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APPLIED FLUID MECHANICS
Sixth Edition

Robert L. Mott

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Description of Spreadsheets Included on the CD in the Book

Introduction

This book includes a CD-ROM that contains ten computational aids that are keyed to the book. The files are written as Microsoft Excel spreadsheets using Version 2002 on Windows XP.

The ten spreadsheets are all included in one workbook called Series Pipe Systems-Master. The names of each spreadsheet described below are on the tabs at the bottom of the workbook when it is opened. You must choose which is appropriate for a given problem. Most names start with either *I, II,* or *III* indicating whether the spreadsheet is for a Class *I, Class II,* or Class *III* pipe line system as defined in Chapter 11 of the text.

The spreadsheets are designed to facilitate the numerous calculations required to solve the variety of problems in Chapter 11 Series Pipeline Systems. Many of the spreadsheets appear in the text. Others were prepared to produce solutions for the Solutions Manual. The given spreadsheets include data and results from certain figures in the text, from example problems, or in problems from the end of Chapters 8, 11, and 13 containing the analysis and design procedures featured in the programs.

The following sections give brief descriptions of each spreadsheet. Many are discussed in the text in more extensive detail. It is expected that you will verify all of the elements of each spreadsheet before using them for solutions to specific problems.

Using the Spreadsheets: ***It is recommended that the given spreadsheets be maintained as they initially appear on the CD. To use them for solving other problems, call up the master workbook in Excel and use the "Save as" command to name it something different. That version can then be used for a variety of problems of your*** **own choice.** ***Be careful that you do not modify the contents of critical cells containing complex equations. However, you are encouraged to add additional features to the spreadsheets to enhance their utility.***

The principles involved in the spreadsheets come from Chapters 6 - 11 and you should study the concepts and the solution techniques for each type of problem before using the given spreadsheets. It is highly recommended that you work sample problems by hand first. Then enter the appropriate data into the spreadsheet to verify the solution. In most spreadsheets, the data that need to be entered are identified by gray-shaded areas and by italic type. Results are typically shown in bold type.

I Power SI: The objective of problems of this type is to compute the amount of power required to drive a pump to deliver a given amount of fluid through a given system. Energy losses are considered. All data must be in the listed SI units. The solution procedure is for a Class I series pipe line system. The following is a summary of the steps you must complete.

1. Enter the problem identification information first. The given data in the spreadsheet are for example Problem 11.1 for the system shown in Figure 11.2.

2. Describe two appropriate reference points for completing the analysis of the general energy equation.

3. Specify the required volume flow rate, *Q*, in m^3/s.

4. Enter the pressures (in kPa), velocities (in m/s), and elevations (in m) at the reference points in the ***System Data:*** at the top of the sheet. If the velocity at either reference point is in a pipe, you may use a computed velocity from $v = Q/A$ that is included in the data cells for the two pipes. In such cases, you enter the Excel command "=B20" for the velocity in pipe 1 and "=E20" for the velocity in pipe 2.

5. Enter the fluid properties of specific weight (in kN/m^3) and kinematic viscosity (in m^2/s).

6. Enter pipe data, including flow diameter *D* (in m), pipe wall roughness *a* (in m from Table 8.2), and length *L* (in m). Other pipe-related data are computed by the spreadsheet. Equation 8-7 is used to compute the friction factor.

7. Enter energy loss coefficients, *K,* for all loss-producing elements in both pipes. See Chapters 8, 10, and 11 for the proper form for *K* for each element and for necessary data. The value for *K* for pipe friction is computed automatically from known data in the *"Pipe"* section. Specify the number of like elements in the *"Qty."* column. Enter brief descriptions of each element so your printout is keyed to the given problem and so you can observe the energy loss contribution of each element. Space is given for up to eight different kinds of energy loss elements. Enter zero for the value of the *K* factor for those not needed.

8. The ***Results:*** section at the bottom of the spreadsheet includes the total energy loss *h<,* the total head on the pump *h¿,* and the power added to the fluid by the pump *P,*. If you enter an efficiency for the pump, the power input to the pump *P,* is computed.

I Power US: Same as ***Power SI:***, except U.S. Customary units are used. The given solution is for Problem 11.29 for the system shown in Figure 11.26. The first reference point is taken just before the pump inlet. Therefore there are no friction losses or minor losses considered in the suction pipe. The length is given ta be zero and all *K* factors are zero for Pipe 1. In Pipe 2, pipe friction, the loss in the elbow, and the loss in the nozzle are included.

I Pressure SI: Most of the layout and data entry for this spreadsheet are the same as those in the first two spreadsheets, ***I Power SI,*** and ***I Power US.*** The difference here is that the analysis determines the pressure at one point in the system when the pressure at some other point is known. Class I systems with one or two pipe sizes including minor losses can be analyzed. This spreadsheet uses the known pressure at some starting point and computes the pressure at a downstream point, considering changes in elevation, velocity head, pipe friction and minor losses. The example is the solution of Problem 11.7 for the system shown in Figure 11.17. p_2 is assumed to be 100 kPa. p_2 is computed to be 78.21 kPa. Then Δp = -21.79 kPa.

I Pressure US: This spreadsheet is virtually identical to ***I Pressure SI:*** except for the different unit system used. The example is the solution for Problem 11.3 using the system shown in Figure 11.13. An important difference occurs here because the objective of the problem is to compute the upstream pressure at the outlet of a pump when the desired downstream pressure at the inlet to the hydraulic cylinder is specified. You should examine the contents of cells B7 and B8 where the pressures are listed and E43 and E44 where the actual calculations for pressure change are performed. The changes demonstrated here between ***I Pressure SI:*** and ***I Pressure US:*** show how the spreadsheets can be adapted to specific types of problems. Knowledge of the fluid mechanics of the problems and familiarity with the design of the spreadsheet are required to make such adjustments accurately.

II-A & II-B SI: This spreadsheet solves Class II series pipe line problems using either Method II-A or Method II-B as described in Chapter 11 of the text. SI Metric units are used. Example Problem 11.3 using the system shown in Figure 11.7 is solved in the given sheet.

You should review the details of these sheets from the discussions in the book. In summary, Method II-A is used for finding the maximum velocity of flow and volume flow rate that a given pipe can deliver while limiting the pressure drop to a specified value, without any minor losses. This is accomplished by the upper part of the spreadsheet only. Enter the pressures at two system reference points in the ***System Data:*** near the top of the sheet. Enter other data called for in the gray shaded cells. Refer to Example Problem 11.2 in the text for an illustration of the use of just the upper part of this sheet to solve Class II problems without minor losses.

The lower part of the spreadsheet implements Method II-B for which minor losses are considered in addition to the friction losses in the pipe. The solution procedure is iterative, requiring you to assume a volume flow rate in the upper part of the lower section of the spreadsheet that is somewhat lower than the result of the Method II-A solution directly above. Enter the minor loss coefficients in the lower part of the spreadsheet. As each estimate for flow rate is entered, the pressure at a target point, called p_2, is computed. You must compare this pressure with the desired pressure. Successive changes in the estimate can be made very rapidly until the desired pressure is acceptable within a small tolerance that you decide.

II-A & II-B US: This spreadsheet is identical to ***II-A & II-B:*** except for using the U.S. Customary unit system. Problem 11.10 is solved in the example. The system in this problem has no minor losses so the upper part of the spreadsheet shows the most pertinent data and results. The lower part has been adjusted to use the same volume flow rate as the result from the upper part and all minor losses have been set to zero. The result is that the pressure at the target point, p_2, is very near the desired pressure. The small difference is due to rounding and a possible difference between the result from Equation 11.3 used to solve for Q in Method II-A and the calculation of friction factor and other terms in Method II-B.

III-A & III-B SI: Class III series pipe line problems require the determination of the minimum required size of pipe to carry a given volume flow rate of fluid with a limiting pressure drop. Both Method III-A and Method III-B as described in the text are shown on this spreadsheet. If only pipe friction loss is considered, then only the upper part using Method III-A is pertinent.

Problem 11.18 is solved by the given spreadsheet data. Only pipe friction losses are included and the solution computes that the minimum acceptable pipe flow diameter is 0.0908 m (90.8 mm). But the problem statement calls for the specification of the smallest standard Type K copper tube. So the lower part of the spreadsheet shows the application of a 4-in Type K copper tube having a flow diameter of 0.09797 m (97.97 mm). The spreadsheet then computes the predicted pressure at the end of the system for the given volume flow rate, 0.06 m'/s. Note that the result predicts that the pressure at the end of the tube would be 48.13 kPa. In reality, the pressure there is zero as the problem states that the flow exits into the atmosphere from the end of the tube. Actually, then, the 4-in tube will permit a higher flow rate for the same pressure drop. You could use the spreadsheet *II-A* 4 *II-B Sl:* to compute the actual expected volume flow rate when using the 4-in Type K copper tube.

Class III systems with minor losses are demonstrated in the next spreadsheet.

III-A & III-B US: This spreadsheet is identical to ***III-A & III-B SI:*** described above except for the use of U.S. Customary units instead of SI Metric units. The solution to Example Problem 11.6 from the text is shown and this spreadsheet is included in the text with extensive description of how it is used. Please refer to the text.

The problem includes some minor losses so that both the upper part (Method III-A) and the lower part (Method III-B) are used. The result from Method III-A predicts that the minimum acceptable pipe flow diameter is 0.3090 ft if no minor losses are considered. Using a standard 4-in schedule 40 steel pipe (D = 0.3355 ft) with the minor losses included in Method III-B shows that the pressure at the target point, p_2, is greater than the minimum acceptable pressure. Therefore, that pipe size is satisfactory.

System Curve US: This spreadsheet is the same as that shown in Figure 13.41 in Chapter 13 of the text. It is used to determine the operating point of a pump selected for the system shown in Figure 13.40 and described in Example Problem 13.4. Refer to the extensive discussion of system curves and this spreadsheet in Sections 13.10 and 13.14.

The spreadsheet includes two pages. The first page is an analysis of the total head on the pump when the desired volume flow rate, 0.5011 ft^3/s (225 gal/min), flows in the system. This sheet is basically the same as that in the spreadsheet called ***I Power US:***, discussed earlier. But the final calculation of the power delivered by the pump to the fluid has been deleted.

After seeing the required total head on the pump for the desired flow rate, the user has selected a centrifugal pump, model 2x3-10 with a 9-in impeller, using the pump performance curves from Figure 13.27. This pump will actually deliver somewhat more flow at this head. The spreadsheet was used to compute data for the system curve that is a plot of the total head versus the volume flow rate (capacity) delivered. Several data points for the resulting total head for different flow rates from zero to 275 gal/min were computed. These were entered on page 2 of the spreadsheet and the system curve was plotted on the graph shown there. Simultaneously, data from the actual performance curve for the selected pump were entered and plotted on the same graph. Where the two curves intersect is the operating point, predicting that the pump will deliver approximately 240 gal/min. Then you must go back to Figure 13.27 to determine the other performance parameters at this operating point, efficiency, power required, and $NPSH_R$ (net positive suction head required).

Note that no spreadsheet system using SI Metric units for operating point is included in this set. It would be good practice for you to copy this given spreadsheet and convert it to SI Metric units. You should examine the contents of each cell to determine if the equations must be modified with different conversion factors to achieve an accurate result.

Friction Factor: This is a simple spreadsheet whose sole purpose is to compute the friction factor using Equation 8-7 from Section 8.8 of the text. We refer to this equation as the *Swamee-Jain Equation* for its developers. See Reference 3 in Chapter 8.

The spreadsheet shows the computation of the friction factor for the data from Problem 8.28. Data entry is similar to that used in the other spreadsheets described above. Either SI Metric or U.S. Customary units can be used because only dimensionless quantities are used in the equation. But units must be consistent within a given problem. You might want to use this spreadsheet to test your ability to read accurately the Moody Diagram, Figure 8.6.

HYDROFLO 2, HCALC, and _PumpBase_ Software
by _TAHOE DESIGN SOFTWARE_
Included on the CD with this book

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This book includes a CD that contains student versions of three powerful software programs for the solution of a variety of pipeline design and analysis problems. Created by Tahoe Design Software of Nevada City, CA, ***HYDROFLO 2, HCALC***, and *PumpBase* can be used for problem solutions in Chapters 8 and 10 -13 of the book. More information about Tahoe Design Software and the professional versions of these programs can be found on their website www.tahoesoft.com.

HYDROFLO 2 is a unique fluid conveyance system design tool for full pipe incompressible flow conditions. It makes it easy to model and analyze fluid transport systems found in industrial process, water supply, petroleum transport, mining de-watering and HVAC systems. During the design process, you view a vertical elevation-scaled representation of your fluid conveyance system in HYDROFLO's workspace. Elements (such as pipes, valves, etc.) can be added to your design with drag-and-drop and cut-and-paste ease. HYDROFLO's clipboard enables near instant creation of duplicate parallel lines. Element data and analysis results can be viewed simply by placing the cursor over an element. HYDROFLO's Group Editor eliminates repef.itive and tedious editing tasks.

The academic version of HYDROFLO can model liquid conveyance systems with single sources and single discharges and up to 20 pipes, 20 fittings and valves, 3 pumps, and up to nine parallels. Gauges can be placed anywhere in a line to determine the pressure head at a point of interest, to start or end parallels, or to depict elevation changes or vertical bends in a line. Many conveyance systems include pumps in series or parallel and HYDROFLO can easily analyze these systems. See Section 13.15 in the book.

Many types of fluid flow problems can be solved, such as

- Validation/calibration of existing pipeline systems.
- Modeling a proposed system’s operation.
- Determination of line head losses at a specific flow rate. (termed a forced-flow system).
- Analysis of cavitation and net positive suction head (NPSH) problems.
- Comparison of equivalent SI unit to English unit designs.
- Modeling of recirculating and gravity (non-pumped) flow systems.

Pipe head losses can be calculated using the Hazen-Williams equation for water flow (Section 8.9 in the book) or the Darcy-Weisbach equation for other types of incompressible fluids. We use the term *Darcy’s equation* in the book. See Section 8.5.

HYDROFLO's extensive liquid property database can be accessed to obtain hundreds of liquid properties. Accurate analyses of liquid transport systems require use of precise liquid property data. Your custom liquid property descriptions can be saved in HYDROFLO's