAT(5X,39HINSIDE CIRCULAR REINFORCING, SQ.IN./FT.,21X,F6.3,/,
15X,34HELLIPTICAL REINFORCING, SQ.IN./FT.,26X,F6.3,/,5X,
240HOUTSIDE CIRCULAR REINFORCING, SQ.IN./FT.,20X,F6.3)
NPR=0
DO 6077 I=1,5
IF(SGOV(I).LE.3..OR.SGOV(I).EQ.6.) GO TO 6077
IF(SGOV(I) .EQ. 9) GO TO 6077
IF(NPR.EQ.1) GO TO 6077
NPR=1
IF(SGOV(I) .EQ. 8) GO TO 6632
IF(IP.EQ.1) WRITE(III,2249)
IF(IPRINT.EQ.0) WRITE(*,2249)
GO TO 6077
6632 IF(IP.EQ.1) WRITE(III,2037)
IF(IPRINT.EQ.0) WRITE(*,2037)
6077 CONTINUE
7077 CONTINUE
IF (STFLAG.EQ.1.0) GO TO 3818
DO 3919 L=1,5
IF (SGOV(L) .GT. 3 .AND. SGOV(L) .LT. 8) GO TO 3717
3919 CONTINUE
GO TO 3818
3717 IF(IPRINT.EQ.0) WRITE(*,3616)
IF(IP.EQ.1) WRITE(III,3616)
3616 FORMAT(/,7X,'*** STIRRUP REINFORCING IS REQUIRED ***')
3818 IF(ITYPE.EQ.4) GO TO 9541
IF(IP.EQ.1) WRITE(III,9430)
9430 FORMAT(5X,71(1H-),/,1X,3H>>>,1X,
167HIF THIS PIPE IS MANUFACTURED WITH ANY REINFORCING SCHEME OTHER
2THAN,/,5X,68HA SINGLE OR DOUBLE CIRCULAR CAGE, THE MANUFACTURER MU
3ST CLEARLY MARK,/,5X,70HTHE PIPE TO INDICATE THE PROPER ORIENTATIO
4N IN THE GROUND. REINFORCING,/,5X,69HDESIGNS SHOULD ALLOW FOR SOME
5 TOLERANCE IN LOCATION OF PIPE INVERT IN ,/,5X,23HTHE FIELD INSTAL
6LATION.)
9541 CONTINUE
IF(IPRINT.EQ.0) WRITE(*,9543)
9543 FORMAT(/)
RETURN
END

```

**Subroutine:** EQUAL

**Function:**

This Subroutine sets common variable values equal to appropriate BDATA values.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

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SUBROUTINE EQUAL
COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R
1,FPF,P0RT,THP
COMMON/BSCALE/BDATA(35),DUM3(5)
COMMON/FILE/III,IP,ISTRP
COMMON/FACT/FLLNP,FLMVLP
REAL NLAY
INTEGER RTYPE
RADI1=BDATA(1)
RADI2=BDATA(2)
H=BDATA(3)
U=BDATA(4)
V=BDATA(5)
TH=BDATA(6)
BETA=BDATA(7)
HH=BDATA(8)
GAMAS=BDATA(9)
GAMAC=BDATA(10)
GAMAF=BDATA(11)
DF=BDATA(12)
FY=BDATA(13)
FCP=BDATA(14)
COUT=BDATA(15)
CIN=BDATA(16)
FLMV=BDATA(17)
FLN=BDATA(18)
DIN=BDATA(19)
DOUT=BDATA(20)
RTYPE=BDATA(21)
NLAY=BDATA(22)
SPIN=BDATA(23)
SPOUT=BDATA(24)
P0=BDATA(25)
FCR=BDATA(26)
EST=BDATA(27)
ECON=BDATA(28)
RADM1=BDATA(29)
RADM2=BDATA(30)
EQUID=BDATA(31)
BETAS=BDATA(32)
P0D=BDATA(33)
FRP=BDATA(34)
FVP=BDATA(35)
RETURN
END

```

**Subroutine:** DCALC

**Function:**

This subroutine calculates the distance from the centroid of the innermost reinforcing to the outside face of the pipe wall.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None

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SUBROUTINE DCALC
C THIS SUBROUTINE CALCULATES THE DISTANCE FROM
C THE C.G. OF THE INNER MOST STEEL TO THE OPPOSITE
C FACE OF THE PIPE WALL. THESE D'S ARE USED FOR BOTH
C FLEXURE AND SHEAR CALCULATIONS.
C
COMMON/PROPP/W(17),C(17),ZL(17),PHI(18)
COMMON/DD/DDIN(37),DDOUT(37)
COMMON /CAGETYP/ ITYPE,RATIO,ELROT,DWI,DWO,TBI,TBO,DWE,
1TBEI,TBEO,DWII,PHII,DWIC,PHIC,DWOS,PHIS,WIREI,WIREO,WIREE,
2WIREIR,WIRECR,WIRESR
COMMON/RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,POR
1,FPF,P0RT,THP
COMMON/COORD/X(37),Y(37),A(37),B,BS
COMMON/ISCALE/IDBUG,IPATH
COMMON/FILE/III,IP,ISTRP
COMMON /MATPVM/ DMMAT(37),DPMAT(37),DVMAT(37),DPRMAT(37)
COMMON/FACT/FLLNP,FLMVLP
DIMENSION DELO(37)
PI=3.141592654
RAD=PI/180.
DO 8 I=1,37
DDIN(I)=0.
DDOUT(I)=0.
8 CONTINUE
GO TO(100,200,300,400,500,600),ITYPE
C
C DOUBLE CIRCULAR CAGE ITYPE=1
C
100 DO 10 I=1,37
DDOUT(I)=TH-TBO-DWO/2.
IF(DWO.EQ.0.) DDOUT(I)=DDOUT(I)-0.04*TH
DDIN(I)=TH-TBI-DWI/2.
IF(DWI.EQ.0.) DDIN(I)=DDIN(I)-0.04*TH
10 CONTINUE
GO TO 1000
C
C SINGLE CIRCULAR CAGE ITYPE=2
C
200 DWO=0.0
IF(DWI.EQ.0.) TBI=TH-TBO-DWO
IF(DWO.EQ.0.) TBO=TH-TBI-DWI
IF(DWI.EQ.0.) DWI=DWO
IF(DWO.EQ.0.) DWO=DWI
IF(DWI.EQ.0.) TBO=TH-0.08*TH
IF(DWO.EQ.0.) TBI=TH-0.08*TH
IF(WIREI.EQ.0.) WIREI=WIREO
IF(WIREO.EQ.0.) WIREO=WIREI
DO 20 I=1,37
DDOUT(I)=TH-TBO-DWO/2.
IF(DWO.EQ.0.) DDOUT(I)=DDOUT(I)-0.04*TH
DDIN(I)=TH-TBI-DWI/2.
IF(DWI.EQ.0.) DDIN(I)=DDIN(I)-0.04*TH
20 CONTINUE

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```

      GO TO 1000
C
C  SINGLE ELLIPTICAL CAGE  ITYPE=3
C
300 CALL DELLIP(DELO)
      DO 30 I=1,37
          DDOUT(I)=DELO(I)
          DDIN(I)=TH-DELO(I)
30 CONTINUE
      GO TO 1000
C
C  DOUBLE CIRCULAR PLUS MATS
C
400 DO 40 I=1,37
      DDOUT(I)=TH-TBO-DWO/2.
      IF(DWO.EQ.0.) DDOUT(I)=DDOUT(I)-0.04*TH
      DDIN(I)=TH-TBI-DWI/2.
      IF(DWI.EQ.0.) DDIN(I)=DDIN(I)-0.04*TH
40 CONTINUE
      ANG1=(PHI1/2.)*RAD
      ANG2=(90.-PHIS/2.)*RAD
      ANG3=(90.+PHIS/2.)*RAD
      ANG4=(180.-PHIC/2.)*RAD
      DO 45 I=1,37
          IF(A(I).LE.ANG1) DDIN(I)=DDIN(I)-DWI/2.-DWI1/2.
          IF(A(I).GE.ANG2.AND.A(I).LE.ANG3) DDOUT(I)=DDOUT(I)-DWO/2.-DWO1/2.
          IF(A(I).GE.ANG4) DDIN(I)=DDIN(I)-DWI/2.0-DWIC/2.0
45 CONTINUE
      GO TO 1000
C
C  SINGLE CIRCULAR PLUS ELLIPTICAL  ITYPE=5
C
500 GO TO 300
C
C  DOUBLE CIRCULAR PLUS ELLIPTICAL  ITYPE=6
C
600 GO TO 300
1000 CONTINUE
      RETURN
      END

```

**Subroutine:** DELLIP

**Function:**

This subroutine calculates the distance from the centroid of the elliptical reinforcing steel to the inner and outer faces of the pipe wall.

**I/O Generated by Subroutine:**

None

**Error Messages Generated by Subroutine:**

None



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SUBROUTINE DELLIP(DELO)
C
C PIPE MODEL. A 'D' FROM THE INNER AND OUTER FACE OF THE PIPE
C THE C.G. OF THE ELLIPTICAL STEEL IS RETURNED
C
COMMON /CAGETYP/ ITYPE,RATIO,ELROT,DWI,DWO,TBI,TBO,DWE,
1TBEI,TBEO,DWII,PHII,DWIC,PHIC,DWOS,PHIS,WIREI,WIREO,WIREE,
2WIREIR,WIRECR,WIRESR
COMMON /RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,P0R
1,FPF,P0RT,THP
COMMON/PROPP/W(17),C(17),ZL(17),PHI(18)
COMMON/PROP/SI(37),CO(37),ALEN(37)
COMMON/COORD/X(37),Y(37),A(37),B,BS
COMMON/ISCALE/IDBUG,IPATH
COMMON/FILE/III,IP,ISTRP
COMMON /MATPVM/ DMMAT(37),DPMAT(37),DVMAT(37),DPRMAT(37)
COMMON/FACT/FLLNP,FLMVLP
DIMENSION DELO(37),DLO(37)
C
C CALCULATE ELLIPTICAL CAGE GEOMETRY
C
PI=3.141592654
RAD=PI/180.
DO 2 I=1,37
DELO(I)=0.
2 CONTINUE
IF(ITYPE-5) 10,20,30
10 A1=RADM1-TH/2.+TBEI+DWE/2.
IF(DWE.EQ.0.) A1=A1+0.04*TH
B1=RADM1+TH/2.-TBEO-DWE/2.
IF(DWE.EQ.0.) B1=B1-0.04*TH
GO TO 40
20 A1=RADM1-TH/2.+TBI+DWI+DWE/2.
IF(DWI.EQ.0.) A1=A1+0.08*TH
IF(DWE.EQ.0.) A1=A1+0.04*TH
B1=RADM1+TH/2.-TBEO-DWE/2.
IF(DWE.EQ.0.) B1=B1-0.04*TH
GO TO 40
30 A1=RADM1-TH/2.+TBI+DWI+DWE/2.
IF(DWI.EQ.0.) A1=A1+0.08*TH
IF(DWE.EQ.0.) A1=A1+0.04*TH
B1=RADM1+TH/2.-TBO-DWO-DWE/2.
IF(DWO.EQ.0.) B1=B1-0.08*TH
IF(DWE.EQ.0.) B1=B1-0.04*TH
40 CONTINUE
C
C DETERMINE D AT EACH JOINT
C
DO 100 I=1,37
RE=SQRT((A1*COS(A(I)))**2.+(B1*SIN(A(I)))**2.)
DELO(I)=(RE-RADM1)+TH/2.
IF(ELROT .EQ. 0.0) GO TO 1313
E1=ELROT*180/(5.0*PI)
IK1=E1

```

```

100 CONTINUE
C FROM 0 TO 90 DEG. ADDS MISALIGNMENT FOR + MOMENT
C FROM 0 TO 90 DEG. SUBTRACTS MISALIGNMENT FOR - MOMENT
C FROM 90+ TO 180 DEG. SUBTRACTS MISALIGNMENT FOR + MOMENT
C FROM 90+ TO 180 DEG. ADDS MISALIGNMENT FOR - MOMENT
DO 1212 I=1,37
  IF (I.GT.19) GO TO 110
  IF(DMMAT(I).GE.0.0) THEN
    DLO(I)=(DELO(I+IK1+1)-DELO(I+IK1))*(E1-IK1)+DELO(I+IK1)
  ELSE
    DLO(I)=(DELO(I-IK1-1)-DELO(I-IK1))*(E1-IK1)+DELO(I-IK1)
  ENDIF
  GO TO 1212
110 CONTINUE
  IF(DMMAT(I).LT.0.0) THEN
    DLO(I)=(DELO(I+IK1+1)-DELO(I+IK1))*(E1-IK1)+DELO(I+IK1)
  ELSE
    DLO(I)=(DELO(I-IK1-1)-DELO(I-IK1))*(E1-IK1)+DELO(I-IK1)
  ENDIF
1212 CONTINUE
DO 1414 I=1,37
  DELO(I)=DLO(I)
1414 CONTINUE
1313 RETURN
END

```

**Subroutine:** MATDES

**Function:**

This subroutine calculates the reinforcing requirements at each joint of the pipe model. This is used to determine where mat reinforcing may be terminated.

**I/O Generated by Subroutine:**

This subroutine prints a table of reinforcing requirements at each joint.

**Error Messages Generated by Subroutine:**

None

```

SUBROUTINE MATDES
COMMON /MATPVM/ DMMAT(37),DPMAT(37),DVMAT(37),DPRMAT(37)
COMMON /DD/DDIN(37),DDOUT(37)
COMMON /CAGETYP/ ITYPE,RATIO,ELROT,DWI,DWO,TBI,TBO,DWE,
1TBEI,TBEO,DWII,PHII,DWIC,PHIC,DWOS,PHIS,WIREI,WIREO,WIREE,
2WIREIR,WIRECR,WIRESR
COMMON /RSCALE/RADI1,RADI2,H,U,V,TH,BETA,HH,GAMAS,GAMAC,GAMAF,DF,
1FY,FCP,COUT,CIN,FLMV,FLN,DIN,DOUT,RTYPE,NLAY,SPIN,SPOUT,P0,FCR,EST
1,ECON,RADM1,RADM2,EQUID,BETAS,P0D,FRP,FVP,FLMVLL,FLNLL,R3,POR
1,FPF,PORT,THP
COMMON /STLAR/AREA1(5),SRATIO(5),SGOV(5),AREADT(5),STEXT(5),
1STSPA(5),DUM2(12)
COMMON /COORD/X(37),Y(37),A(37),B,BS
COMMON /PROP/SI(37),C(37),ALEN(37)
COMMON /FILE/III,IP,ISTRP
COMMON /FACT/FLLNP,FLMVLP
REAL M1, N1, M1PSI, N1PSI, MO, NO
REAL AS(2),ACONT(2),PHI(37)
CHARACTER*8 DLOC(37),SLOC(6)
DATA DLOC/8HINVERT ,17*8H ,8HSPRING ,8HLINE ,
116*8H ,8HCROWN /
DATA SLOC/8HFLEXURE ,8HMINIMUM ,8HCOMPRESS,8HSHEAR ,
1 8HCRACK ,8HTENSION /
B1=0.85-0.05*(FCP-4.)
IF(B1.GT.0.85) B1=0.85
IF(B1.LT.0.65) B1=0.65
FCPPSI=FCP*1000.
FYPSI=FY*1000.
PI=3.1415926535897
DO 515 I=1,37
PHI(I)=A(I)*180./PI
515 CONTINUE
SPMN=(RADM1+U)*2.
IF(IP.EQ.1) WRITE(III,340)
IF(IP.EQ.1) WRITE(III,350)
340 FORMAT(///,T30,28HMINIMUM REQUIRED REINFORCING,/,T32,
125HAROUND PIPE CIRCUMFERENCE,/,T30,28(1H-))
350 FORMAT(///,15X,8H DESIGN ,7X,10H INSIDE ,5X,15X,
110H OUTSIDE ,/,15X,8HLOCATION,6X,11HREINF. AREA,5X,
29HGOVERNING,5X,11HREINF. AREA,5X,9HGOVERNING,/,15X,
39H(DEGREES),6X,12H(IN.SQ./FT.),3X,6H MODE,9X,12H(IN.SQ./FT.),
43X,6H MODE,/)
C
C DESIGN STEEL FOR EACH OF 18 NODES OF MODEL
C DESIGN FOR FLEXURE,CRACK,MINIMUM, AND CHECK IF STEEL
C WAS INCREASED FOR SHEAR
C
DO 100 I=1,37
DO 200 K=1,2
AS(K) = 0.0
FLG=0.
CASMN=1.0
C01=0.
FLAY=0.
D=DDIN(I)*P0
IF(K.EQ.1) GO TO 10

```

```

CASMN=0.75
D=DDOUT(I)*P0
10 M1=ABS(DMMAT(I))
N1=DPMAT(I)
M1PSI=M1*1000.
N1PSI=N1*1000.
Q=10.2*FCPPSI
IF(DMMAT(I).LT.0..AND.K.EQ.1) FLG=1.
IF(DMMAT(I).GT.0..AND.K.EQ.2) FLG=1.
C
C   REQUIRED STEEL FOR FLEXURE
C
IF(FLG.EQ.1.) GO TO 70
IF(Q*(Q*D*D-N1PSI*(2.*D-TH)-2.*M1PSI).LT.0.) GO TO 90
AS(K)=(Q*D-N1PSI-SQRT(Q*(Q*D*D-N1PSI*(2.*D-TH)-2.*M1PSI)))
1/FYPSI
ACONT(K)=SLOC(1)
C
C   MINIMUM STEEL REQUIREMENTS
C
70 IF(AS(K).GT.CASMN*SPMN**2./65000..AND.AS(K).GT.0.07) GO TO 20
AS(K)=CASMN*SPMN**2./65000.
IF(AS(K).LT.0.07) AS(K)=0.07
ACONT(K)=SLOC(2)
20 IF(FLG.EQ.1) GO TO 30
C
C   CHECK CONCRETE COMPRESSION
C
ASCC=5.5E4*12.*B1*FCPPSI*D/
1(FYPSI*(87000.+FYPSI))-0.75*N1PSI/FYPSI
IF(AS(K) .LT. ASCC) GO TO 395
90 AS(K)=1.0E26
ACONT(K)=SLOC(3)
GO TO 200
C
C   STEEL AREA BASED ON 0.01 INCH CRACK
C
395 AREA01 = 0.0
AREO12 = 0.0
SIM = 12.0 / WIREI
CIM = TBI
IF(K .EQ. 2) CIM = TBO
IF(K .EQ. 2) SIM = 12.0 / WIREO
ITMP = IFIX(RTYPE)
GO TO (1000, 2000, 3000), ITMP
1000 CO = 1.0
B2 = (0.5 * CIM**2 * SIM / NLAY)**(1./3.)
GO TO 400
2000 CO = 1.5
B2 = 1.0
FLAY = CIM**2 * SIM / NLAY
GO TO 400
3000 CO = 1.9
B2 = (0.5 * CIM**2 * SIM / NLAY)**(1./3.)
400 MO = M1PSI / FLMV
NO=N1PSI/FLN

```

```

D = D / P0
E = MO/NO + D - TH/2.0
IF((E/D) .LT. 1.15) GO TO 30
BJ = 0.74 + 0.1*E/D
IF(BJ .GT. 0.90) BJ = 0.90
P = 1.0 / (1.0 - BJ*D/E)
420 CONTINUE
Q1 = (MO + NO*(D-TH/2.0))*B2 / (30000.0*BJ*P*P0*D*FCR)
R1 = CO*B2*12.0*TH**2*SQRT(FCPPSI) / (30000.0*FCR*D*P0)
AREAO1 = Q1 - R1
IF(CO1 .EQ. 1.0) GO TO 430
IF(FLAY .LT. 3.0) GO TO 440
CO1 = 1.0
CO = 1.9
B2 = (0.5*FLAY)**(1./3.)
AREO12 = AREAO1
GO TO 420
430 IF(AREO12 .GT. AREAO1) AREAO1 = AREO12
440 CONTINUE
CRACK = AREAO1 / AS(K)
C
C SERVICE LOAD CRACK CONTROL INDEX
C
IF(CRACK .LE. 1) GO TO 30
AS(K) = AREAO1
ACONT(K) = SLOC(5)
C
C CHECK INCREASED STEEL AREA FOR SHEAR
C
30 IF(K.EQ.2) GO TO 200
IF(PHI(I).GT.90.) GO TO 40
IF(AS(K).LT.AREA1(2)) AS(K)=AREA1(2)
IF(AS(K).EQ.AREA1(2)) ACONT(K)=SLOC(4)
GO TO 200
40 IF(AS(K).LT.AREA1(4)) AS(K)=AREA1(4)
IF(AS(K).EQ.AREA1(4)) ACONT(K)=SLOC(4)
200 CONTINUE
IF(IP.EQ.1) WRITE(III,375) DLOC(I),PHI(I),AS(1),ACONT(1),
1AS(2),ACONT(2)
375 FORMAT(A8,7X,F8.2,7X,F8.3,7X,A8,7X,F8.3,7X,A8)
100 CONTINUE
RETURN
END

```

**Subroutine:**           3EDGBRG

**Function:**

This subroutine, accessed from the main menu evaluates reinforcing requirements for pipe under the three-edge bearing load condition.

3EDGBRG is written in BASICA. Design equations used in this subroutine are listed in Appendix C.

**I/O Generated by Subroutine:**

The three-edge bearing module generates reinforcing designs for given load conditions or strengths for given reinforcing amounts. All output is written to the screen or the printer.

**Error Messages Generated by Subroutine:**

The subroutine monitors input and provides error messages to the screen if parameter ranges are exceeded.

```

10 KEY OFF
20 REM
30 REM - PIPECAR - THREE EDGE BEARING DESIGN PROGRAM
40 REM - DESIGNS REINFORCING FOR, OR ANALYSES D-LOAD CAPACITY OF
50 REM - CIRCULAR, ELLIPTICAL OR ARCH CONCRETE PIPES
60 REM - REVISED 2/10/88
70 REM
80 CLS:LOCATE 10,1
90 PRINT" PIPECAR INDIRECT DESIGN PROGRAM":PRINT
100 PRINT" Design and analysis of reinforced concrete pipe for the three"
110 PRINT" edge bearing load condition. This is a completely independent"
120 PRINT" module of PIPECAR that requires its own input and does not write"
130 PRINT" any files to disk.":PRINT:PRINT
140 PRINT" Enter Project Description "; INPUT "",JDSCP$
150 DESNUM=0
160 REM - INITIALIZE VARIABLES
170 REM
180 CLS
190 N9=1 : REM - # OF REINFORCEMENT LAYERS
200 S1=4 : REM - REINFORCEMENT SPACING
210 B0=12 : REM - RESISTING WIDTH OF PIPE
220 INDIA=0 : REM - INNER SPAN OF PIPE
230 WALLT=0 : REM - WALL THICKNESS
240 IRECOVER=1 : REM - INSIDE REINFORCEMENT COVER
250 ORECOVER=1 : REM - OUTSIDE REINFORCEMENT COVER
260 RETYPE=2 : REM - REINFORCEMENT TYPE
270 FY=65000! : REM - YIELD STRENGTH OF REINFORCEMENT
280 FSU=75000! : REM - ULTIMATE TENSILE STRENGTH
290 PSHAPE$="CIRCULAR" : REM - PIPE SHAPE
300 PSHAPEF$=PSHAPE$ : REM - FOR OUTPUT
310 SHIFT$=" " : REM - FOR OUTPUT
320 DESCRIT$="ULTIMATE" : REM - DESIGN CRTIERIA
330 FPRIMEC=5000 : REM - CONCRETE STRENGTH, F'c
340 PHIF=.95 : REM - FLEXURAL CAPACITY REDUCTION FACTOR
350 PHIC=.95 : REM - 0.01 CRACK CAPACITY REDUCTION FACTOR
360 PHID=.9 : REM - DIAG. TENS. CAPACITY REDUCTION FACTOR
370 PHIR=.9 : REM - RAD. TENS. CAPACITY REDUCTION FACTOR
380 CM=1 : REM - DESIGN COEFFICIENT
390 CMO=1 : REM - DESIGN COEFFICIENT
400 CW=1 : REM - DESIGN COEFFICIENT
410 CS=.6 : REM - DESIGN COEFFICIENT
420 CX=1 : REM - DESIGN COEFFICIENT
430 CSHP=3.3 : REM - DESIGN COEFF FOR PIPE WEIGHT
440 TYPE3T$="C" : REM - TYPE 3 REINF ASSUMED WIRE OR WWF
450 IOUT=1 : REM - INITIAL OUTPUT TO SCREEN
460 RDSGN=1
470 OPEN "SCRN:" FOR OUTPUT AS #1
480 OPEN "LPT1:" FOR OUTPUT AS #2
490 KEY(1) ON: KEY(2) ON: KEY(3) ON: KEY(4) ON: KEY(5) ON: KEY(10) ON
500 ON KEY(1) GOSUB 1030:REM PIPE GEOMETRY
510 ON KEY(2) GOSUB 1510:REM MATERIAL PROPERTIES
520 ON KEY(3) GOSUB 2070:REM DESIGN COEFFICIENTS
530 ON KEY(4) GOSUB 7430:REM MAIN MENU
540 ON KEY(5) GOSUB 6840:REM HELP
550 ON KEY(10) GOSUB 2510:REM CONTINUE
560 GOSUB 590

```



```

570   A$=INKEY$:GOTO 570:REM - WAIT FOR SOFTKEY INPUT
580   REM
590   REM - MAIN MENU
600   REM
610   CLS
620   REM
630   KEY(1) ON: KEY(2) ON: KEY(3) ON: KEY(4) ON: KEY(5) ON: KEY(10) ON
640   LOCATE 1,1:PRINT"---PIPECAR - THREE EDGE BEARING PROGRAM --- DESIGN
PARAMETERS-----"
650   LOCATE 3,2:PRINT "PIPE GEOMETRY <F1>:";TAB(54);"DESIGN COEFFICIENTS <F3>:"
660   LOCATE 4,4:PRINT"Pipe shape";TAB(37);"= ";PSHAPES$
670   LOCATE 5,4:PRINT"Inner diameter or span (in.);TAB(37);"= ";INDIA;TAB(52);"PhiF =
";PHIF;TAB(65);"Cs = ";CS
680   LOCATE 6,4:PRINT"Wall thickness (in.);TAB(37);"= ";WALLT;TAB(52);"PhiC =
";PHIC;TAB(65);"(Aso/Asi)"
690   LOCATE 7,4:PRINT"Inside reinforcing cover (in.);TAB(37);"= ";IRECOVER;TAB(52);"PhiD =
";PHID;TAB(65)
700   LOCATE 8,4:PRINT"Outside reinforcing cover (in.);TAB(37);"= ";ORECOVER;TAB(52);"PhiR
= ";PHIR;TAB(65);"Cx = ";CX
720   IF PSHAPES$="ARCH   " THEN LOCATE 9,4:PRINT"Arch pipe invert radius (in.);TAB(37);"=
";RARCHIN
750   IF PSHAPES$="ARCH   " THEN LOCATE 10,4:PRINT"Arch pipe crown radius (in.);TAB(37);"=
";RARCHCR
760   LOCATE 12,20:PRINT"MATERIAL PROPERTIES <F2>:"
770   LOCATE 13,24:PRINT"Reinforcing type";TAB(57);"= ";RETYPE;SPC(10)
780   LOCATE 14,24:PRINT"Reinforcing yield stress (psi);TAB(57);"= ";FY;SPC(10)
790   LOCATE 15,24:PRINT"Reinf. ultimate stress (psi);TAB(57);"= ";FSU;SPC(10)
800   LOCATE 16,24:PRINT"Design criteria (YIELD/ULTIMATE)";TAB(57);"= ";
810   IF DESCRIT$="ULTIMATE" THEN PRINT DESCRIT$ ELSE PRINT MID$(DESCRIT$,4)
820   LOCATE 17,24:PRINT"Concrete strength, f'c (psi);TAB(57);"= ";FPRIMEC;SPC(10)
830   LOCATE 18,24:PRINT"No. of reinforcing layers";TAB(57);"= ";N9;SPC(10)
840   LOCATE 19,24:PRINT"Circum. reinf. spacing (in.);TAB(57);"= ";S1;SPC(10)
850   LOCATE 25,1:PRINT " <F1>";:COLOR 0,7:PRINT"PIPE GEOM";:COLOR 7,0
860   PRINT " <F2>";:COLOR 0,7:PRINT"MAT PROP";:COLOR 7,0:PRINT " <F3>";
870   COLOR 0,7:PRINT"DES COEF";:COLOR 7,0:PRINT " <F4> ";:COLOR 0,7:PRINT"MAIN
MENU";
880   COLOR 7,0:PRINT " <F5>";:COLOR 0,7:PRINT"HELP";:COLOR 7,0:PRINT " <F10>";:COLOR
0,7:PRINT"CONT";:LOCATE CSRLIN,POS(0)-2
890   COLOR 7,0
900   LOCATE 20,1,0
910   FOR I=1 TO 5
920   PRINT SPC(60)
930   NEXT I
940   IF RDSGN=1 GOTO 980
950   LOCATE 21,1: PRINT"DO YOU WISH TO SAVE THESE PARAMETERS
(Y/N)?":CHK$=INPUT$(1)
960   IF CHK$="y" THEN CHK$="Y"
970   RDSGN=1: IF CHK$="Y" GOTO 900 ELSE CLOSE:GOTO 160
980   LOCATE 21,27:COLOR 31,0:PRINT "WAITING FOR SOFT KEY INPUT":COLOR 7,0
990   RETURN
1000  REM
1010  REM - PIPE GEOMETRY
1020  REM
1030  LOCATE 3,2:COLOR 0,7:PRINT "PIPE GEOMETRY": COLOR 7,0
1040  LOCATE 20,1,1:PRINT"ALTER PIPE GEOMETRY:"+SPACE$(40)
1050  NEWVS$=""

```

```

1060 LOCATE 21,1:PRINT SPC(60)
1070 LOCATE 21,1:PRINT"New pipe shape (C,V,H,A) or <ENTER> to continue"
1080 COLOR 15,0:PRINT"C";:COLOR 7,0:PRINT"IRCULAR, ";:COLOR 15,0:PRINT"V";:COLOR 7,0
1090 PRINT"ELLIPT, ";:COLOR 15,0:PRINT"H";:COLOR 7,0:PRINT"ELLIPT, ";:COLOR
15,0:PRINT"A";:COLOR 7,0:PRINT"RCH"
1100 PRINT"? ";:NEWV$$ = INPUT$(1)
1110 IF ASC(NEWV$$)=13 THEN 1180
1120 IF ASC(NEWV$$)>96 AND ASC(NEWV$$)<123 THEN NEWV$$=CHR$(ASC(NEWV$$)-32)
1130 IF NEWV$$="C" OR NEWV$$="V" OR NEWV$$="H" OR NEWV$$="A" THEN 1140 ELSE
BEEP:GOTO 1070
1140 IF NEWV$$ = "C" THEN PSHAP$$="CIRCULAR":GOSUB 7110
1150 IF NEWV$$ = "V" THEN PSHAP$$="VELLIPT ":GOSUB 7160
1160 IF NEWV$$ = "H" THEN PSHAP$$="HELLIPT ":GOSUB 7210
1170 IF NEWV$$ = "A" THEN PSHAP$$="ARCH " :GOSUB 7260
1180 NEWV$$=""
1190 GOSUB 7340
1200 IF PSHAP$$="CIRCULAR" THEN PRINT"New inner diameter or <ENTER> to continue"
1210 IF PSHAP$$<>"CIRCULAR" THEN PRINT "New span or <ENTER> to continue"
1220 INPUT NEWV
1230 IF NEWV=0 THEN 1260
1240 INDIA=NEWV
1250 NEWV=0
1260 IF PSHAP$$<>"ARCH " THEN GOTO 1350
1270 GOSUB 7340
1280 PRINT "Input arch pipe radii (See ASTM C 506) or <ENTER> to continue"
1290 PRINT " Invert radius:"
1300 PRINT " Crown radius:"
1310 LOCATE 22,37:INPUT NEWV
1320 IF NEWV<>0 THEN RARCHIN=NEWV:NEWV=0
1330 LOCATE 23,37:INPUT NEWV
1340 IF NEWV<>0 THEN RARCHCR=NEWV:NEWV=0
1350 GOSUB 7340
1360 PRINT"New wall thickness or <ENTER> to continue"
1370 INPUT NEWV
1380 IF NEWV<>0 THEN WALLT=NEWV
1390 GOSUB 7340
1400 PRINT"New inside reinforcing cover or <ENTER> to continue"
1410 INPUT NEWV
1420 IF NEWV<>0 THEN IRECOVER=NEWV
1430 GOSUB 7340
1440 PRINT"New outside reinforcing cover or <ENTER> to continue"
1450 INPUT NEWV
1460 IF NEWV<>0 THEN ORECOVER =NEWV
1470 NEWV=0
1480 CLS
1490 GOSUB 590:REM - GOTO MENU
1500 RETURN
1510 REM - MATERIAL PROPERTIES
1520 LOCATE 21,1:PRINT SPC(60)
1530 LOCATE 12,20:COLOR 0,7:PRINT "MATERIAL PROPERTIES": COLOR 7,0
1540 NEWV=0
1550 LOCATE 20,1,1:PRINT"ALTER MATERIAL PROPERTIES"+SPACE$(40)
1560 PRINT"New reinforcing type or <ENTER> to continue"
1570 INPUT NEWV
1580 IF NEWV<>0 THEN RETYPE=NEWV:RETEMP=RETYPE
1590 IF RETYPE=1 OR RETYPE=2 OR RETYPE=3 GOTO 1600 ELSE BEEP:GOTO 1550

```

```

1600 IF RETYPE<>3 GOTO 1670
1610 GOSUB 7340
1620 PRINT "For Type 3 reinforcing specify: D for deformed bars or"
1630 LOCATE 22,33:PRINT"C for any wire reinforcement"
1640 LOCATE 23,33
1650 INPUT TYPE3T$
1660 IF TYPE3T$="C" OR TYPE3T$="D" GOTO 1670 ELSE BEEP:GOTO 1610
1670 GOSUB 7340
1680 PRINT"New Fy or <ENTER> to continue"
1690 INPUT NEWV
1700 IF NEWV<>0 THEN FY=NEWV
1710 GOSUB 7340
1720 PRINT"New Reinforcing ultimate strength,Fsu or <ENTER> to continue"
1730 PRINT"If Reinforcing is deformed bars input Fsu=Fy"
1740 INPUT NEWV
1750 IF NEWV<>0 THEN FSU=NEWV
1760 GOSUB 7340
1770 PRINT"New design criteria (Y/U) or <ENTER> to continue"
1780 COLOR 15,0:PRINT"Y";:COLOR 7,0:PRINT"IELD OR ";:COLOR 15,0:PRINT"U";:COLOR
7,0:PRINT"LTIMATE
1790 PRINT"? ";:NEWV$$ = INPUT$(1)
1800 IF ASC(NEWV$$)=13 THEN 1890
1810 IF ASC(NEWV$$)>96 AND ASC(NEWV$$)<123 THEN NEWV$$=CHR$(ASC(NEWV$$)-32)
1820 IF NEWV$$="Y" OR NEWV$$="U" THEN 1830 ELSE BEEP:GOTO 1760
1830 IF NEWV$$ = "Y" THEN DESCRIT$=" YIELD"
1840 IF NEWV$$ = "U" THEN DESCRIT$="ULTIMATE"
1850 IF PSHAPE$="CIRCULAR" THEN GOSUB 7110
1860 IF PSHAPE$="VELLIPT " THEN GOSUB 7160
1870 IF PSHAPE$="HELLIPT " THEN GOSUB 7210
1880 IF PSHAPE$="ARCH " THEN GOSUB 7260
1890 NEWV$=""
1900 GOSUB 7340
1910 PRINT"New F'c or <ENTER> to continue"
1920 INPUT NEWV
1930 IF NEWV<>0 THEN FPRIMEC=NEWV
1940 GOSUB 7340
1950 PRINT"New no. of layers of reinforcing or <ENTER> to continue"
1960 INPUT NEWV
1970 IF NEWV=0 GOTO 2000
1980 IF NEWV=1 OR NEWV=2 GOTO 1990 ELSE BEEP:GOTO 1940
1990 N9=NEWV
2000 GOSUB 7340
2010 PRINT"New circumferential reinforcing spacing or <ENTER> to continue"
2020 INPUT NEWV
2030 IF NEWV<>0 THEN S1=NEWV
2040 'CLS
2050 GOSUB 590:REM - RETURN TO MENU
2060 RETURN
2070 REM - DESIGN COEFFICIENTS
2080 LOCATE 3,54:COLOR 0,7:PRINT "DESIGN COEFFICIENTS": COLOR 7,0
2090 NEWV=0
2100 LOCATE 20,1,1:PRINT"ALTER DESIGN COEFFICIENTS"+SPACE$(40)
2110 PRINT"New flexural strength reduction factor (PhiF) or <ENTER> to continue"
2120 INPUT NEWV
2130 IF NEWV<>0 THEN PHIF= NEWV
2140 GOSUB 7340

```

```

2150 PRINT"New 0.01 inch crack strength reduction factor PhiC) or <ENTER> to continue"
2160 INPUT NEWV
2170 IF NEWV<>0 THEN PHIC= NEWV
2180 GOSUB 7340
2190 PRINT"New diag. tens. strength reduction factor (PhiD) or <ENTER> to continue"
2200 INPUT NEWV
2210 IF NEWV<>0 THEN PHID= NEWV
2220 GOSUB 7340
2230 PRINT"New rad. tens. strength reduction factor (PhiR) or <ENTER> to continue"
2240 INPUT NEWV
2250 IF NEWV<>0 THEN PHIR= NEWV
2260 GOSUB 7340
2390 PRINT"New Cs (Aso/Asi) or <ENTER> to continue"
2400 INPUT NEWV
2410 IF NEWV<>0 THEN CS=NEWV
2420 GOSUB 7340
2430 PRINT"New Cx (for outside reinf.) or <ENTER> to continue"
2440 INPUT NEWV
2450 IF NEWV<>0 THEN CX=NEWV
2460 GOSUB 590:REM - RETURN TO MENU
2470 REM
2480 REM - END OF INPUT
2490 REM
2500 RETURN
2510 REM - CALCULATE WEIGHT OF PIPE
2520 REM
2530 W1=CSHP*WALLT*(INDIA+WALLT)
2532 REM
2534 REM - COMPUTE COEFFICIENT Cmp
2536 DRAT=(0.96*WALLT-ORECOVER)/(0.96*WALLT-IRECOVER)
2538 CMP=1+WALLT/INDIA+(0.562*CS*DRAT/CM-0.364/CMO)*(INDIA+WALLT)/INDIA
2539 CMPI=CMP
2540 IF DESCRIT$=" YIELD" THEN CMP=1
2545 REM
2550 REM - DETERMINE TASK: ANALYSIS OR DESIGN
2560 REM
2570 GOSUB 7340
2580 IF INDIA=0 OR WALLT=0 GOTO 2590 ELSE GOTO 2620
2590 LOCATE 22,10:BEEP:PRINT "INSIDE DIAMETER AND WALL THICKNESS MUST BE
SPECIFIED"
2600 LOCATE 23,10:PRINT" PRESS ANY KEY TO CONTINUE"
2610 IF INKEY$="" GOTO 2610 ELSE GOTO 590
2620 KEY(1) OFF: KEY(2) OFF: KEY(3) OFF: KEY(4) OFF: KEY(5) OFF: KEY(10) OFF
2630 LOCATE 25,1:PRINT"
";
2640 LOCATE 21,1:PRINT"Enter required task:"
2650 PRINT SPC(4);(";;COLOR 15,0:PRINT"1";:COLOR 7,0:PRINT ") Determine D-Load capacity
for specified inside reinforcing"
2660 PRINT SPC(4);(";;COLOR 15,0:PRINT"2";:COLOR 7,0:PRINT ") Determine required reinforcing
for specified D-loads"
2670 LOCATE 22,1:TASK$ = INPUT$(1)
2680 IF TASK$="1" OR TASK$="2" THEN 2690 ELSE BEEP:GOTO 2670
2690 IF TASK$="1" THEN TASK$="ANALYSIS" : GOSUB 5930
2700 TASK$="DESIGN" : GOSUB 3560
2710 REM
2720 REM - SUBROUTINE TO SEND INPUT TO PRINTER FOR ANALYSIS OR DESIGN

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2730 REM
2750 CLS:LOCATE 9,30:COLOR 31,0:PRINT" OUTPUT PRINTING "
2760 LOCATE 10,30:PRINT" PLEASE WAIT ":COLOR 7,0
2765 IF DESNUM=1 GOTO 2945
2767 DESNUM=1:PAGE=1
2770 JOB$=JDSCP$+SPACE$(50-LEN(JDSCP$))
2780 TOP$="PIPECAR - 3EB - "+JOB$+" PAGE"
2790 LPRINT CHR$(12):LPRINT:LPRINT TOP$+" 1":FOR J = 1 TO 7:LPRINT:LPRINT:NEXT J
2800 LPRINT " P I P E C A R"
2810 LPRINT " 3 - EDGE BEARING DESIGN AND ANALYSIS PROGRAM"
2812 LPRINT " VERSION 1.0 - 1 NOVEMBER 1988":LPRINT:LPRINT
2814 LPRINT " Developed by":LPRINT
2816 LPRINT " Simpson Gumpertz & Heger Inc."
2818 LPRINT " Arlington, Massachusetts":LPRINT
2820 LPRINT " in Cooperation with":LPRINT
2822 LPRINT " The Federal Highway Administration"
2824 LPRINT " and "
2826 LPRINT " The American Concrete Pipe Association":LPRINT:LPRINT:LPRINT
2842 LPRINT " The application of this nonproprietary software is the responsibility"
2844 LPRINT " of the user. The user must select input values suitable to his specific"
2860 LPRINT " installation. Use of default parameters does not assure a safe design"
2870 LPRINT " for all installations. The information presented in the computer output"
2880 LPRINT " is for review, interpretation, application, and approval by a qualified"
2890 LPRINT " engineer who must assume full responsibility for verifying that said"
2900 LPRINT " output is appropriate and correct. There are no express or implied"
2910 LPRINT " warranties. Use of this product does not constitute endorsement by FHWA"
2915 LPRINT " or any other agents."
2920 FOR J=1 TO 4:LPRINT "":NEXT J
2930 LPRINT " DATE: ";DATE$
2940 LPRINT " TIME: ";TIME$
2945 PAGE=PAGE+1
2950 LPRINT CHR$(12):LPRINT:LPRINT TOP$+" ";PAGE:LPRINT
2960 IF TASK$="ANALYSIS" GOTO 2990
2970 LPRINT" PIPECAR - THREE EDGE BEARING - REINFORCING DESIGN"
2980 GOTO 3000
2990 LPRINT" PIPECAR - THREE EDGE BEARING - D-LOAD ANALYSIS"
3000 LPRINT TAB(20);SHIFT$;INDIA;"INCH SPAN ";PSHAPEF$;" PIPE"
3010 LPRINT"*****"
3020 IF TASK$="ANALYSIS" GOTO 3070
3030 LPRINT"SPECIFIED D - L O A D S"
3040 LPRINT"-----"
3050 LPRINT USING" DL.01 = ##### LBS/FT/FT DLult = #####
LBS/FT/FT";DL01;DLU
3060 GOTO 3100
3070 LPRINT"SPECIFIED REINFORCING AREAS"
3080 LPRINT"-----"
3090 LPRINT USING" INSIDE REINFORCING AREA, Asi = #.### SQ.IN./FT";INAREA
3100 LPRINT:LPRINT"CAPACITY REDUCTION FACTORS"
3110 LPRINT"-----"
3120 LPRINT USING" PhiF = #.## PhiC = #.## PhiD = #.## PhiR =
#.##";PHIF;PHIC;PHID;PHIR
3130 LPRINT:LPRINT"DESIGN COEFFICIENTS"
3140 LPRINT"-----"
3150 LPRINT USING" Cm = #.## Cmo = #.## Cs = #.## Cx = #.##
Cmp = #.##";CM;CMO;CS;CX;CMP
3160 REM - PIPE SPECIFICATIONS

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3170 LPRINT:LPRINT"PIPE SPECIFICATIONS"
3180 LPRINT"-----"
3190 LPRINT USING"WALL THICKNESS (IN.)-----" ###.##";WALLT
3200 IF PSHAPES <>"ARCH " GOTO 3230
3210 LPRINT USING"INSIDE INVERT RADIUS (IN.)-----" ###.##";RARCHIN
3220 LPRINT USING"INSIDE CROWN RADIUS (IN.)-----"
###.##";RARCHCR
3230 LPRINT USING"INSIDE REINFORCING COVER (IN.)-----"
###.##";IRECOVER
3240 LPRINT USING"OUTSIDE REINFORCING COVER (IN.)-----"
###.##";ORECOVER
3250 LPRINT USING"NO. OF REINFORCING LAYERS-----" ###";N9
3260 LPRINT USING"PIPE WEIGHT (LBS/FT)-----" #####";W1
3270 LPRINT USING"CONCRETE STRENGTH (PSI)-----"
#####";FPRIMEC
3280 LPRINT USING"REINFORCING YIELD STRENGTH (PSI)-----"
#####";FY
3290 LPRINT USING"REINFORCING ULTIMATE STRENGTH (PSI)-----"
#####";FSU
3300 IF FV=0 GOTO 3320
3310 LPRINT USING"DEVELOPABLE STIRRUP STRESS (PSI)-----"
#####";FV
3320 LPRINT"DESIGN CRITERIA-----";DESCRIT$
3330 LPRINT USING"SPACING OF CIRCUMFERENTIAL REINF. (IN.)-----"
###";S1
3340 REM - REINFORCING TYPE
3350 IF RETYPE>1 GOTO 3400
3360 LPRINT"TYPE 1 REINFORCEMENT"
3370 LPRINT" SMOOTH WIRES OR PLAIN BARS"
3380 LPRINT
3390 GOTO 3500
3400 IF RETYPE=3 GOTO 3450
3410 LPRINT"TYPE 2 REINFORCEMENT"
3420 LPRINT" WELDED SMOOTH WIRE FABRIC, 8 INCH MAX. SPACING OF
LONGITUDINALS"
3430 LPRINT
3440 GOTO 3500
3450 LPRINT"TYPE 3 REINFORCEMENT"
3460 LPRINT" WELDED DEFORMED WIRE FABRIC, DEFORMED BARS"
3470 LPRINT" OR ANY REINFORCEMENT WITH STIRRUPS"
3480 LPRINT
3490 REM
3500 RETURN:REM - END OF PRINTING DESIGN AND ANALYSIS INPUT
3510 REM
3520 REM
3530 REM - DESIGN SUBROUTINE
3540 REM - DETERMINES STEEL REINFORCEMENT REQUIRED FOR GIVEN
3550 REM - INPUT VALUES: DL.01-D AND DLU
3560 REM - DESIGN:
3570 REM
3580 DL01=0
3590 DLU=0
3600 GOSUB 7340
3610 LOCATE 21,1:PRINT "Determine reinforcing required for specified D-load"
3620 PRINT " Enter 0.01 inch D-load (lbs/ft/ft)"
3630 PRINT " Enter ultimate D-load (lbs/ft/ft)"

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3640 LOCATE 22,41:INPUT DL01
3650 LOCATE 23,41:INPUT DLU
3660 REM
3670 REM - DESIGN OUTSIDE REINFORCING FIRST
3680         TBFLAG=1:CRCK=0
3690         TBTEMP=IRECOVER
3700         IRECOVER=ORECOVER
3710         D=.96*WALLT-IRECOVER
3720 Z=0:FV=0:DTARCH=0
3730 RETEMP=RETYPE
3740 EC4R=1000000!
3750 REM
3760 REM - STEEL AREA BASED ON FLEXURE (R1)
3770 REM - TRIAL AREA OF STEEL
3780 REM
3790 IF FY=FSU THEN CYLD=1! ELSE CYLD=.95
3800 IF DESCRIT$=" YIELD" THEN F4=FY ELSE F4=CYLD*FSU
3810         Q1=1.75E-07*DLU*INDIA^2/D/PHIF
3820         A=F4*Q1/10.2/FPRIMEC
3830         D1=D*PHIF-.5*A
3840 REM - CRITERIA FOR SMALL PIPE WITH WIRE REINF, DESIGNED FOR ULTIMATE
3850         IF WALLT>5 GOTO 3920
3860         IF TYPE3T$="D" GOTO 3920
3870         IF PSHAPES<>"CIRCULAR" GOTO 3920
3880         IF DESCRIT$=" YIELD" GOTO 3920
3890         IF IRECOVER<.9 OR IRECOVER>1.1 GOTO 3920
3900         IF ORECOVER<.9 OR ORECOVER>1.1 GOTO 3920
3910         IF A<.7 THEN D1=D1+.7-A
3920 IF TASK$="ANALYSIS" GOTO 6200
3930 R1=Q1
3940 Q1=INDIA*(INDIA+WALLT)*(DLU+9*W1/INDIA)/(85*CM*CMP*F4*D1)
3950 IF ABS(Q1-R1)>.005 THEN 3820
3960 R1=Q1
3970 REM
3980 REM -CHECK MINIMUM INSIDE REINFORCING
3990 REM
4000 IF R1 < CX*(INDIA+WALLT)^2/FY THEN R1 = CX*(INDIA+WALLT)^2/FY
4010 IF R1<.07 THEN R1=.07
4020 REM
4030 IF TBFLAG=1 THEN GOTO 4460 REM - OUTSIDE REINF DESIGN
4040 REM
4050 REM - STEEL AREA BASED ON DIAGONAL TENSION (R2)
4060 REM - DTPARAM - DETERMINE FPRIMEC, DEPTH AND CURVATURE FACTORS.
4070 IF FPRIMEC>7000 THEN F7=7000 ELSE F7=FPRIMEC
4080         Q2=.8+1.6/D
4090 IF Q2>1.25 THEN Q2=1.25
4100 REM - DETERMINE RADIUS TO CENTERLINE OF PIPE (R0).
4110 REM - SELECT PSHAPES$
4120 IF PSHAPES$="CIRCULAR" THEN R0=.5*(INDIA+WALLT):GOTO 4160
4130 IF PSHAPES$="VELLIPT " THEN R0=.27*INDIA+(WALLT/2): GOTO 4160
4140 IF PSHAPES$="HELLIPT " THEN R0=.86*INDIA+(WALLT/2): GOTO 4160
4150 IF PSHAPES$="ARCH      " THEN R0=RARCHIN+WALLT/2
4160         Q3=1+PHID*D/2/R0 : REM - CURVATURE FACTOR FC
4170 REM - CORRECTION COEFFICIENT FOR VARYING M/VD.
4180         X0=(.063*(INDIA+WALLT)+.251*PHID*D)/D/PHID
4190 IF X0>1 THEN X0=1

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4200 IF TASK$="ANALYSIS" THEN 6440
4210 R2=(((.00065*(DLU+11*CW*W1/INDIA)*Q3*INDIA/(Q2*SQR(F7)))*X0)/PHID-.21*D)
4220 IF PSHAPE$ <> "ARCH " GOTO 4290
4230 IF DTARCH=1 GOTO 4270
4240 R2TEMP=R2: Q3=1+PHID*D/2/(RARCHCR+WALLT/2)
4250 CW=0: DTARCH=1
4260 GOTO 4210
4270 CW=1: DTARCH=0: Q3=1+PHID*D/2/(R0)
4280 IF R2<R2TEMP THEN R2=R2TEMP
4290 IF R2<0 THEN R2=0
4300 IF R2<=.24*D GOTO 4330
4310 Z=3
4320 REM
4330 REM - EVALUATE RADIAL TENSION D-LOAD CAPACITY (E4)
4340 REM -
4350 R9=R0-(.5*WALLT-IRECOVER)
4352 RTSF=1+0.00833*(72-2*(R0-0.5*WALLT))
4354 IF 2*(R0-0.5*WALLT) > 72 THEN RTSF=(2*(R0-0.5*WALLT)-144)^2/26000+0.8
4356 IF 2*(R0-0.5*WALLT) > 144 THEN RTSF=0.8
4360 E4=RTSF*1230*R9*PHIR*D*SQR(FPRIMEC)/(INDIA*(INDIA+WALLT))-9*CW*W1/INDIA
4370 REM -FOR ARCH PIPE CHECK RADIAL TENSION AT CROWN
4380 IF PSHAPE$ <> "ARCH " GOTO 4420
4390 R9CR=RARCHCR+IRECOVER
4392 RTSFCR=1+0.00833*(72-2*RARCHCR)
4394 IF 2*RARCHCR > 72 THEN RTSFCR=(2*RARCHCR-144)^2/26000+0.8
4396 IF 2*RARCHCR > 144 THEN RTSFCR=0.8
4400 E4CR=RTSFCR*1230*R9CR*PHIR*D*SQR(FPRIMEC)/(INDIA*(INDIA+WALLT))
4410 IF E4CR<E4 THEN E4=E4CR
4420 IF TASK$="ANALYSIS" THEN 6490
4430 IF E4>DLU GOTO 4460
4440 IF Z<>3 THEN Z=1
4450 REM
4460 REM - STEEL AREA BASED ON 0.01 INCH CRACK (R3).
4470 REM
4480 REM - CRKPARAM. DETERMINE B.01 AND C.01
4490 REM
4500 IF RETEMP=1 THEN B2=(.5*IRECOVER^2*S1/N9)^.3333:C0=1:GOTO 4530
4510 IF RETEMP=2 THEN B2=(.5*IRECOVER^2*S1/N9)^.3333:C0=1.5:GOTO 4530
4520 IF RETEMP=3 THEN B2=(.5*IRECOVER^2*S1/N9)^.3333:C0=1.9
4530 REM
4540 IF TASK$="ANALYSIS" THEN 6270
4550 REM
4560 R3=(DL01+9*W1/INDIA)*INDIA*(INDIA+WALLT)*B2/(2100000!*PHIC*D*CM)
4570 R3=R3-C0*B2*WALLT^2*SQR(FPRIMEC)/(2500*D*PHIC)
4580 IF R3<0 THEN R3=0
4590 IF CRCK=1 THEN R3SPEC=R3:RETEMP=3:CRCK=2:GOTO 4460
4600 REM
4610 IF TBFLAG=2 GOTO 4700 REM - OUTER REINF ALREADY DESIGNED
4620 REM
4630 REM - FIND REQUIRED OUTER REINFORCEMENT.
4640 IF R1>R3 THEN R4=R1*CS ELSE R4=R3*CS
4650 IF R4<.07 THEN R4=.07
4660 CRCK=1
4670 TBFLAG=2
4680 IRECOVER=TBTEMP
4690 GOTO 3710

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4700 REM
4710 REM - EVALUATE GOVERNING REINFORCING
4720 REM
4730 IF R1>=R3SPEC THEN A1=R1 ELSE A1=R3SPEC
4740 IF R2>A1 AND R2<.24*D AND Z<>1 THEN Z=2
4750 IF Z=0 THEN 5470
4760 IF R1>R3 THEN A1=R1 ELSE A1=R3
4770 CLS:LOCATE 3,10
4780 PRINT"*****"
4790 PRINT"          STIRRUPS ARE REQUIRED - DESIGNS REQUIRING STIRRUPS"
4800 PRINT"          WILL ASSUME TYPE 3 REINFORCING FOR 0.01 INCH CRACK"
4810 PRINT"          *****"
4820 LOCATE 11,10:PRINT"INPUT STIRRUP STRENGTH AND SPACING"
4830 LOCATE 13,15:PRINT"Stirrup strength, fv (psi)"
4840 LOCATE 14,15:PRINT"Stirrup spacing (in.)"
4850 SMAX=.75*PHID*D
4860 LOCATE 16,15:PRINT"Maximum allowable stirrup spacing is ";SMAX;" in."
4870 LOCATE 18,15:PRINT"Stirrup anchorage must be capable of developing the specified"
4880 LOCATE 19,15:PRINT"stirrup strength."
4890 LOCATE 13,42:INPUT FV
4900 LOCATE 14,42:INPUT STSP
4910 IF STSP>SMAX THEN BEEP: GOTO 4900
4920 REM
4930 REM - STIRRUP BASED ON RADIAL TENSION (R7).
4940 REM
4950     U=.013*INDIA*(INDIA+WALLT)/(PHID*D*R9)
4960     V=(DLU+9*CW*W1/INDIA)
4970     R7=U*V*STSP/FV
4980 REM
4990 REM - STIRRUP AREA BASED ON DIAGONAL TENSION (R6).
5000 REM
5010     PCTSTEEL=A1/(B0*D)
5020 IF PCTSTEEL>.02 THEN PCTSTEEL=.02
5030     A=.045*INDIA/D/PHID
5040     B=(Q3+.25*(INDIA+WALLT)/R9)*(DLU+11*CW*W1/INDIA)
5050 IF (1+57*PCTSTEEL)*Q2<1.8 THEN 5070
5060     Q2=1.8/(1+57*PCTSTEEL)
5070     C=(322*(1+57*PCTSTEEL)*PHID*D*SQR(FPRIMEC)/INDIA)*Q2/Q3
5080     R6=A*(B-C)*STSP/FV
5090 IF PSHAPES <> "ARCH    " GOTO 5170
5100     IF DTARCH = 1 GOTO 5140
5110         R6TEMP=R6: R7TEMP=R7: DTARCH=1: CW=0
5120         Q3=1+PHID*D/2/(RARCHCR+WALLT/2): R9=RARCHCR+IRECOVER
5130         GOTO 4950
5140     IF R6<R6TEMP THEN R6=R6TEMP
5150     IF R7<R7TEMP THEN R7=R7TEMP
5160     CW=1
5170 IF R6<R7 THEN R8=R7 ELSE R8=R6
5180 REM
5190 REM - EXTENT OF STIRRUPS
5200 REM
5210 IF PSHAPES="ARCH    " GOTO 5390
5220 IF PSHAPES="HELLIPT " GOTO 5340
5230 IF PSHAPES="VELLIPT " GOTO 5290
5240 REM - STIRRUP EXTENT CIRCULAR PIPE
5250 IF DLU<=2000 THEN STEXT=.4*INDIA:GOTO 5440

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5260 IF DLU <= 3000 THEN STEXT=.6*INDIA:GOTO 5440
5270 IF DLU <= 3750 THEN STEXT=.8*INDIA:GOTO 5440
5280 STEXT=INDIA:GOTO 5440
5290 REM - STIRRUP EXTENT VERTICAL ELLIPTICAL PIPE
5300 IF DLU <= 2000 THEN STEXT=.3*INDIA:GOTO 5440
5310 IF DLU <= 3000 THEN STEXT=.5*INDIA:GOTO 5440
5320 IF DLU <= 3750 THEN STEXT=.7*INDIA:GOTO 5440
5330 STEXT=.9*INDIA:GOTO 5440
5340 REM - STIRRUP EXTENT HORIZONTAL ELLIPTICAL PIPE
5350 IF DLU <= 2000 THEN STEXT=.5*INDIA:GOTO 5440
5360 IF DLU <= 3000 THEN STEXT=.7*INDIA:GOTO 5440
5370 IF DLU <= 3750 THEN STEXT=.9*INDIA:GOTO 5440
5380 STEXT=INDIA:GOTO 5440
5390 REM - STIRRUP EXTENT ARCH PIPE
5400 IF DLU <= 2000 THEN STEXT=.6*INDIA:STEXTCR=.4*INDIA:GOTO 5440
5410 IF DLU <= 3000 THEN STEXT=.8*INDIA:STEXTCR=.6*INDIA:GOTO 5440
5420 IF DLU <= 3750 THEN STEXT=1!*INDIA:STEXTCR=.8*INDIA:GOTO 5440
5430 STEXT=1.1*INDIA:STEXTCR=1!*INDIA
5440 NUMLIN=INT(STEXT/STSP+2)
5450 NUMLINCR=INT(STEXTCR/STSP+2)
5460 REM
5470 REM - OUTPUT DESIGN: IOUT = 1 IS PRINTER
5480 REM IOUT = 2 IS SCREEN
5490 REM
5500 CLS
5510 PRINT #IOUT,"R E I N F O R C I N G   D E S I G N   C R I T E R I A"
5520 PRINT #IOUT,"-----"
5530 IF DESCRIT$=" YIELD" THEN 5560
5540 PRINT #IOUT, USING" FLEXURE STEEL AREA (ULTIMATE) - (SQ.IN./FT)-----
###";R1
5550 GOTO 5570
5560 PRINT #IOUT, USING" FLEXURE STEEL AREA (FIRST YIELD) - (SQ.IN./FT)-----
###";R1
5570 PRINT #IOUT, USING" 0.01 INCH CRACK STEEL AREA - (SQ.IN./FT)-----
###";R3SPEC
5580 IF Z=0 GOTO 5610
5590 IF RTYPE=3 GOTO 5610
5600 PRINT #IOUT, USING" 0.01 INCH CRACK STEEL AREA WITH TYPE 3 REINF. -
(SQ.IN./FT)---- ###";R3
5610 IF Z <> 2 GOTO 5615
5612 IF CMPI < 1 GOTO 5620
5615 PRINT #IOUT,
5620 IF Z=3 THEN PRINT #IOUT," DIAGONAL TENSION REINF. EXCEEDS 0.02 bd,
STIRRUPS ARE REQUIRED"
5630 IF Z <> 3 THEN PRINT #IOUT, USING" DIAGONAL TENSION STEEL AREA -
(SQ.IN./FT)----- ###";R2
5640 PRINT #IOUT, USING" MAXIMUM RADIAL TENSION D-LOAD -
(LBS/FT/FT)----- #####;E4
5650 IF Z <> 2 GOTO 5654
5652 IF CMPI < 1 GOTO 5655
5654 PRINT #IOUT,
5655 PRINT #IOUT,"G O V E R N I N G   R E I N F O R C I N G   D E S I G N"
5660 PRINT #IOUT,"-----"
5670 PRINT #IOUT, USING" INNER REINFORCING AREA -
(SQ.IN./FT)-----###";A1
5680 PRINT #IOUT, USING" OUTER REINFORCING AREA -

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(SQ.IN./FT)-----###.###";R4
5690 IF Z=0 THEN PRINT #IOUT, " NO STIRRUPS REQUIRED":GOTO 5840
5692 IF Z<>2 GOTO 5700
5694 IF CMPI<1 GOTO 5710
5700 PRINT #IOUT,
5710 PRINT #IOUT," STIRRUPS ARE REQUIRED AT THE CROWN AND INVERT"
5720 PRINT #IOUT, USING" REQUIRED STIRRUP AREA -
(SQ.IN./FT/LINE)-----###.###";R8
5730 IF PSHAPES<>"ARCH " GOTO 5770
5740 PRINT #IOUT, USING" REQUIRED INVERT STIRRUP SPACING AND EXTENT----- ###
LINES AT ###.### IN.";NUMLIN,STSP
5750 PRINT #IOUT, USING" REQUIRED CROWN STIRRUP SPACING AND EXTENT----- ###
LINES AT ###.### IN.";NUMLINCR,STSP
5760 GOTO 5780
5770 PRINT #IOUT, USING" REQUIRED STIRRUP SPACING AND EXTENT----- ### LINES
AT ###.### IN.";NUMLIN,STSP
5780 IF Z<>2 GOTO 5834
5790 IF R2>R3SPEC THEN RALT=R2 ELSE RALT=R3SPEC
5795 IF IOUT=2 THEN PRINT #IOUT,
5800 PRINT #IOUT,"A L T. R E I N F O R C I N G D E S I G N W / O S T I R R U P
S"
5810 PRINT #IOUT,"-----"
5820 PRINT #IOUT, USING" INNER REINFORCING AREA - (SQ.IN./FT)-----
###.###";RALT
5830 PRINT #IOUT, USING" OUTER REINFORCING AREA -
(SQ.IN./FT)-----###.###";R4
5834 IF Z<>2 THEN PRINT #IOUT,
5840 IF CMPI>=1 GOTO 5854
5844 PRINT #IOUT, "NOTE: Cmp computed with PIPECAR User Manual Eq. C.7 has a
value less"
5848 PRINT #IOUT, " than 1. This means that the springline reinforcing will yield"
5852 PRINT #IOUT, " before the invert reinforcing. The calculation of ultimate"
5853 PRINT #IOUT, " flexural strength and 0.01 inch crack strength may be in error."
5854 IF IOUT=2 GOTO 5910
5858 REM
5860 REM END OF OUTPUT TO SCREEN
5870 REM
5880 PRINT" DO YOU WANT A PRINTED COPY OF THE RESULTS?
(Y/N)":HRDCOPY$=INPUT$(1)
5890 IF HRDCOPY$="y" THEN HRDCOPY$="Y"
5900 IF HRDCOPY$="Y" THEN IOUT=2:GOSUB 2720: GOTO 5510
5910 IOUT=1:HRDCOPY$="":RDSGN=2:GOTO 490
5920 REM
5930 REM - SUBROUTINE TO CALCULATE THE D-LOAD CAPACITY
5940 REM - FOR PIPE WITH KNOWN INSIDE REINFORCEMENT
5950 REM - INPUT VALUE IS INSIDE TENSION REINFORCEMENT
5960 REM - OUTPUT VALUES ARE DLUF (FLEXURE D-LOAD),
5970 REM - DL01 (0.01 INCH CRACK D-LOAD), DLUDT (DIAGONAL TENSION D-LOAD),
5980 REM - AND DLURT (RADIAL TENSION D-LOAD).
5990 REM - ANALYSIS IS BASED SOLELY ON INSIDE REINFORCING
6000 REM
6010 REM
6020 REM - INPUT INSIDE REINFORCING AREA
6030 REM
6040 GOSUB 7340
6050 LOCATE 21,1:PRINT "Evaluate D-load capacity for specified inside reinforcing"

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6060 PRINT" Enter inner reinforcing area - sq.in./ft)"
6070 LOCATE 22,50:INPUT INAREA
6080 KEY(1) OFF: KEY(2) OFF: KEY(3) OFF: KEY(4) OFF: KEY(5) OFF: KEY(10) OFF
6090 REM
6100 REM
6110 REM - CALCULATE FLEXURAL D-LOAD CAPACITY
6120 REM
6130 RETEMP=RETYPE
6140 D=(WALLT-IRECOVER-.163*(S1*INAREA)^.5)
6142 REM - COMPUTE COEFFICIENT Cmp
6144 DRAT=(0.96*WALLT-ORECOVER)/D
6146 CMP=1+WALLT/INDIA+(0.562*CS*DRAT/CM-0.364/CMO)*(INDIA+WALLT)/INDIA
6147 CMPI=CMP
6148 IF DESCRIT$=" YIELD" THEN CMP=1
6149 REM
6150 IF DESCRIT$=" YIELD" THEN REALFY=FY:GOTO 6190
6160 IF DESCRIT$="ULTIMATE" AND TYPE3T$="D" THEN REALFY=FY:GOTO 6180
6170 REALFY=.95*FSU
6180 A=REALFY*INAREA/(10.2*FPRIMEC)
6190 GOTO 3830: REM - GET FLEXURAL PARAMTER FROM DESIGN SUBROUTINE

6200 REM
6210 DLUF=((85*CM*CMP*INAREA*REALFY*D1)/(INDIA*(INDIA+WALLT)))
6220 DLUF=DLUF-((9*W1)/INDIA)
6230 REM
6240 REM - CALCULATE 0.01 INCH D-LOAD
6250 REM
6260 GOTO 4480:REM - CRKPARAM - CALCULATE B.01 AND C.01
6270 PCTSTEEL=INAREA/(B0*D)
6280 FS01=(30000/B2)+((C0*WALLT^2*FPRIMEC^.5)/(PCTSTEEL*PHIC*D*D))
6290 REM
6300 IF RETYPE=2 THEN CONDTN=(SQR(IRECOVER)*S1)/N9
6310 IF CONDTN<3 GOTO 6370
6320 BTEMP=(.5*CONDTN)^.3333:CTEMP=1.9
6330 FTEMP=(30000/BTEMP)+(CTEMP*WALLT^2*FPRIMEC^.5)/(PCTSTEEL*PHIC*D*D)
6340 IF FTEMP<FS01 THEN FS01=FTEMP
6350 REM
6360 REM
6370 IF FS01>FY THEN FS01=FY:REM - FS01<=FY
6380 DL01=(70*CM*FS01*INAREA*PHIC*D)/(INDIA*(INDIA+WALLT))-((9*W1)/INDIA)
6390 REM
6400 REM - CALCULATE DIAGONAL TENSION D-LOAD.
6410 REM
6420 GOTO 4060:REM - DTPARAM - DETERMINE F'c, DEPTH AND CURVATURE FACTORS.
6430 REM
6440 IF PCTSTEEL>.02 THEN PCTSTEEL=.02
6450 DLUDT=(322*Q2*(1+57*PCTSTEEL)*PHID*D*F7^.5)/(Q3*INDIA*X0)-(11*CW*W1/INDIA)
6460 REM
6470 GOTO 4330: REM - USE COMPUTATION FROM DESIGN SUBROUTINE
6480 REM
6490 DLURT=E4
6500 REM
6510 REM - END OF D-LOAD CAPACITY CALCULATIONS
6520 REM
6530 REM - PRINT D-LOADS IOUT = 1 FOR SCREEN
6540 REM IOUT = 2 FOR PRINTER

```

```

6550 REM
6560 CLS
6570 PRINT #IOUT,"CALCULATED D-LOAD CAPACITIES"
6580 PRINT #IOUT,"-----"
6590 IF DESCRIT$=" YIELD" GOTO 6610
6600 PRINT #IOUT, USING" D-LOAD BASED ON ULTIMATE FLEXURE (COLLAPSE) -
(LBS/FT/FT)-----#####";DLUF:GOTO 6620
6610 PRINT #IOUT, USING" D-LOAD BASED ON ULTIMATE FLEXURE (YIELD) -
(LBS/FT/FT)-----#####";DLUF
6620 PRINT #IOUT,:PRINT #IOUT, USING" D-LOAD BASED ON 0.01 INCH CRACK -
(LBS/FT/FT)-----#####";DL01
6630 PRINT #IOUT,:PRINT #IOUT, USING" D-LOAD BASED ON DIAGONAL TENSION -
(LBS/FT/FT)-----#####";DLUDT
6640 PRINT #IOUT,:PRINT #IOUT, USING" D-LOAD BASED ON RADIAL TENSION -
(LBS/FT/FT)-----#####";DLURT
6650 PRINT #IOUT,
6660 PRINT #IOUT, TAB(4);"This analysis of D-load capacity is based solely on the inside
reinforcing."
6670 PRINT #IOUT, TAB(4);"Outside reinforcing is normally provided as a fraction of the inside"
6680 PRINT #IOUT, TAB(4);"reinforcing. The user should reference appropriate ASTM Standards
for"
6690 PRINT #IOUT, TAB(4);"for the appropriate criteria. The most common standards are ASTM
C 76"
6700 PRINT #IOUT,TAB(4);"for circular pipe, ASTM C 506 for arch pipe and ASTM C 507 for
elliptical"
6710 PRINT #IOUT, TAB(4);"pipe"
6714 IF CMPI >= 1 GOTO 6734
6718 PRINT #IOUT,:PRINT #IOUT,"NOTE: Cmp computed with PIPECAR User Manual Eq. C.7
has a value less"
6722 PRINT #IOUT, " than 1. This means that the springline reinforcing will
yield"
6726 PRINT #IOUT, " before the invert reinforcing. The calculation of ultimate"
6730 PRINT #IOUT, " flexural strength and 0.01 inch crack strength may be
in error."
6734 IF IOUT=2 THEN RETURN
6738 REM
6740 REM - END OF OUTPUT
6750 REM
6760 REM - ANALYSIS RESULTS TO PRINTER
6770 REM
6780 PRINT:PRINT" DO YOU WANT A PRINTED COPY OF THE RESULTS? (Y/N)"
6790 HRDCOPY$=INPUT$(1)
6800 IF HRDCOPY$="y" THEN HRDCOPY$="Y"
6810 IF HRDCOPY$="Y" THEN IOUT =2:GOSUB 2720:GOSUB 6570
6820 HRDCOPY$="":IOUT=1:RDSGN=2:GOTO 490

6840 REM - ON LINE HELP

6860 COLOR 7,0:CLS
6870 LOCATE 1,1:PRINT"----PIPECAR - THREE EDGE BEARING PROGRAM ----- HELP SCREEN
-----"
6890 LOCATE 3,5:PRINT "Input variables for the three edge bearing program have the same"
6900 LOCATE 4,5:PRINT "definitions as the main version of PIPECAR. Additional items pertinent"
6910 LOCATE 5,5:PRINT "to this program are:"
6920 LOCATE 7,5:PRINT " D-loads are the three edge bearing load in units of lbs per"
6930 LOCATE 8,5:PRINT " linear foot of pipe per foot of inside diameter of pipe."

```

```

6960 LOCATE 10,5:PRINT "
6970 LOCATE 11,5:PRINT "
6980 LOCATE 12,5:PRINT "
6990 LOCATE 13,5:PRINT "
7000 LOCATE 14,5:PRINT "
7010 LOCATE 16,5:PRINT "
7020 LOCATE 17,5:PRINT "
7030 LOCATE 18,5:PRINT "
7040 LOCATE 19,5:PRINT "
507."
7050 LOCATE 23,5:COLOR 0,7:PRINT "PRESS ANY KEY TO EXIT HELP":COLOR 7,0:IS=INPUT$(1)
7060 GOSUB 590 :REM MAIN MENU
7070 RETURN

7090 REM - DESIGN COEFFICIENTS

7110 REM - DESIGN COEFFICIENTS FOR CIRCULAR PIPE
7120 CM=1!:CMO=1.0:CS=.6:CX=.6:CW=1!:CSHP=3.3
7140 PSHAPEF$=PSHAPE$:SHIFT$=" "
7150 RETURN

7160 REM - DESIGN COEFFICIENTS FOR VERTICAL ELLIPTICAL PIPE
7170 CM=.93:CMO=1.11:CS=.6:CX=.6:CW=1!:CSHP=4.2
7190 PSHAPEF$="VERTICAL ELLIPTICAL":SHIFT$=" "
7200 RETURN

7210 REM - DESIGN COEFFICIENTS FOR HORIZONTAL ELLIPTICAL PIPE
7220 CM=1.06:CMO=0.89:CS=1!:CX=1!:CW=1!:CSHP=2.8
7240 PSHAPEF$="HORIZONTAL ELLIPTICAL":SHIFT$=""
7250 RETURN

7260 REM - DESIGN COEFFICIENTS FOR ARCH PIPE
7270 CM=1!:CMO=0.94:CS=.75:CX=.75:CW=1!:CSHP=2.8
7290 PSHAPEF$="ARCH":SHIFT$=" "
7300 RETURN
7310 REM
7320 REM - END OF DESIGN COEFFICIENTS
7330 REM
7340 REM - CLEAR INPUT LINES
7350 REM
7360 NEWV=0
7370 LOCATE 21,1
7380 FOR I=1 TO 4
7390 PRINT SPC(60)
7400 NEXT I
7410 LOCATE 21,1
7420 RETURN
7430 REM - REUTRN TO PIPECAR MAIN MENU
7440 COLOR 7,0:CLS
7450 CLOSE
7460 OPEN "PSYSTEM.DEF" FOR INPUT AS #1
7470 INPUT #1, DDRIV$
7480 INPUT #1, PDRIV$
7490 IF PDRIV$="A" OR PDRIV$="B" OR PDRIV$="a" OR PDRIV$="b" THEN 7500 ELSE GOTO
7530
7500 CLS:SOUND 1000,1:SOUND 500,1:COLOR 0,7

```

```
7510 LOCATE 10,15:PRINT "Insert Program Disk 1 into Drive ";PDRIV$
7520 LOCATE 11,15:PRINT "Then hit <SPACEBAR> to continue":I$=INPUT$(1)
7530 CLOSE:COLOR 7,0
7540 RUN PDRIV$ + ":" + "PIPECAR"
7550 END
```

## REFERENCES

1. McGrath, T.J., Heger, F.J., "Structural Design Manual for Improved Inlets and Culverts," Federal Highway Administration, Report No. IP-83-6, June, 1983.
2. Olander, H.C., "Stress Analysis of Concrete Pipe," Engineering Monographs No. 6, U.S. Department of the Interior, Bureau of Reclamation, October, 1950.
3. "Standard Specifications for Highway Bridges," American Association of State Highway and Transportation Officials, Thirteenth Edition, 1983 (As amended by interim specifications 1984, 1985, 1986).
4. Heger, F.J., McGrath, T.J., "Design Method for Reinforced Concrete Pipe and Box Sections," a report by Simpson Gumpertz & Heger Inc. for the American Concrete Pipe Association, December, 1982.
5. Manual for Railway Engineering, Chapter 8, Concrete Structures and Foundations, American Railway Engineering Association, Washington, DC, 1986.
6. Paris, J.M., "Stress Coefficients for Large Horizontal Pipes," Engineering News Record, Vol 87, No. 19, November 10, 1921.



APPENDIX A

INPUT PARAMETERS FOR PIPECAR

Screen No.	Description	Units	Default Value
1	Pipe Shape: Circular Elliptical		Circular
2C	Circular Pipe Inner Diameter	in.	None
2E	Elliptical Pipe Inside Radius -- Springline	in.	None
	Elliptical Pipe Inside Radius -- Crown/Invert	in.	None
	Horizontal Offset	in.	None
	Vertical Offset	in.	None
2C, E	Pipe Wall Thickness	in.	None
	Load System: Radial		Uniform
	Uniform		
	Uniform/Manual		
3R, U,	Depth of Fill	ft	None
M	Soil Structure Interaction Coefficient	None	1.2
3R	Load Angle	deg.	270.
	Bedding Angle (Soil, Water, Live Load)	deg.	60.
	Bedding Angle (Pipe Weight)	deg.	0.
3U	Lateral Pressure Coefficient	None	0.25
	Bottom Reaction Width (Soil, Water, Live Load)	% of Span	50.
	Bottom Reaction Width (Pipe Weight)	% of Span	0.
3M	Vertical Pressure	psf	None
	Lateral Pressure at Top	psf	None
	Lateral Pressure at Bottom	psf	None
	Top Load Width	% of Span	100.
	Bottom Reaction Width (Soil, Water, Live Load)	% of Span	50.
	Bottom Reaction Width (Pipe Weight)	% of Span	0.
	Invert to Bottom of Side Load	in.	None
	Height of Side Load	in.	None
4	Steel Reinforcing Yield Strength	ksi	65.
	Reinforcing Type (Note 1)	None	2.
	Number of Layers	None	1.

Screen No.	Description	Units	Default Value
	Design Concrete Strength	ksi	5.
	Concrete Density	pcf	150.
4	Dead Load Factor (Shear and Moment)	None	1.3
	Dead Load Factor (Thrust)	None	1.0
	Live Load Factor (Shear and Moment)	None	2.17
	Live Load Factor (Thrust)	None	1.0
	Internal Pressure Load Factor	None	1.8
5	Flexure Capacity Reduction Factor	None	0.95
	Radial Tension Strength Reduction Factor	None	0.9
	Diagonal Tension Strength Reduction Factor	None	0.9
6	Soil Density	pcf	120.
6	Live Load Options:		
	HS-Series Truck		HS-20
	Interstate Truck		
	Cooper E-Series Locomotive		
	Other		
	None		
6	Depth of Fluid	ft	Inside Rise
	Fluid Density	pcf	62.4
6H	HS-Series Live Load Magnitude	tons	20.
6C	Cooper E-Series Live Load Magnitude	kips	80.
6O	User Specified Live Load Magnitude	kips	None
	Effective Width of Resistance	in.	None
	Effective Length of Resistance	in.	None
7	Concrete Covers:		
	Inside Face	in.	1.
	Outside Face	in.	1.
7	Reinforcing Diameters:		
	Inside Steel	in.	0.08T
	Outside Steel	in.	0.08T
7	Minimum Wire Spacing:		
	Inside Steel	in.	4.
	Outside Steel	in.	4.

## APPENDIX B

### DIRECT DESIGN METHOD

This Appendix presents the design method used in PIPECAR based on AASHTO Section 17.4.. One enhancement that has been incorporated in PIPECAR is that where  $\phi$  appears in the AASHTO design equations the user may specify separate factors for flexure ( $\phi_f$ ), 0.01 inch crack ( $F_{Cr}$ ), radial tension ( $\phi_R$ ) and diagonal tension ( $\phi_D$ ).

#### B1 Reinforcement

##### B1.1 Reinforcement for Flexural Strength

$$A_s f_y = g \phi_f d - N_u - \sqrt{g[\phi_f d]^2 - N_u(2\phi_f d - h) - 2M_u} \quad \text{Eq. B.1}$$

where  $g = 0.85 b f_c$

##### B1.2 Minimum Reinforcement

$$\text{For inside face of pipe: } A_s = (S + h)^2 / 65,000 \quad \text{Eq. B.2}$$

$$\text{For outside face of pipe: } A_s = 0.75 (S + h)^2 / 65,000 \quad \text{Eq. B.3}$$

For elliptical reinforcement in circular pipe and for pipe 33-inch diameter and smaller with a single cage of reinforcement in the middle third of the pipe wall:

$$A_s = 2(S + h)^2 / 65,000 \quad \text{Eq. B.4}$$

where

$h$  = wall thickness in inches;

$S$  = internal diameter or horizontal span of pipe in inches.

In no case shall the minimum reinforcement be less than 0.07 square inches per linear foot.

### B1.3 Maximum Flexural Reinforcement Without Stirrups

#### B1.3.1 Limited by Radial Tension

$$R_{rt} = \frac{(M_u - 0.45N_u d)F_{rp}}{1.2b \phi_r r_s \sqrt{f'_c} F_{rt}} \quad \text{Eq.B.5}$$

where

- $R_{rt}$  = radial tension index, stirrups are required if  $R_{rt} > 1.0$   
 $F_{rp}$  = 1.0 unless a higher value substantiated by test data is approved by the Engineer;  
 $r_s$  = radius of the inside reinforcement in inches.  
 $F_{rt}$  = size factor for radial tension strength

for  $S_i \geq 144$  in.

$$F_{rt} = 0.8$$

for  $144 \text{ in.} \geq S_i \geq 72$  in.

$$F_{rt} = \frac{(144 - S_i)^2}{26000} + 0.8$$

for  $72 \text{ in.} \geq S_i$

$$F_{rt} = 1 + 0.00833 (72 - S_i)$$

#### B1.3.2 Limited by Concrete Compression

$$A_{smax.f_y} = \left[ \frac{5.5 \times 10^4 g' \phi_f d}{(87,000 + f_y)} \right] - 0.75N_u \quad \text{Eq.B.6}$$

where:

$$g' = bf'_c \left[ 0.85 - 0.05 \frac{(f'_c - 4,000)}{1,000} \right]$$

$$g'_{max} = 0.85bf'_c \text{ and } g'_{min} = 0.65bf'_c$$

### B1.4 Crack Width Control (Service Load Design)

$$F_{cr} = \frac{B_1}{30,000 \phi_f d A_b} \left[ \frac{M_s + N_s \left( d - \frac{h}{2} \right)}{ij} - C_1 b h^2 \sqrt{f'_c} \right] \quad \text{Eq. B.7}$$

where

$F_{cr}$	=	crack control factor, see Note c;
$M_s$	=	bending moment, service load;
$N_s$	=	thrust (positive when compressive). service load;
$j$	=	$0.74 + 0.1 e/d$ ;
$j_{max}$	=	0.9;
$i$	=	$\frac{1}{1 - \frac{jd}{e}}$
$e$	=	$\frac{M}{N} + d - \frac{h}{2}$
$e/d_{min}$	=	1.15;
$s$	=	spacing of circumferential reinforcement in inches;
$t_b$	=	clear cover over reinforcement in inches;
$h$	=	wall thickness of pipe in inches;
$B_1$ and $C_1$	=	crack control coefficients dependent on type of reinforcement used as follows:

Type Reinforcement:	$\frac{B_1}{(\text{in.})}$	$\frac{C_1}{\left( \frac{\text{lb.}}{\text{in.}^2} \right)}$
1. Smooth wire or plain bars	$\sqrt[3]{\frac{0.5 t_b^2 s}{n}}$	1.0
2. Welded smooth wire fabric. 8 inches maximum spacing of longitudinals	$\sqrt[3]{\frac{0.5 t_b^2 s}{n}}$	1.5
3. Welded deformed wire fabric, deformed wire, deformed bars or any reinforcement with stirrups anchored thereto.	$\sqrt[3]{\frac{0.5 t_b^2 s}{n}}$	1.9

Notes:

- a. Use  $n = 1$  when the inner and the outer cages are each a single layer. Use  $n = 2$  where the inner and the outer cages are each made up from multiple layers.
- b. For type 2 reinforcement having  $(t_b^2 s)/n > 3.0$ , also check for  $F_{Cr}$  using coefficients  $B_1$  and  $C_1$  for type 3 reinforcement, and use larger value for  $F_{Cr}$ .
- c. When  $F_{Cr} = 1.0$  the reinforcement area,  $A_s$ , will produce an average maximum crack width of 0.01 inch. For  $F_{Cr}$  values less than 1.0 the probability of a 0.01 inch crack is reduced, and for larger values, cracks greater than 0.01 inch may occur.
- d. Higher values for  $C_1$  may be used if substantiated by test data and approved by the Engineer.

### B1.5 Shear Strength

The area of reinforcements,  $A_s$  determined in B1.1 through B1.4 must be checked for shear strength adequacy, so that the basic shear strength,  $V_b$ , is greater than the factored shear force,  $V_{UC}$ , at the critical section located where  $M_U/M_V\phi d = 3.0$

$$V_b = b\phi_D d F_{vp} \sqrt{f'_c} (1.1 + 63\rho) \left[ \frac{F_d}{F_c F_n} \right] \quad \text{Eq. B.8}$$

where

$$V_b = \text{shear strength of section where } M_U/V_U\phi d = 3.0$$

$$F_{vp} = 1.0 \text{ unless a higher value substantiated by test data is approved by the Engineer:}$$

$$\rho = \frac{A_s}{bd}; \quad \rho_{\max} = 0.02$$

$$f'_c \max = 7,000 \text{ psi}$$

$$F_d = 0.8 + \frac{1.6}{d} \quad F_{d \max} = 1.25$$

$$F_c = 1 \pm \frac{\phi_D d}{2r} \quad \begin{array}{l} (+) \text{ tension on the inside of the pipe} \\ (-) \text{ tension on the outside of the pipe} \end{array}$$

$$F_N = 1.0 - 0.12 \frac{N_u}{V_u} \quad F_{N \min} = 0.75$$

If  $V_b$  is less than  $V_{UC}$ , radial stirrups must be provided. See B1.6.

## B1.6 Radial Stirrups

### B1.6.1 Radial Tension Stirrups

$$A_{vr} = \frac{1.1 s (M_u - 0.45 N_u d)}{f_v r_s \phi_D d} \quad \text{Eq. B.9}$$

where

- $A_{vr}$  = required area of stirrup reinforcement for radial tension;  
 $s$  = circumferential spacing of stirrups ( $s_{\max} = 0.75\phi_D d$ );  
 $f_v$  = maximum developable strength of stirrup material ( $f_{\max} = f_y$ , or anchorage strength whichever is less).

### B1.6.2 Shear Stirrups

$$A_{vs} = \frac{1.1s}{f_v \phi_D d} [V_u F_c - \phi_D V_c] + A_{vr} \quad \text{Eq. B.10}$$

where

- $A_{vs}$  = required area of stirrups for shear reinforcement;  
 $V_u$  = factored shear force at section

$$V_c = \frac{4V_B}{\frac{M_u}{V_u \phi_D d} + 1}$$

$$V_{c \max} = 2\phi_D b d \sqrt{f_c}$$

## APPENDIX C – EQUATIONS FOR INDIRECT DESIGN METHOD

This Appendix presents the design equations used in the Indirect Design Module of PIPECAR. These equations are based on Chapter 3 of Reference 4 with some modifications to reflect the current AASHTO design specification.

### C1 NOTATION

The notations used in this Chapter are the same as those used in ACI 318-77, wherever applicable, and are listed below:

$A_{si}$	inside tension reinforcement area, in. <sup>2</sup> /ft
$A_{so}$	outside tension reinforcement area, in. <sup>2</sup> /ft
$A_v$	stirrup reinforcement area, in. <sup>2</sup> /ft, in each line of stirrups at circumferential spacing, s, in.
a	effective depth of compressive stress block at ultimate strength when average compressive stress in concrete is $B_1 f_c'$ , in.
$B_1$	coefficient which defines the depth of the equivalent rectangular stress block in "balanced" sections
$B_{.01}$	crack control coefficient for effect of cover and spacing of reinforcement
$C_{.01}$	crack control coefficient for type of reinforcement
$C_m$	coefficient for invert bending moment, based on elastic behavior for shapes other than circular (i.e. $C_m = 1.0$ for circular pipes)
$C_{mo}$	coefficient for springline bending moment based on elastic behavior for shapes other than circular (i.e. $C_{mo} = 1.0$ for circular pipes).
$C_{mp}$	coefficient for increased bending strength, based on plastic behavior
$C_s$	coefficient for flexural reinforcing at springlines based on ASTM Specifications
$C_w$	coefficient for shear force due to weight of pipe for shapes other than circular (i.e. $C_w = 1.0$ for circular pipes)
$C_x$	coefficient for minimum reinforcement
$D_i$	pipe inside diameter, in. For elliptical or arch pipe with a variable radius, $D_i$ is twice the inside radius at a particular section.



DL	3-edge bearing D-Load strength defined as test load in pounds per foot of pipe length divided by pipe inside span in feet, lbs/ft/ft
DL <sub>p</sub>	an equivalent D-Load for the weight of pipe, lbs/ft/ft
DL <sub>u</sub>	required or predicted 3-edge bearing ultimate D-Load strength, lbs/ft/ft
DL <sub>uT</sub>	reduced average ultimate test D-Load strength from proof of design tests, as defined in ASTM C 655, for a specific pipe design, lbs/ft/ft
DL <sub>.01</sub>	required or predicted 3-edge bearing 0.01 inch crack D-Load, lbs/ft/ft
DL <sub>.01T</sub>	reduced average 0.01 inch crack test D-Load strength from proof of design tests, as defined in ASTM C 655, for a specific pipe design, lbs/ft/ft
d	distance from compression face to centroid of tension reinforcement, in.
d <sub>i</sub>	distance from outside face to centroid of inner reinforcement, in.
d <sub>o</sub>	distance from inside face to centroid of outer reinforcement, in.
F <sub>c</sub>	factor for effect of curvature on diagonal tension (shear) strength in curved components
F <sub>cr</sub>	factor for adjusting crack control relative to average maximum crack width of 0.01 inch when F <sub>cr</sub> = 1.0
F <sub>crT</sub>	factor for correcting 0.01 inch crack strength based on proof of design tests
F <sub>d</sub>	factor for crack depth effect resulting in increase in diagonal tension (shear) strength with decreasing d
f' <sub>c</sub>	design compressive strength of concrete, lbs/in. <sup>2</sup>
f <sub>s</sub>	tension stress in reinforcement at cracked section subject to M and N, lbs/in. <sup>2</sup>
f <sub>su</sub>	ultimate tensile strength of cold drawn wire, and welded wire fabric reinforcements. If mild steel reinforcement is provided, use f <sub>y</sub> instead of f <sub>su</sub> , lb/in. <sup>2</sup>
f <sub>s.01</sub>	tension stress in reinforcement at average predicted formation of 0.01 inch crack, lbs/in. <sup>2</sup>
f <sub>v</sub>	developable stress in stirrup, lbs/in. <sup>2</sup> . May be governed by maximum anchorage force that can be developed between stirrup and each inner reinforcement wire or bar, or by yield strength, f <sub>y</sub> , whichever is less
f <sub>y</sub>	specified yield strength of reinforcement, lbs/in. <sup>2</sup>
h	overall thickness of member (wall thickness), in.
L <sub>s</sub>	minimum circumferential length requiring stirrup reinforcement, in.
n	number of layers of reinforcement in a cage (1 or 2)
q	factor in Equation 2.12 for area of reinforcement for ultimate flexure

$r$	radius to centerline of pipe wall, in.
$r_s$	radius to inside reinforcement, in.
$R_{dtm}$	maximum index limit for diagonal tension (shear) failure
$S_j$	horizontal span between inside of walls of circular, elliptical or arch pipe, in.
$s$	circumferential spacing of shear or radial tension stirrup reinforcement, in.
$s_c$	longitudinal spacing or circumferential reinforcement (wires or bars), in.
$t_b$	clear cover distance from tension face of concrete to edge of tension reinforcement, in.
$W_p$	weight of unit length of structure, lbs/ft
$W_t$	total test load per unit length, lbs/ft
$\rho$	ratio of reinforcement area, as given by Eq. C.13
$\phi_F$	capacity reduction factor on flexure for variability in manufacture
$\phi_C$	capacity reduction factor on 0.01 in. crack for variability in manufacture
$\phi_D$	capacity reduction factor on diagonal tension for variability in manufacture
$\phi_R$	capacity reduction factor on radial tension for variability in manufacture

## C2 EFFECTIVE DEPTH TO REINFORCEMENT

### C2.1 Task 1 – Analysis of D-Load Capacity

In Task 1 all the data needed to compute the depth of reinforcement is available.

$$d = h - t_b - 0.163 \sqrt{s_c A_{si}} \quad \text{Eq.C.1}$$

### C2.2 Task 2 – Reinforcing Design

In Task 2 the wire diameter is not known prior to design. Therefore, the depth of reinforcement is estimated as:

$$d = 0.96 h - t_b \quad \text{Eq.C.2}$$

### C3 WEIGHT OF PIPE SECTION

The total weight of structure per unit length,  $W_p$ , is estimated in lbs per ft (when  $h$  and  $D_i$  or  $S_i$  are in inches):

$$\text{Circular:} \quad W_p = 3.3 h (D_i + h) \quad \text{Eq.C.3}$$

$$\text{Arch or horizontal elliptical:} \quad W_p = 2.8 h (S_i + h) \quad \text{Eq.C.4}$$

$$\text{Vertical elliptical:} \quad W_p = 4.2 h (S_i + h) \quad \text{Eq.C.5}$$

### C4 ULTIMATE FLEXURE

#### C4.1 Ultimate 3-edge bearing:

$$\left( DL_u + \frac{9 W_p}{S_i} \right) = \frac{85 C_m C_{mp} A_{si} f_y (\phi_F d - 0.5a)}{S_i (S_i + h)} \quad \text{Eq.C.6}$$

$$a = \frac{f_y A_{si}}{10.2 f_c} \quad \text{Eq.C.6a}$$

If ultimate flexural strength is to be based on elastic moment distribution and "first yield" in reinforcement (the conventional design basis), use  $C_{mp} = 1.0$  and the values of the  $C_m$  given in the table below for the applicable standard pipe shape.

If the ultimate flexural strength is to be the expected "collapse" load on the pipe in 3-edge loading (the conventional test strength basis), compute  $C_{mp}$  as:

$$C_{mp} = 1 + \frac{h}{S_i} + \left[ \frac{.562 C_s}{C_m} \left( \frac{d_o}{d_i} \right) - \frac{.364}{C_{mo}} \right] \frac{(S_i + h)}{S_i} \quad \text{Eq.C.7}$$

Use values of  $C_m$  and  $C_{mo}$  from the table below. The coefficient  $C_s$  is the ratio of the amount of reinforcing proved at the springline to the amount of reinforcing provided at the invert. Typical values for  $C_s$  from ASTM Specifications are listed Below. Non standard reinforcing arrangements (such as circular plus elliptical) may result in other values of  $C_s$ .

<u>Pipe Shape - Reinforcement Layout</u>	<u>C<sub>m</sub></u>	<u>C<sub>mo</sub></u>	<u>C<sub>s</sub>*</u>
Circular, two cages	1.00	1.00	0.60
Circular, one cage,	1.00	1.00	1.00
Horizontal elliptical, one or two cages	1.06	0.89	1.00
Vertical elliptical, two cages	0.93	1.11	0.60
Arch, two cages	1.00	0.94	0.75

\* Standard values from ASTM. Use actual value in calculations.

If the value for  $C_{mp}$  computed by Eq. C7 is less than 1., whether first yield or ultimate collapse is selected as the design condition, then reinforcing at the springline may yield before the reinforcing at the invert. If this occurs the calculations for ultimate flexure and 0.01 inch crack may be in error.

If cold drawn wire or fabric reinforcement is used,  $0.95 f_{su}$  may be used in place of  $f_y$  in Eqs. C.6 and C.6a for determination of estimated collapse load.

For pipe with wall thickness 5 inches or less, 1 inch nominal cover concrete, and outer cage reinforcement equal to six-tenths of inner cage reinforcement, tests show that both the inner and the outer cages will develop their full tension strengths at the crown and invert prior to collapse. Thus, to account for this behavior when flexural strength is to be based on collapse load rather than on first yield if  $a < 0.7$ , add  $(0.7 - a)$  to  $(d \phi_F - 0.5a)$  in Eq.C.6.

#### C4.2 Reinforcement required at invert, and crown, to obtain required $DL_U$ .

$$A_{si} = \frac{S_i(S_i + h) \left( DL_U + \frac{9W_p}{S_i} \right)}{85 C_m C_{mp} f_y (\phi_F d - 0.5 a)} \quad \text{Eq.C.8}$$

Determine "a" from Eq.C.7 using trial  $A_{si}$ :

$$\text{Trial } A_{si} = \frac{1.75 \times 10^{-7} DL_U D_i^2}{\phi_F d} \quad \text{Eq.C.9}$$

Equations C.6a and C.8 are solved iteratively until they converge.

If a design based on flexural collapse is desired, take  $C_{mp}$  = values given in Section C4.1 and, for cold drawn wire reinforcements only, use  $0.95 f_{su}$  instead of  $f_y$ .

If  $DL_U$  for diagonal tension (Eq.C.17) is between  $DL_U$  for flexural yield ( $C_{mp} = 1.0$ ) and  $1.1 \times DL_U$  for flexural collapse, use  $DL_U$  for flexural yield as maximum ultimate load.

#### C4.3 Minimum reinforcement area:

$$\text{min. } A_s = C_x (S_i + h)^2 / f_y \quad \text{Eq.C.10}$$

<u>Reinforcement Arrangement</u>	$C_x$	
Inner cage of two concentric cages, with nominal cover, $t_b$ , to inside	1.0	
Outer cage of two concentric cages, with nominal cover, $t_b$ , to outside	0.6	circular
	0.75	arch
	1.00	horizontal elliptical
	0.60	vertical elliptical
A single cage, with nominal cover, $t_b$ , to inside at crown and invert, and $t_b$ to outside at springlines (elliptical reinforcement) (96 in. max. inside span)	1.1	
A single concentric cage at mid-depth of wall (33 in. max. inside span)	1.1	

#### C4.4 Anchorage of Discontinuous Reinforcement and Splices

Where reinforcement is terminated at sections where it is no longer required, it must be extended sufficiently to develop at least  $0.5 f_y A_s$ .

Reinforcement splices made in zones of flexural tension must develop  $f_y A_s$ , where  $A_s$  is given by Eq.C.8 with  $C_{mp} = 1.0$ . Use  $f_{su}$  and  $C_{mp} = 1.1$  if reinforcement design is based on collapse condition.

Inner reinforcement splices made in zones of flexural compression must develop  $f_y$  (min  $A_{si}$ ) where min.  $A_{si}$  is given by Eq.C.10.

**C5 0.01 INCH CRACK**

The following equations are for pipes 48 inches in diameter and larger. They may be used for smaller pipe but become increasingly more conservative as pipe diameter decreases from 48 inches.

**C5.1 Predicted D-Load at 0.01 inch crack**

$$\left( DL_{.01} + \frac{9W_p}{S_i} \right) = \frac{70 C_m f_{s.01} A_{si} \phi_c d}{S_i(S_i+h)} \quad \text{Eq.C.11}$$

$$f_{s.01} = \frac{30,000}{B_{.01}} + \frac{C_{.01} h^2 \sqrt{f_c}}{\rho \phi_c d^2} \leq f_y \quad \text{Eq.C.12}$$

$C_m$  – See table in Section 3.5.1

$$\rho = \frac{A_{si}}{bd} \quad \text{Eq.C.13}$$

$B_{.01}$  and  $C_{.01}$  as follows:

Type Reinforcement:	$B_{.01}$	$C_{.01}$
1. Smooth wire or plain bars		
2. Welded smooth wire fabric. 8 inches maximum spacing of longitudinales	$3\sqrt{\frac{0.5 t_b^2 s_c}{n}}$	1.0
3. Welded deformed wire fabric, deformed wire, deformed bars, or any reinforcement with stirrups anchored thereto	$3\sqrt{\frac{0.5 t_b^2 s_c}{n}}$	1.5
	$3\sqrt{\frac{0.5 t_b^2 s_c}{n}}$	1.9

Notes:

- (1.) Use  $n = 1$  when the inner and the outer cages are each a single layer.  
Use  $n = 2$  when the inner and the outer cages are each made up from multiple layers. Note: More research is needed to establish the effects of multiple layers of reinforcement.
- (2.) For Type 2 reinforcement having  $(t_b^2 s_c)/n > 3.0$ , also check  $f_{s,01}$  using coefficients  $B_{,01}$  and  $C_{,01}$  for type 3 reinforcement and use smaller value of  $f_{s,01}$ .
- (3.) Use nominal design  $h$  and  $t_b$  in Eq.C.12.

**C5.2 Reinforcement required at invert to obtain required  $DL_{,01}$ :**

$$A_{si} = \frac{\left( DL_{,01} + \frac{9W_p}{S_i} \right) S_i(S + h) B_{,01}}{2,100,000 \phi_c d C_m} - \frac{C_{,01} B_{,01} h^2 \sqrt{f'_c}}{2500 \phi_c d} \quad \text{Eq.C.14}$$

**C5.3 Method for using "proof of design" tests to modify estimate of 0.01 inch crack strength given by Eq.C.11 for particular manufacturing and materials conditions**

The equations given above for 0.01 inch crack D-Load strength, are semi-empirical with design constants determined by analyzing a large number of tests on pipe having many different manufacturing and materials conditions. Sometimes, process or materials characteristics at a particular plant, or locality, may result in pipe with increased (or occasionally decreased) 0.01 inch strength. In such cases, the designer may obtain improved estimates of 0.01 inch crack strength by applying modification factors obtained as described below to the design equations given previously in this Sub-section.

- (1) Determine a series of maximum 0.01 inch crack index limits,  $F_{crT}$ , using "proof of design" tests (ASTM C 655) of specific designs tested to 0.01 inch D-Load strength:

$$F_{crT} = \frac{1.1 \times 10^{-3} B_{,01} S_i(S_i + h) \left( DL_{,01T} + \frac{9W_p}{S_i} \right)}{2500 A_{si} d + C_{,01} B_{,01} h^2 \sqrt{f'_c}} \quad \text{Eq.C.15}$$

The tested designs, should cover the range of variables expected to occur in the design practice with particular manufacturing and materials conditions. Average measured values of  $d$ ,  $t_b$ , and  $f'_c$  for the test specimens should be used in Eq.C.15.

- (2) Select either the lowest value of  $F_{crT}$ , or the arithmetic mean  $F_{crT}$  less 1.07 standard deviations, as defined in paragraph 9.1.1 of ASTM C 655, as the 0.01 inch crack strength modification factor.
- (3) Multiply the right side of Eq.C.11 by the value of  $F_{crT}$  selected above to obtain estimated 0.01 inch crack strengths, based on "proof of design" tests of pipe having specific manufacturing and materials conditions. Alternately the required  $(DL_{.01} + 9 W_p/S_i)$  may be divided by  $F_{crT}$  on the right side of Eq.C.14.

## C6 REINFORCEMENT REQUIRED AT SPRINGLINE

Outside reinforcing requirements at the springline are computed by the following:

$$A_{SO} = C_S A_{Si} \quad \text{Eq.C.16}$$

Values for  $C_S$  based on ASTM Specifications may be taken from the table following Equation C7.

$A_{Si}$  is the maximum reinforcing required for ultimate flexure or 0.01 inch crack.

## C7 ULTIMATE DIAGONAL TENSION WITHOUT STIRRUPS

C7.1 Predicted D-Load at diagonal tension failure:

$$DL_u + \frac{11 C_w W_p}{S_i} = 322 F_d (1.0 + 57\rho) \phi_D d \sqrt{f'_c} \quad \text{Eq.C.17}$$

Use  $\rho = 0.02$ , if actual  $\rho > 0.02$

(Note: This is beyond limit of practical design for pipe.)

Use  $f'_c = 7,000$  psi if  $f'_c > 7,000$  psi.



$$F_d = 0.80 + \frac{1.6}{\phi_D d} \quad \text{Eq.C.18}$$

Use  $F_d = 1.25$ , if calculated  $F_d > 1.25$ .

$$F_c = 1 + \frac{\phi_D d}{2r} \quad \text{Eq.C.19}$$

Shape of Pipe	$r$	$C_w$
Circular	$0.5 (D_i + h)$	1.0
Horizontal elliptical	$0.86 S_i + h/2$	1.0
Vertical elliptical	$0.27 S_i + h/2$	1.0
Arch – invert	$R_1 + h/2$ ( $R_1$ from ASTM C 506)	1.0
Arch – crown	$R_2 + h/2$ ( $R_2$ from ASTM C 506)	0

**C7.2 Area of reinforcement for required ultimate D-Load based on diagonal tension strength**

$$A_{si} = \frac{6.5 \times 10^{-4} \left( DL_u + \frac{11C_w W_p}{S_i} \right) F_c S_i}{\phi_D F_d \sqrt{f'_c}} (F_{MV}) - 0.21d \leq 0.24d \quad \text{Eq.C.20}$$

$F_{MV}$  is a factor which accounts for the effect of the moment to shear ratio ( $M/Vd$ ) on the shear strength of a pipe in three edge bearing

$$F_{MV} = 0.25 + \frac{0.063 (S_i + h)}{d} \quad \text{Eq.C.21}$$

If  $F_{MV} \geq 1.0$ , then the  $M/Vd$  ratio is greater than 3.0 and use  $F_{MV} = 1.0$  in Eq.C.20.

If  $A_{si}$  from Eq.C.20 is greater than  $0.24d$ , stirrups must be used, with  $A_{si}$  governed by flexure or 0.01 inch crack.

Use  $f'_c = 7,000$  psi, if  $f'_c > 7,000$  psi

**C7.3 Method for using "proof of design" tests to modify estimate of ultimate diagonal tension strength given by Eq.C.17 for particular manufacturing and materials conditions:**

The equations given above for ultimate diagonal tension strength are semi-empirical, with design constants determined by analyzing a large number of tests on pipe having many different manufacturing and materials conditions. Sometimes, process or materials characteristics at a particular plant or locality may result in pipe with increased (or occasionally decreased) diagonal tension strength. In such cases, the designer may obtain improved estimates of diagonal tension strength by applying modification factors obtained as described below to the design equations given previously in this Sub-section.

- (1.) Determine a series of maximum diagonal tension strength index limits,  $R_{dtm}$ , using proof of design tests (ASTM C 655) of specific designs that fail in diagonal tension:

$$R_{dtm} = \frac{F_c S_i \left( DL_{uT} + \frac{11 C_w W_p}{S_i} \right)}{322 F_d (1+57 \rho) d \sqrt{f'_c}} \quad \text{Eq.C.22}$$

The tested designs should cover the range of variables expected to occur in the design practice with particular manufacturing and materials conditions. Average measured values of  $d$  at the section of maximum shear and  $f'_c$  for the test specimens should be used in Eq.C.22.

- (2.) Select either the lowest value of  $R_{dtm}$ , or the arithmetic mean  $R_{dtm}$  less 1.07 standard deviations, as defined in paragraph 9.1.1 of ASTM C 655, as the diagonal tension strength modification factor.
- (3.) To preclude an excessive correction caused by some local distortion in test results, limit the maximum  $R_{dtm}$  to:

$$R_{dtm} \leq 1.20. \quad \text{Eq.C.23}$$

- (4.) Multiply the right side of Eq.C.17 by the value of  $R_{dtm}$  selected above to obtain estimated diagonal tension strengths, based on proof of design tests of pipe having specific manufacturing and materials conditions. Alternately, the required  $(DL_u + 11 C_w W_p/S_i)$  may be divided by  $R_{dtm}$  on the right side of Eq.C.20.

## C8 ULTIMATE RADIAL TENSION WITHOUT STIRRUPS

### C8.1 Predicted D-Load at radial tension failure:

$$\left( DL_u + \frac{9 C_w W_p}{S_i} \right) = \frac{1230 r_s \phi_R d \sqrt{f_c}}{S_i(S_i + h)} F_{rt} \quad \text{Eq.C.24}$$

$$\text{for } S_i \geq 144 \text{ in.}$$

$$F_{rt} = 0.8$$

$$\text{for } 144 \text{ in.} \geq S_i \geq 72 \text{ in.}$$

$$F_{rt} = \frac{(144 - S_i)^2}{26000} + 0.8$$

$$\text{for } 72 \text{ in.} \geq S_i$$

$$F_{rt} = 1 + 0.00833 (72 - S_i)$$

.Obtain  $C_w$  from table following Eq.C.19.

Obtain  $r_s$  by deducting  $(0.5h - t_b)$  from the values of  $r$  given in the table following Eq.C.19.

## C9 STIRRUP DESIGN FOR DIAGONAL AND RADIAL TENSION STRENGTH

If the required  $DL_u$  exceeds the  $DL_u$  provided by the diagonal tension strength of the concrete, stirrups may be used at the crown and invert regions to increase the ultimate diagonal tension strength of the pipe.

Maximum stirrup spacing:

$$\text{Max. } s = 0.75 \phi_D d \quad \text{Eq.C.25}$$

Required stirrup reinforcement area per foot of pipe per line of stirrups:

$$A_v = \frac{0.045 s S_i}{f_v \phi_D d} \left\{ \left[ F_c + \frac{0.25 (S_i + h)}{r_s} \right] \left[ DL_u + \frac{11 W_p}{S_i} \right] - \left[ \frac{322(1 + 57\rho) \phi_D d \sqrt{f_c}}{S_i} \right] \frac{F_d}{F_c} \right\} \quad \text{Eq.C.26}$$

$r_s$ ,  $F_d$ , and  $F_c$  from Sections C7.1 and C8.1.

For circular pipe  $r_s = 0.5 (D_i + 2 t_b)$

Use  $\rho = 0.02$  if actual  $\rho > 0.02$

Use  $(1.0 + 57 \rho) F_d = 1.8$ , if actual value  $> 1.8$

Required minimum stirrup reinforcement area per foot of pipe per line of stirrups:

$$\text{min. } A_v = \frac{0.013s S_i(S_i + h)}{f_v \phi_D d r_s} \left( DL_u + \frac{9W_p}{S_i} \right) \quad \text{Eq.C.27}$$

Use the larger value of  $A_v$  from Eq.C.26 or C.27.

Circumferential length,  $L_s$ , centered on crown and invert where stirrups are required:

$L_s$  should be determined based on field load and bedding conditions.

In the absence of a design for field loading conditions, provide stirrups over minimum lengths in the crown and invert region:

$$L_s = C_L S_i \quad \text{Eq. C.28}$$

Shape	C <sub>L</sub> – Strength Class			
	3	4	5	5+
Circular	0.4	0.6	0.8	1.0
Horizontal elliptical	0.5	0.7	0.9	1.0
Vertical elliptical	0.3	0.5	0.7	0.9
Arch – Invert	0.6	0.8	1.0	1.1
Arch – Crown	0.4	0.6	0.8	1.0

