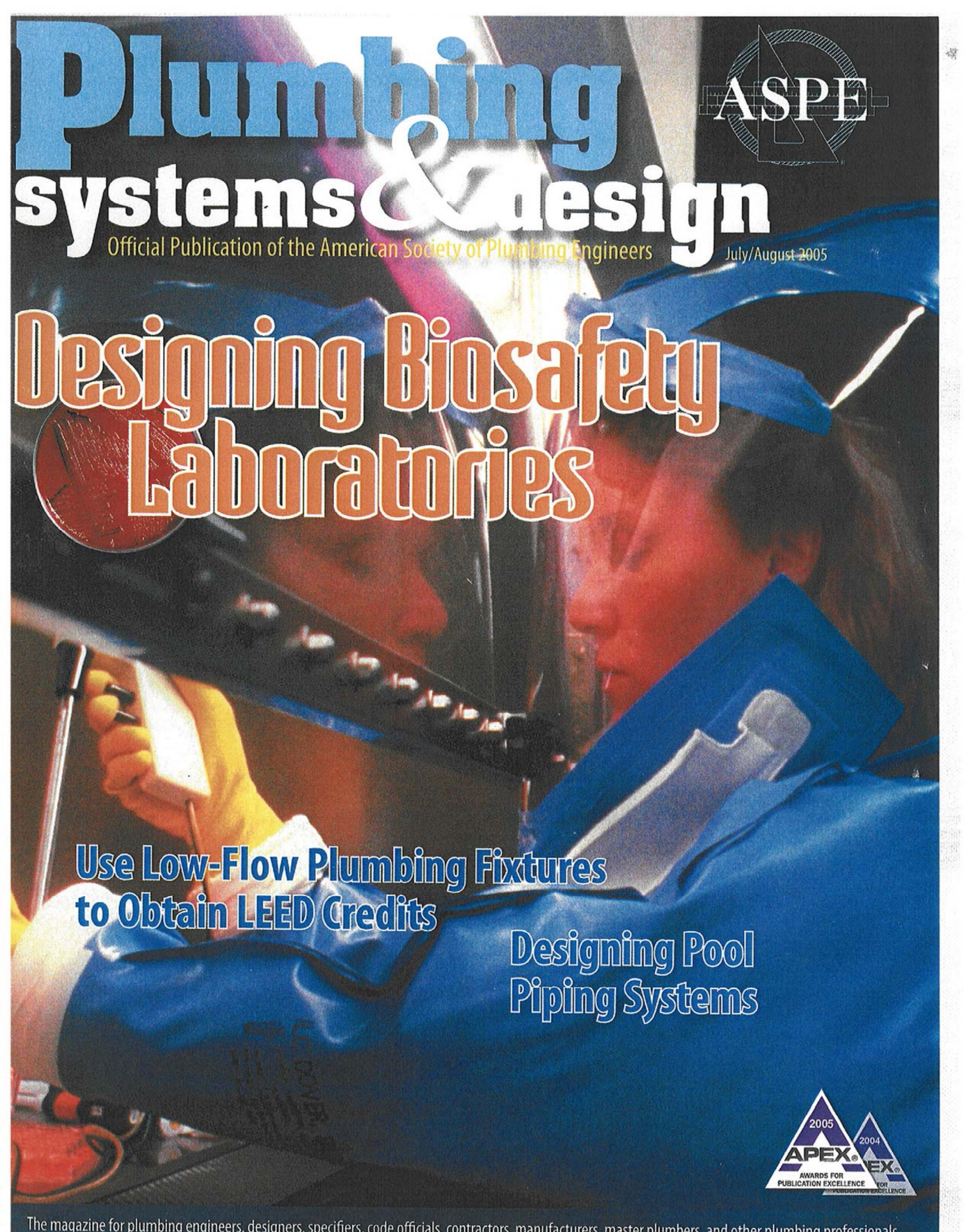
Plumbing Systems & Design

Official Publication of the American Society of Plumbing Engineers

ASPE

July/August 2005



Designing Biosafety Laboratories

Use Low-Flow Plumbing Fixtures to Obtain LEED Credits

Designing Pool Piping Systems

The magazine for plumbing engineers, designers, specifiers, code officials, contractors, manufacturers, master plumbers, and other plumbing professionals

Computer-Aided Hot-Water Circulation System Sizing

Anjian Lu, CPD

***Author's Note:** The following column describes an Excel program I wrote to make hot-water circulation system sizing easier. For a free copy of the template contact me at luaj@yahoo.com. Upcoming "Computer Corner" columns will discuss the techniques used in developing this template and other programs relating to plumbing system design.*

In his article "Hot-Water Recirculation Systems" in *Plumbing System & Design*'s May/June 2004 issue, Joseph Messina summarized the importance of hot-water circulation system sizing with practical, simplified methods. Sometimes, though, designers oversize hot-water recirculation systems in an effort to save energy. Thus, I want to introduce a computer-aided sizing procedure that can make sizing more accurate.

How It Works

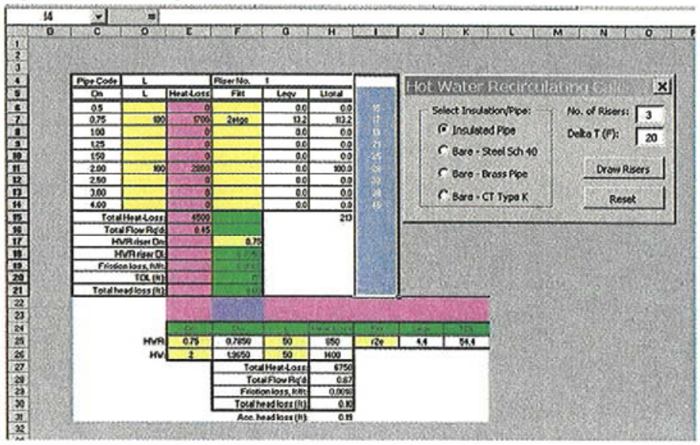
Microsoft Excel is one of the most popular spreadsheets for engineering calculations. Its User-Defined Functions (UDFs) and Visual Basic for Applications (VBA) offer numerous capabilities that simply calculate engineering problems.

Excel has many functions ready for use under the Paste Function icon on the standard toolbar. However, they are not advanced enough for engineering use, such as when you want to calculate friction loss using the Hazen-Williams Formula. A UDF is a function that you can define to perform a job like this. VBA is Microsoft's common programming (macro) language. By using UDFs and VBA you can design a single spreadsheet to calculate hot-water recirculation system sizing.

The Procedures

To perform the calculation, you need to prepare an Excel template with UDFs and VBA procedures and save it in the template directory. In this case the template is called HWRcalc.xlt. Each time you use the program, Excel makes a copy from the template, so you can use it repeatedly without overwriting the original file.

Figure 1. Riser Template and UserForm



When you open the file, a UserForm (a VBA component) appears with a hot-water recirculation system sizing calculation template (see **Figure 1**).

The UserForm. On the right side of the screen is the UserForm, where you can select the pipe type: insulated or bare. If it is bare, select one of the three choices: Bare – Steel Sch 40, Bare – Brass Pipe, or Bare – CT Type K. You also can specify the number of risers (the default is one) and delta T (the default is 20). The reset button in the UserForm restarts new calculations. The draw riser button calculates a simulated riser diagram (explained later).

The Template. On the left side of the screen is the template simulating a typical hot-water recirculation system riser diagram. The pink cells indicate the hot water supply, and the green cells indicate the return. All yellow cells are for user input.

Cell D4 shows the pipe code, a letter indicating the pipe's material and schedule. If you select insulated pipe in the UserForm, the pipe code is L, which means copper tube type L. The code for Bare – Steel Sch 40 is S; the code for Bare – Brass Pipe is B; and the code for Bare – CT Type K is K.

Range C5:C14 lists different pipe sizes. In range D5:D14 you input the riser length of different diameters. Range E5:E14 shows the heat loss, calculated by multiplying the physical riser length in column D by the heat loss per unit pipe length. To calculate the head loss, the program uses the total length (physical or developed length) plus the equivalent length of valves and fittings. When you input the fittings in range F5:F14, their equivalent lengths appear in range G5:G14. In this example there are two elbows, one tee, one gate or ball valve, and one check valve in the hot water return riser. Therefore, you enter 2etgc in cell F7. Range H5:H14 shows total pipe lengths. You can see range I6:I14 if it is highlighted. These figures are specific heat losses for different pipe sizes in Btu/hr per lineal foot when water temperature is 140°F and room temperature is 70°F (see **Table 1**). Range F4:G4 automatically numbers the risers.

Range C15:F21 outputs the results, except for range C17:F17 where you enter the return pipe size in cell F17 (0.75, or three-fourths inches, in this case). Cell E15 summarizes the heat losses. Dividing cell E15 by a factor to obtain the flow in gallons per minute derives the total flow required in gpm, which is shown in cell E16. The factor is 10,000 for a temperature differential of 20°F, 5,000 for 10°F temperature differential, 2,500 for 5°F, and so on. Excel automatically enters the factor based on the delta T you

Table 1. Piping Heat Loss

(Btu/hr. Per Lineal Ft. For 140°F. Water Temp and 70°F. Room Temp.)				
		Bare Pipe		
Nominal Pipe Size	Insulated Pipe (½" Fiberglass)	Sched. 40 Steel	Brass, Copper, T.P.	Type K Copper
½"	15	35	26	19
¾"	17	43	32	26
1"	19	53	38	32
1¼"	21	65	46	39
1½"	25	73	53	46
2"	28	91	65	58
2½"	32	108	75	68
3"	38	129	90	81
4"	46	163	113	103
5"	55	199	138	127
6"	63	233	161	149
8"	80	299	201	188

Source: *Engineered Plumbing Design*, Alfred Steele, PE, CIPE

From the Publisher

Plumbing Systems & Design is the winner and recipient of two 2005 APEX awards. The magazine took top honors in two categories: Technical Writing and Magazines & Journals–Printed Four Color. For the first award, the honor goes to Winston Huff, CPD, LEED AP, for his article "Sustainable-Plumbing-System Technologies for Space and Earth." For the second award, the honor is given to the entire *PSD* staff.

PSD has been publishing for only a short time, since September/October 2002. The magazine is the only one in the plumbing engineering and design industry that can claim the honor of having won an APEX award for every year it has been published! This is a great achievement for the wonderful and hard-working staff, authors, and editors (oh yes, and the publisher too).

This magazine also can lay claim to being well on its way to accomplishing the very purpose for its creation: providing best practices and current and timely technical material directed to plumbing engineers, designers, and contractors. This issue's cover feature, "Designing Biosafety Laboratories," is a good example. For the past century or more, the world has been blessed, or maybe just been lucky, that a major catastrophe in the form of an unstoppable bug getting loose in the world has not occurred, despite all of the research conducted by biological and pharmaceutical companies. With ongoing contracts from the federal government for defensive and offensive weaponry, and public and private research delving into the DNA structure of every living entity on our planet, it's a wonder that it remains safe to breathe the air and drink the water. The thanks go to our plumbing engineers and designers who are responsible for creating safe environments for inhospitable bugs and chemicals.

For all our readers, there's also "A Primer on Liability for Plumbing Professionals" by Steven Nudelman. No one wants to be sued, and Steve, in this second part of his three-part series, helps us understand what a professional must watch out for to avoid negligence, malpractice, fraud, misrepresentation, deceptive practices, and tortuous interference. Steve doesn't provide direct answers. (As he says, "Attorneys give legal advice; magazine articles do not."). What he does provide is an overview of claims issues that plumbing engineering and design professional face on a daily basis. Ignore at your peril.

Anjian Lu, CPD, in his "Computer Corner" column, continues exploring special Excel features that are handy in the engineering profession. In this issue, Lu shows how to create custom menus to go along with custom applications or macros as add-ins to the Excel interface. He actually makes it pretty simple to tackle some fairly complex and advanced issues in using and making the most of the software.

If you still have a mind for the math, check out David Hague's "Focus on Fire Protection" column. In Part 3 of his series on hydraulic design requirements for storage applications, David goes into area and density requirements based on commodities classifications and storage configurations. As he makes clear, "Hydraulic requirements for storage occupancies are not based on the occupancy classification; they are based on the type of commodity protected and the configuration of the storage arrangement." A little light reading for a midsummer night? Not!

For those who just have to work with formulas, check out the Continuing Education section on the fundamentals of domestic water heating. Read the article and take the small exam to earn a continuing education credit. It couldn't be easier, right? These continuing education articles are designed to take about an hour to read and complete the exam and are a unique benefit of *PSD*.

When you're ready for a little lighter reading, check out "Lessons Learned" by Joe Scott. His discovery this issue is that "the time of the year that you preheat the cold water to the heater is the same time of the year that the cold water temperature generally rises anyway: the summer." His lesson? It's "having knowledge of some of a system's peculiar aspects can save [building owners'] money."

If you're ready for a little international journey, check out the "International Digest." From Brazil comes "Application of a Vacuum Toilet System in a Rio de Janeiro Airport." Authors O. Oliveira Jr. and J. Silva Neto summarize the benefits of vacuum toilet systems as significant water usage savers when compared to the more typical gravitational toilets. As they conclude, "It is difficult to imagine any other action that could lead to better results."

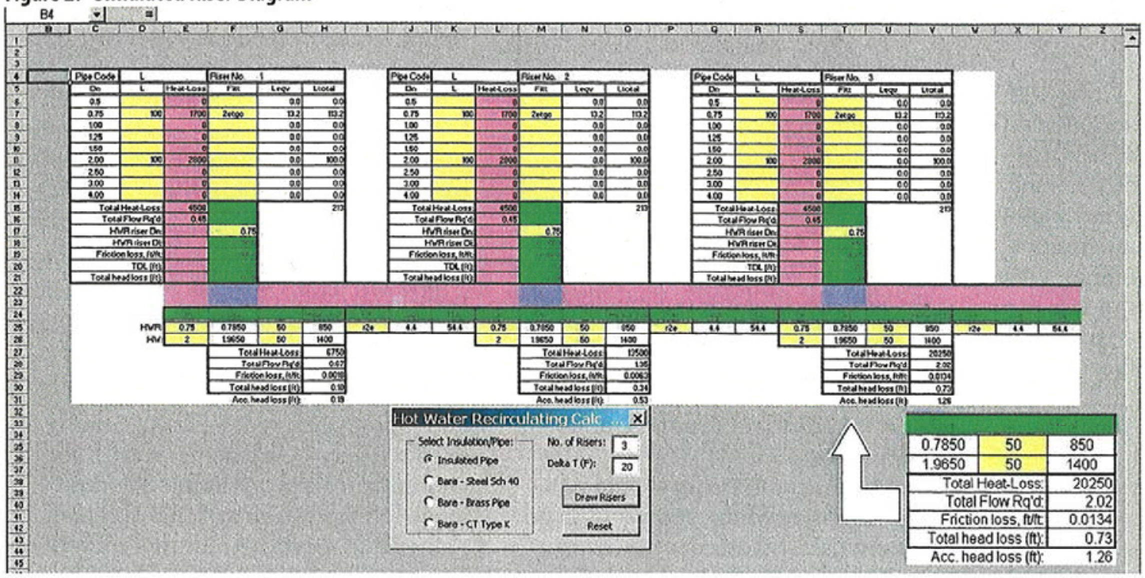
While on the issue of saving, Winston Huff in his "Using Low-Flow Plumbing Fixtures to Obtain LEED Credits" article for "Plumbing Technology of the Future" examines the latest generation of low-flow fixtures. As he notes, the current crop of fixtures in no longer in response to a federal mandate but more a response to owners' and designers' interest in voluntary energy-saving programs such as LEED. Winston takes a look at dual-flush water closets, low-flow water closets, low-flow showerheads, and even some water-free products. His mission is clear: "The industry is growing and changing every day, and plumbing engineers need to keep ahead of the curve."

Every issue of *PSD* is jam-packed with technical articles of educational and professional interest. There's the "World of Design/Build," "Peer to Peer," "Plumbing Design by the Numbers," and "Designer's Notebook." "Hydronics for Plumbing Engineers" and "Code Update" help round out the technical material in this issue. Subjects covered include "Designing Zone Pumping Systems" to "A Foot Is not Always a Foot: Disparities in Code Terminology," to "Pool Piping Primer" and "What Plumbing Engineers Should Know About Radon Gas."

It is a joy and a pleasure for all of us to continue to bring you this award-winning magazine. ◆

Stanley Wolfson

Figure 2. Simulated Riser Diagram



previously entered. (Note: 1 gal = 8.34 lb; 1 hr = 60 min; 1 Btu = 1 lb water at 1°F temperature change. Heat loss for 1 gpm flow at 1°F temperature drop = 8.34 × 60 = 500 (Btu/hr/°F/gpm). Therefore, required flow (gpm) = heat loss/500/delta T.)

Based on the pipe code in cell D4, the flow rate in cell E16, and the nominal riser size in cell F17, the actual inner diameter then appears in cell F18, and friction loss in feet/feet is calculated and displayed in cell F19. Cell H14 is the total riser length (the developed length plus equivalent length) of both supply and return piping. Because the return pipe length is roughly half of the total developed length, cell F20 shows the total length of the return piping ([100 + 100]/2 + 213 – [100 + 100] = 113). Cell F21 shows the total head loss within the riser section (in feet).

Range D24:K31 is for horizontal piping data and related calculation results. You input return and supply pipe sizes in cells E25 and E26 respectively, and cells F25 and F26 show actual inner sizes. You input developed lengths in cells G25 and G26 and fittings in cell I25. Cells H25 and H26 show heat losses, and cells J25 and K25 show the equivalent length and total length respectively.

The number in cell H27 is the total loss of both the risers and horizontal piping. Cell H28 shows the total flow required; cell 29 shows the friction loss in the horizontal piping; and cell H30 shows the total head loss of the horizontal piping. Cell H31 shows the total or accumulated head loss of the first section, including the risers and horizontal piping.

Drawing Riser Diagram. After inputting data in the template and selecting the pipe type, number of risers, and temperature differential in the UserForm (Insulated Pipe, three risers, and 20°F in this example), press the draw riser button. A simulated riser diagram appears on the screen (see **Figure 2**). The riser diagram shows the following:

- the total flow required for the whole system is 2.02 gpm (cell V28) and
- the total head loss for the whole system is 1.26 feet (cell V31).

The drawn risers are identical. You can input data according to actual size, length, and fittings, and the results will change accordingly. You don't need to recalculate the system. If you change the number of risers or temperature differential in the UserForm and press the draw riser button, the screen automatically resets.

Analysis

If you enlarge the horizontal sections from 50 feet to 100 feet and assume there are four elbows, one tee, one gate valve, and one check valve (4etgc) between the circulation pump and the last riser, the total heat loss is 28,400 Btu/hr, and the circulation flow required is 2.84 gpm. With the assigned pipe size and fittings the head loss will be 4.5 feet. (See **Figure 3**.)

If the temperature differential is set for 5°F, the flow will be 11.03 gpm and the head loss will be 15.7 feet by enlarging the horizontal recirculation piping from three-fourths inch to one inch.

In another example, consider a building that has 50 stories with four three-inch risers that are each 600 feet high, and the horizontal pipe between two adjoining risers is four inches in diameter and 150 feet long. The total heat loss then is 177,900 Btu/hr, and the circulation pump can deliver 17.8 gpm

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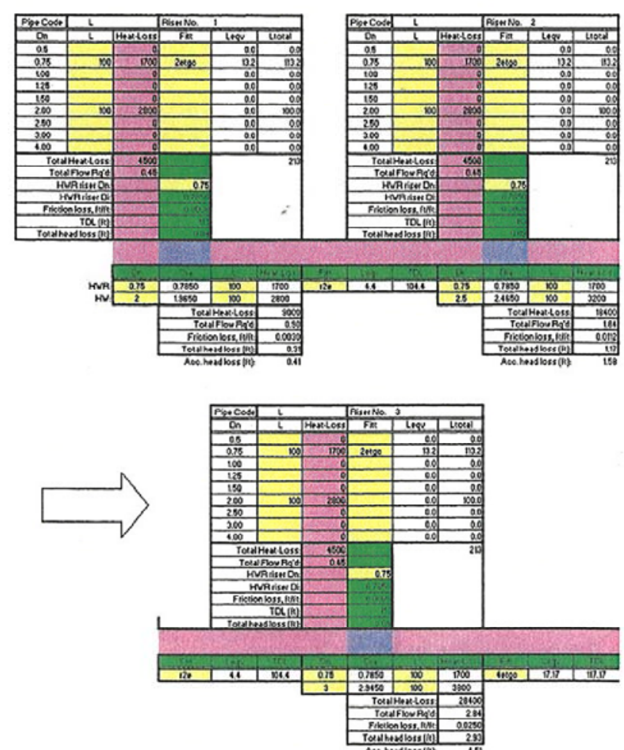
Figure 3. A Simplified Three-Riser Hot-Water Distribution System With Recirculation



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at 20.1-foot head. The circulation piping sizes are from one inch to 1½ inch. (This riser diagram is not shown.) In this example, if the piping is copper tube type K without insulation, the total heat loss will be increased to 347,319 Btu/hr, and the pump shall have a flow of 34.7 gpm at 60.5-foot head if the circulation pipe sizes stay the same. But you easily can lower the head to 27.3 feet by increasing the circulation pipe diameter by one size.

The above-mentioned examples are simplified for analysis purpose. Hot-water recirculation is a closed loop system. Therefore, you don't need to consider elevation nor static losses.

Hot-water recirculation mostly is needed when few people are using the system and typically is least needed during peak hours, except in areas remote from the hot water source. Therefore, the head loss in the supply piping portion can be neglected. Some engineers prefer to double the friction loss in the circulation piping when sizing a circulator, which provides enough of a safety factor for the calculation.

Other than in very big buildings, recirculation pumps do not present a significant power consumption problem. A 1/6 recirculation pump can provide 15 gpm at 15 feet, which equals a 150-watt light bulb. Therefore, an aquastat may not be a critical component for the system.

You never should overlook the fact that a hot-water recirculation system is based on proper flow balancing. A hot-water recirculation system should not be oversized unnecessarily in order to save energy, whereas flow balancing and other unconsidered factors should be taken into account.

Field study is recommended to establish the relationship between adequate recirculation and energy savings. ■

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