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Transitioning to Management

One of the proudest moments of my early career was when I received a promotion from senior engineer to first-line manager. It took about a week for the elation to wear off, as I began to realize how much responsibility I had for producing results through others. This was a role that my engineering training did not prepare me for.

Other engineers who transitioned to management have had similar experiences. “Many engineers become uncomfortable when they feel they’re losing some of their technical edge as they devote more time to managing people, budgets, and administrative duties. I know I did,” comments Michael Shaffron, P.E., president of Motive Engineering (Morrison, CO). Carol S. Dougherty, president of Delta Consulting Group (Crystal Lake, IL), adds, “When you’re used to being able to calculate the solution to a technical problem, people problems can be challenging.”

Management requires a different mindset. We engineers, by nature and training, are detail-oriented and know how to go from root cause to solution. Being a manager, however, is less about being the one who develops the solution and more about engaging and motivating others to find the solution. “You must allow others to contribute and feel empowered,” says Mike Martorella, founder and CEO of MMI Communication (Pittsburgh, PA), a senior executive coaching and management advisory firm. “You must ask for advice, solicit input, challenge, and allow others to challenge.”

Communication skills are crucial. A manager must be able to engage with a wide range of people, many of whom do not have the same technical training. Martorella points out, “You have to know your audience. For example, are you talking to an executive who doesn’t know your specialty? Are you briefing the financial or public relations person? In any of these cases, you need to summarize, simplify, and leave out much of the detail.”

You will also need the ability to see beyond your project to enterprise-level challenges. “A good manager sees the big picture,” says Alicia Butler Pierre, founder of Equilibria (Atlanta, GA). “He or she understands and regularly monitors key performance indicators, making sure that critical day-to-day activities and compliance issues don’t fall through the cracks.” Advanced degrees can help you develop enterprise-level insight. Butler Pierre says, “I pursued an MBA because I recognized that I knew very little about the ‘business’ behind the production facilities where I worked. Taking business courses gave me an edge.”

What the boss wants. An important part of the manager’s job is “managing up” and meeting the boss’s expecta-

tions. I realized early in my management career that my boss expected me to come to him with recommendations and solutions, not problems. “The boss wants results,” says Martorella. “The boss wants you to provide the right information so he or she can communicate effectively to higher management.”

But what is “right” to an engineer is often not what the boss wants. “The boss doesn’t want detailed information. He or she wants you to summarize the key points in order to quickly understand project status,” says Martorella. “Start with a two-minute summary. If the boss wants more detail, he or she will ask for it.”

A balancing act. Many companies expect their managers to continue to do some technical work while managing their team. Finding the right balance between delegating work and doing it oneself is important. “The effective manager must learn to delegate and oversee the work, and resist the temptation to do it all themselves,” says Shaffron.

In my experience, finding this balance was a challenge, especially when a former peer was not pulling his or her weight. Martorella, who works with many engineers transitioning from technical roles, counsels, “You have to distance yourself from former peers. Be prepared to look them in the eye and give them feedback — sometimes negative feedback.”

Transitioning successfully. How can an engineer transition to management without crashing and burning? “Find a mentor who can help you understand what it takes to become a good manager,” advises Martorella. “You may think you know what is involved, but a mentor can tell you how it really is when you’re the one in the hot seat.”

Before you start your new management position, write down what you learned from your mentor and what you observed when you interviewed for the job. Then list what you want to accomplish in your first three to six months. This will help you set reasonable expectations for yourself in the new role.

Early on, meet with your direct reports and find out what is important to them, says Martorella. This will help you to build trust and gauge individuals’ strengths and weaknesses. You must also begin to clearly articulate your team’s mission and find ways to motivate your people around the mission. “When you start as a manager, you have a group of people. Your job is to make them a highly functioning team,” says Martorella.

Read more of Loraine’s interview with senior executive coach Mike Martorella on AIChE’s ChEnected blog: <http://chenected.aiche.org/professional-career-development>.

CEP

Use Spreadsheets for ChE Problem-Solving

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This article will help you improve your Excel spreadsheet skills and will provide you with tools to solve common chemical engineering problems.

Ever since Lotus 1-2-3 and the IBM PC became popular in the early 1980s, chemical engineers have been using spreadsheets for day-to-day problem-solving. This occurred without a major marketing campaign by Lotus Development, which was focused on business applications, and without spreadsheets being included in the formal education of ChEs. This phenomenon speaks loudly to the viability of the spreadsheet, but it also means that chemical engineers often pick up the use of spreadsheets on the fly in a haphazard fashion. Many practitioners miss out on key features and skills in applying the modern versions of the predominant spreadsheet product, Microsoft Excel. This article reviews several useful features of Excel 2013 and techniques for using it.

To be sure, many other software tools — both numerical- and simulation-driven — are available to chemical engineers, especially those employed in larger organizations. Each of these requires a separate learning curve and may be more suitable for calculations associated with larger-scale projects. In many cases, the spreadsheet can be the introduction to these tools. For example, a simpler flowsheet material balance carried out in Excel can produce starting values for a simulator that will enable successful convergence of the flowsheet calculation. Those other software packages, which could cost many thousands of dollars per year in license fees, may be out of reach of chemical engineers in many smaller organizations, who must rely on the ubiquitous spreadsheet for their problem-solving work.

This article is based on the AIChE online course, “Spreadsheet Problem-Solving for Chemical Engineers.” To register for this course, or to watch a webinar presented by David Clough, visit www.aiche.org/academy.

Spreadsheets: Scaling the learning curve

Two features of spreadsheets make them appealing to chemical engineers: their appearance and their function. The row-column layout promotes an organized approach to problem-solving and naturally accommodates tables of data. It is especially convenient for flowsheet material- and energy-balance calculations. Additionally, the answers (the numbers) are displayed in the front while the formulas are in the background. Although many of my faculty colleagues prefer to see the equations and are less concerned with the results, spreadsheets appeal to the practical, upfront nature of the engineer.

The second appealing feature is the “live” calculation nature of the spreadsheet. Change the value in one cell, and any calculations that depend on that cell update automatically. This environment allows ChEs to experiment with their calculations and develop an inherent feel for the sensitivity of results to changes in various parameters. This live calculation environment also provides an ideal setting for group interaction where engineers and managers review and brainstorm design and economic calculations to reach decisions.

As chemical engineers increase their skills, their spreadsheets, which normally begin in the upper left-hand corner, tend to expand in both size and content. Consequently, it becomes a challenge to keep the entire content of a large spreadsheet in mind, and, naturally, these larger spreadsheets lack organization and modular design. In the extreme, a large spreadsheet can become barely comprehensible to the author and impenetrable to others. This can create a crisis when the author is no longer available. Unfortunately, in

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these situations, the spreadsheet must often be jettisoned, and a new author must start over.

Spreadsheets satisfy the need for efficiency and reliability in problem-solving. As chemical engineers learn to use spreadsheets, certain operations become repetitive. Repeating the same action takes time, but learning how to make these operations more efficient will help you save time. Methods to make your spreadsheet more efficient can range from elementary selection techniques to the programming of timesaving macros in VBA (*i.e.*, Visual Basic for Applications, Excel's companion programming language).

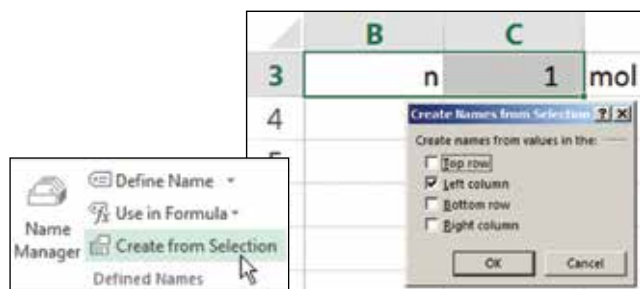
If you allow your spreadsheet to grow incrementally without consideration for organization and modularity, the spreadsheet may become bogged down with embedded errors that are difficult to root out. Or, if you use formulas that are composed primarily of cell address references, your spreadsheet can become very difficult to understand and reverse-engineer. Lack of text documentation in adjacent cells and graphical elements, such as cell formatting, schematic diagrams, well-formatted charts, and embedded typeset equations, exacerbate the difficulty.

Certain features of Excel allow you to solve problems that seem nearly impossible. Learning about these features and incorporating them into your problem-solving activities will increase your capabilities significantly.

The six areas of focus described in this article, taken from a much longer list, can produce immediate results in your spreadsheet work.

	B	C	D
2	Rgas	8314	Pa*L/(mol*K)
3	n	1	mol
4	T	273.15	K
5	V	22.4	L
6	P	101383	Pa

▲ **Figure 1.** For easy readability, this ideal gas law calculation has labels in the left column, values in the center column, and units in the right column.



▲ **Figure 2.** Create names for cells using the Create from Selection command.

1. Use names in lieu of cell addresses

Consider the ideal gas law calculation in the Excel spreadsheet in Figure 1. Contrast the following formulas for calculating the value in cell C6:

	C
6	=C3*C2*C4/C5
	C
6	=n*Rgas*T/V

Although this is a simple example, the advantage of the formula on the right is evident. In order to reverse-engineer formulas that use cell addresses, such as the one on the left, you would have to trace back the source of each quantity. The formula on the right uses cell names that relate to the variable names from the familiar algebraic ideal gas equation. The style of the spreadsheet layout also improves readability. In Figure 1, the labels in column B are the same as the names on the cells in column C.

There are three common ways to create names for cells. A convenient method is to select the cell, and type the name into the Name Box field above the column A label:



You can also transfer the label from an adjacent cell onto the cell of interest using Create from Selection in the Defined Names group on the Formula tab of the Ribbon (Figure 2). In fact, more than one label can be transferred with a single command.

Use the Name Manager in the same Defined Names group to create, edit, and delete names. Cell names generally have global scope in the workbook, but it is possible, using the Name Manager, to create names that have scope only in the worksheet where they are created.

Note that certain names are not allowed. First, you cannot create a name that is the same as a cell address. Given the size of the modern worksheet (the Excel spreadsheet has $2^{14} = 16,384$ columns and $2^{20} = 1,048,576$ rows — a total of 2^{34} cells), with columns out to XFD, it is easy to confuse a name with a cell address. Second, you cannot use the letters R or C as names or those letters followed by any digits. This restriction harkens back to the R-C method of cell addressing (*i.e.*, row-column), which is rarely used today. Finally, if you transfer labels as names, you will find that in some cases Excel takes editorial license and changes them; for example, the label A(0) becomes the name A_0. For this reason, it is always good practice to check the transferred names before you proceed.

Names can also be defined for rectangular ranges of cells. These names can then be used conveniently in formu-

las that reference those ranges, such as statistical functions and array formulas.

Names can also be used in VBA code. It is bad practice to use cell addresses in VBA Subs and Functions, because these references will not update in the event any changes are made on the spreadsheet that move the content of these cells.

So, the proverbial bottom line is to use names wherever possible. This raises three additional points:

It is good practice to create a nomenclature table for names, possibly on a separate worksheet. This can be started conveniently using the Paste List command on the Paste Names dialog window. You can access the Paste Names dialog window via the Defined Names group and Use in Formula drop-down list. Your nomenclature list will not be updated automatically, so it is best to generate it as part of the final documentation of a spreadsheet.

When should names not be used? The advantage of cell addresses, both relative and mixed-reference, is in copying formulas and patterns, like index columns, into other cells, for example, using the Autofill feature of Excel, initiated by double-clicking the Fill Handle in the lower right-hand corner of a selected cell. In such cases, the use of cell addresses should be preserved.

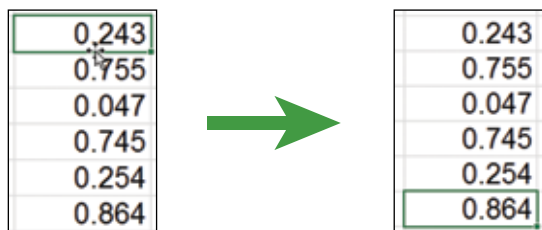
If you create formulas that involve cell addresses and later create names for those cells, the names in the formulas will not be automatically updated. You can update the formulas with cell names via the Apply Names dialog window accessed from the drop-down list under Define Name in the Defined Names group (on the Formula tab of the Ribbon).

The use of cell names is especially valuable on larger spreadsheets and even smaller ones that will be used, and hopefully understood, by others.

2. Learn and practice efficient selection, copy, and move techniques

All ChEs should know how to move around the spreadsheet, select blocks of cells, copy cells to other locations, and move cells or blocks of cells. Many of these techniques can be accomplished with the mouse, with the keyboard and the mouse in combination, or using the keyboard alone.

First to consider is moving a selected cell to another



▲ **Figure 3.** Jump to the last cell in a column by double-clicking the lower boundary of the cell selected at the top.

location on the spreadsheet. To choose an active cell, click on that cell. The active cell location can be moved quickly to an adjacent cell using the arrow keys. A quick way to jump to a cell far away is to type the cell address or name into the Name Box and press Enter. If a cell name has been defined, you can also use the drop-down list in the Name Box and click on the name there. Another way to do this is with the F5 “Go To” shortcut key.

When operating within a column of filled cells, you can jump to the last filled cell in the column by double-clicking the lower boundary of the cell selected at the top (Figure 3). You can also use the same technique to jump across a column of blank cells to a filled cell.

Of course, if a column is short, like the one in Figure 3, you could simply click on the last cell. However, the jump technique is handy for much longer columns (of several hundred cells). As a keyboard alternative, you can use the Ctrl-arrow key combination (Ctrl-↓).

To make block selections rather than jumps, add the Shift key to any of the above techniques. Select an entire block of cells with either the Ctrl-a or Ctrl-* key combination. If you need to select cells or blocks of cells that are not contiguous, you can hold down the Ctrl key and proceed through the selections (Figure 4).

Once cells are selected, you can change their format together, rather than using a tool like the Format Painter and moving from cell to cell. Another application of this technique is to select nonadjacent columns of data to create a chart.

When selecting a lengthy column of data using the Ctrl-Shift-↓ key combination, the bottom of the column is in view with the last cell as the active cell. A neat trick to bring the top of the selection back into view is to press the Tab key followed by the Shift-Tab combination. Of course, you can also drag the slider on the side of the spreadsheet window.

The standard technique for copying cells to adjacent locations is to drag the Fill Handle, located in the lower right corner of the selection. To copy one or more cells to a more distant location, you can initiate the copy with the Ctrl-C key combination, select the destination's upper left-hand corner

	K	L	M	N
1	s			
2		0.243		0.254
3		0.755		0.864
4				
5			0.047	
6			0.745	

▲ **Figure 4.** To select cells that are not contiguous, hold down the Ctrl key and proceed through selections.

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cell, and press the Enter key. Alternatively, you can drag the selection to the destination with the Ctrl key pressed; a small + sign will appear adjacent to the mouse cursor arrow when you use this method.

Moving cells is similar to copying cells. To move a cell to an adjacent location, rather than drag the Fill Handle as for copying, you can drag the cell boundary using the arrow cursor. You can also drag selected blocks of cells in that manner. A move can also be initiated with a “cut” shortcut command, Ctrl-X, and terminated with the Enter key, as with the copy technique.

3. Manage units and avoid “magic numbers” in spreadsheet formulas

Chemical engineers work with a wide variety of engineering units in their day-to-day calculations. Because of this, ChEs are practiced at making calculations consistent when it comes to the units of different variables. This raises the issue of how best to manage conversion of units to a consistent basis for formula-based calculations on spreadsheets. As shown in the ideal gas law example earlier, placing unit labels in adjacent cells is a good practice. And, you should always carry out unit conversions in separate cells on the spreadsheet. Figure 5 shows an example of this in which a pressure is specified in psi but the internal calculations of the spreadsheet require the use of pascals.

Engineers often include unit conversion factors within formulas — this is bad form because it places a number in the formula that may be difficult to understand and interpret. These are sometimes referred to as “magic numbers.” In the spirit of keeping the spreadsheet explicit and easier to analyze and comprehend, avoid putting magic numbers into formulas.

A related tip is to let the spreadsheet carry out the calculations — do not place a number in a cell or formula that is the result of an off-line calculation. For example, it may be tempting to enter one-half a known diameter in a formula that requires a radius. Avoid the temptation and show the divide-by-two calculation explicitly.

In the rush to put a spreadsheet calculation together

	G	H	I	J
2	28.6 psi		Conversion factor:	
3	197197 Pa		6895 Pa/psi	

	G	H	I	J
2	28.6 psi		Conversion factor:	
3	=G2*PsiToPa		6895 Pa/psi	

▲ **Figure 5.** Carry out unit conversions in separate cells in your spreadsheet.

quickly, we often cut corners, and this comes back to haunt us later. The spreadsheet calculation inevitably expands, and it becomes difficult to interpret formulas that use magic numbers.

4. Set up calculations in their natural sequence and employ targeting methods

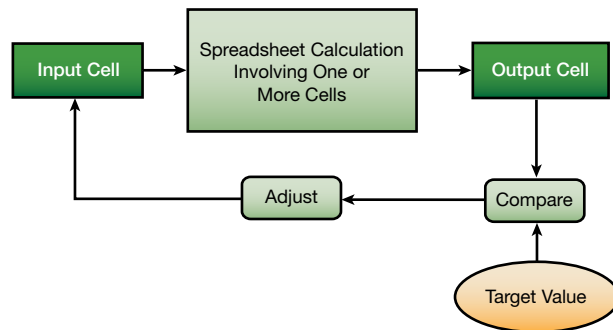
It has been said before many times to start at the beginning and finish at the end. For most chemical engineering problems, there is a natural sequence that starts with basic data and proceeds step-by-step to a final result. However, in many calculations, you may need to find one or more starting values that yield a desired final result, or a target value (Figure 6). The target may be a specific value, or it could be the minimum or maximum of a function, such as cost or profitability. The calculation may have more than one input cell, and there may be constraints on various elements of the calculation.

For one-time solutions of these targeting problems, you can often simply adjust the input value by trial-and-error and meet the target after only a few tries. Excel offers two tools that automate this procedure: Goal Seek and Solver. (The Solver is an add-in provided by Frontline Systems. For information and guidance on using the Solver, see www.solver.com.)

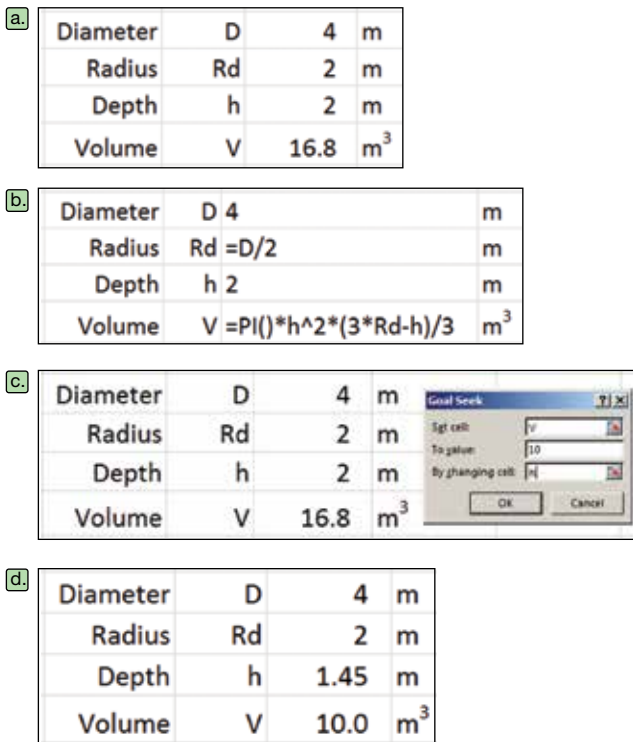
Excel’s Goal Seek is only able to solve target value problems. It is a black-box tool that does not give the user options or control over its numerical procedure. For example, we want to determine the liquid depth in a 4-m-dia. spherical tank that corresponds to a volume of 10 m³. The formula is:

$$V = \frac{\pi h^2 (3Rd - h)}{3} \quad (1)$$

where V is the volume, h is the liquid depth in the tank, and Rd is the radius of the tank. We set up a calculation on the spreadsheet based on a test value of 2 m for the depth (Figure 7a-b).



▲ **Figure 6.** Targeting methods, such as Goal Seek or Solver, can help you determine the input value that yields a desired output or target value.



▲ **Figure 7.** The total volume of a liquid in a tank is calculated for an arbitrary liquid height of 2 m (a) by the formulas shown in (b). Use Goal Seek to set the volume equal to 10 m³ by changing cell *h* (c) to find the depth corresponding to a 10-m³ volume (d).

Invoke Goal Seek from the What-If Analysis drop-down list in the Data Tools group of the Data tab of the Ribbon. Complete its fields, as shown in Figure 7c, by setting cell *V* equal to 10 m³ by changing cell *h*. Upon clicking the OK button and accepting the result, we have the solution that *h* = 1.45 m (Figure 7d).

The Solver is a more versatile tool that, in addition to solving target value problems, can also solve optimization problems and incorporate constraints. You also have more control of the numerical method used and parameters such as the convergence criterion.

In this example, we use Solver to determine the optimum size of a bin with a cylindrical upper section, a conical lower section, a defined volume, and a minimum bin angle to exceed the angle of repose of the granular material. The optimum is defined as a minimum surface area or area of material used in constructing the bin for a volume of 5 m³.

The required formulas are:

$$V_{cyl} = \pi r^2 h_{cyl} \quad (2)$$

where V_{cyl} is the volume of the cylindrical upper section, r is the radius, and h_{cyl} is the height of the cylindrical upper section,

$$V_{con} = \frac{\pi r^2 h_{con}}{3} \quad (3)$$

where V_{con} is the volume of the conical lower section and h_{con} is the height of the cone,

$$V_{bin} = V_{cyl} + V_{con} \quad (4)$$

where V_{bin} is the bin volume,

$$\theta = \tan^{-1} \left(\frac{h_{con}}{r} \right) \quad (5)$$

where θ is the conical angle,

$$A_{cyl} = 2\pi r h_{cyl} \quad (6)$$

where A_{cyl} is the cylindrical area,

$$A_{top} = \pi r^2 \quad (7)$$

where A_{top} is the area on the top of the cylinder,

$$A_{con} = \pi r \sqrt{h_{con}^2 + r^2} \quad (8)$$

where A_{con} is the conical area,

$$A_{bin} = A_{cyl} + A_{top} + A_{con} \quad (9)$$

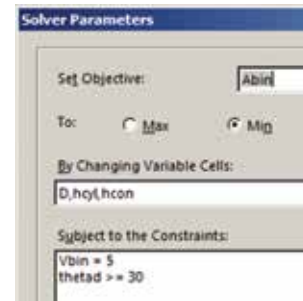
where A_{bin} is the total bin surface area.

The constraints are defined as:

$$V_{bin} = 5 \text{ m}^3 \text{ and } \theta \geq 30 \text{ deg.} = \pi/6.$$

The starting spreadsheet with a trial calculation is shown in Figure 8a (next page), and the associated formulas are shown in Figure 8b.

The bin volume does not meet the specification of 5 m³ (although the bin angle is greater than 30 deg.). Thus, this is not the optimal solution. Next, specify the Solver Parameters, setting the value of the bin surface area (A_{bin}) to a minimum by changing the diameter, and the heights of the cylindrical (h_{cyl}) and conical (h_{con}) sections. Then, input the constraints:



Clicking the Solve button produces the solution in Figure 8c. The bin volume meets the specification of 5 m³, and the angle requirement is easily satisfied. The minimum bin area, and material requirement, is 15.48 m².

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a.	Diameter	D	2 m	Cylindrical Area	Acyl	9.42 m ²	
	Radius	Rd	1 m	Top Area	Atop	3.14 m ²	
	Cylindrical Height	hcyl	1.5 m	Conical Area	Acon	4.44 m ²	
	Conical Height	hcon	1 m	Bin Area	Abin	17.01 m ²	
	Cylindrical Volume	Vcyl	4.71 m ³	Conical Angle	theta	0.79 rad	
	Conical Volume	Vcon	1.05 m ³		thetad	45 deg	
	Bin Volume	Vbin	5.76 m ³				

b.	Diameter	D	2	m	Cylindrical Area	Acyl = 2*PI()*Rd*hcyl	m ²
	Radius	Rd	1	m	Top Area	Atop = PI()*Rd^2	m ²
	Cylindrical Height	hcyl	1.5	m	Conical Area	Acon = PI()*Rd*SQRT(Rd^2+hcon^2)	m ²
	Conical Height	hcon	1	m	Bin Area	Abin = Acyl+Atop+Acon	m ²
	Cylindrical Volume	Vcyl	=PI()*Rd^2*hcyl	m ³	Conical Angle	theta = ATAN(hcon/Rd)	rad
	Conical Volume	Vcon	=PI()*Rd^2*hcon/3	m ³		thetad = theta/PI()*180	deg
	Bin Volume	Vbin	=Vcyl+Vcon	m ³			

c.	Diameter	D	2.00 m	Cylindrical Area	Acyl	8.13 m ²	
	Radius	Rd	1.00 m	Top Area	Atop	3.14 m ²	
	Cylindrical Height	hcyl	1.29 m	Conical Area	Acon	4.21 m ²	
	Conical Height	hcon	1 m	Bin Area	Abin	15.48 m ²	
	Cylindrical Volume	Vcyl	4.06 m ³	Conical Angle	theta	0.73 rad	
	Conical Volume	Vcon	0.94 m ³		thetad	41.8 deg	
	Bin Volume	Vbin	5.00 m ³				

▲ **Figure 8.** To determine the minimum surface area for a bin with a volume of 5 m³ and conical angle of at least 30 deg., the spreadsheet (a) is constructed with the formulas shown in (b). Solver is used to satisfy the constraints and find the minimum value (c).

Although these are elementary examples, they do demonstrate the importance of setting up calculations in their natural order and using one of the targeting tools to obtain a solution. This is in contrast to reformulating the problem mathematically into one or more nonlinear equations that you would solve, or attempt to solve, using an analytical or numerical method. Although an applied mathematician (or perhaps a ChE faculty member) may prefer to use an analytical or numerical method, using Solver or Goal Seek is more realistic in the world of the practicing ChE.

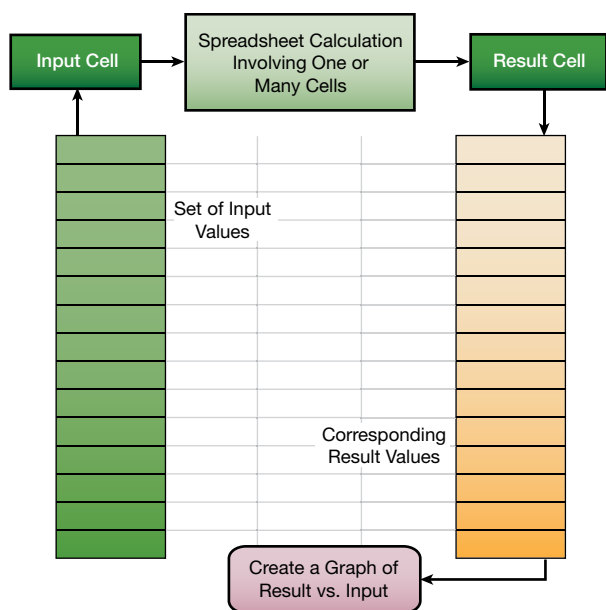
5. Take advantage of data tables for case studies

Once chemical engineers develop a spreadsheet calculation, however large or small in scale, they are typically interested in running case studies. Case studies

can produce results for variations in input values. Engineers very often do this manually, by copying-and-pasting calculation results into an adjacent table and then generating charts to depict the relationships. However, there is a better way.

Figure 9 illustrates the application of Excel's Data Table tool for a "one-way" case study. A set of input values is mapped into an input cell, and the corresponding values from a result cell are tabulated. This feature is live on the spreadsheet and is implemented with Excel's TABLE array function.

We can use the Data Table tool to study the cash flow table in Figure 10. In this example, the internal rate of return (IRR) and net present value (NPV) are calculated based on net cash flows in years 0 through 5. The under-



▲ **Figure 9.** Excel's Data Table tool can tabulate resulting values from a range of input cells.

► **Figure 10.** This cash flow table (a) uses the formulas in (b) to calculate IRR and NPV.

	A	B	C	D	E	F	G
1		Selling Price	12	\$/kg		Cost of Capital	8%
2		Operating Cost	6	\$/kg		Inflation	2%
3			Year				
4		Startup	1	2	3	4	5
5	Capital Investment	\$100	\$0	\$0	\$0	\$0	\$0
6	Production (MMkg/yr)	0	3	5	6	6	5
7	Product Sales	\$0	\$37	\$62	\$76	\$78	\$66
8	Operating Cost	\$0	\$18	\$31	\$38	\$39	\$33
9	Net Cash Flow	-\$100	\$18	\$31	\$38	\$39	\$33
10	IRR	16%				Amounts in \$MM	
11	NPV	\$23.4					

	A	B	C	D
1		Selling Price	12	\$/kg
2		Operating Cost	6	\$/kg
3			Year	
4		Startup	1	2
5	Capital Investment	100	0	0
6	Production (MMkg/yr)	0	3	5
7	Product Sales	=B6*Sell	=C6*Sell*(1+Infl)^C4	=D6*Sell*(1+Infl)^D4
8	Operating Cost	=B6*OpCost	=C6*OpCost*(1+Infl)^C4	=D6*OpCost*(1+Infl)^D4
9	Net Cash Flow	=-B5+B7-B8	=-C5+C7-C8	=-D5+D7-D8
10	IRR	=IRR(B9:G9,Cap)		
11	NPV	=NPV(Cap,B9:G9)		

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engine. Several case studies can be adjoined to a spreadsheet calculation, anticipating questions that might arise about the sensitivity of results to changes in input parameter values. Take advantage of Data Tables!

6. Use Excel's iterative solver to close recycles and other circular calculations

One of the main reasons chemical engineers became attracted to spreadsheets was for their ability to carry out flowsheet calculations. A process with a recycle stream involves a circular calculation that cannot proceed automatically because of its iterative nature. In a more general sense, many process calculations, when laid out in logical sequence, involve circular calculations.

In such a situation, a value is needed to continue the calculation, but that value is calculated later in the scheme. The strategy for solving such calculations is to specify a starting value and then “recycle” the value calculated later until the loop converges. It is possible in some cases to reformulate this problem mathematically to eliminate the circular calcu-

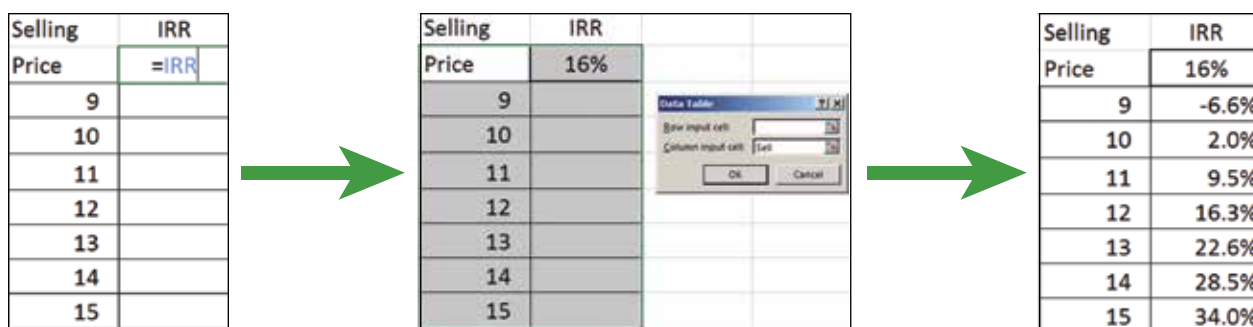
lation, but that leaves the scheme in an unnatural format that is more difficult to manage and understand.

Circular calculations that use a simple substitution method do not always converge, but in chemical engineering problem-solving they commonly do converge. For cases of nonconvergence, numerical methods are available, notably that of Wegstein, that may force convergence.

I suggest taking advantage of Excel's Iterative Solver to converge circular calculations. As a simple example, we can use the Colebrook equation relating the Moody friction factor (f_M), Reynolds number (Re), pipe inside diameter (D_i), and pipe roughness (ϵ) for turbulent flow:

$$\frac{1}{\sqrt{f_M}} = -2.0 \log_{10} \left(\frac{\epsilon/D_i}{3.7} + \frac{2.51}{Re \sqrt{f_M}} \right) \quad (10)$$

Notice that in order to compute f_M , we need a value of f_M for the right-hand side of Eq. 10. Therefore, a simple, analytical solution is not available. So, a circular calculation arises. Figure 12a is a spreadsheet that arranges this



▲ **Figure 11.** You can carry out a case study of IRR vs. selling price using the Data Table command.

a.

	A	B	C	D	E	F	G
2		fMstart	0.010		Di	50	mm
3		sqrt(fM)	0.100		eps	0.05	mm
4		Colebrook sqrt(fM)	0.196		Re	10000	
5		fM	0.038		$\frac{1}{\sqrt{f_M}} = -2.0 \log_{10} \left(\frac{\epsilon/D_i}{3.7} + \frac{2.51}{Re \sqrt{f_M}} \right)$		
6							

b.

	B	C	D	E	F	G
2	fMstart	0.01		Di	50	mm
3	sqrt(fM)	=SQRT(fMstart)		eps	0.05	mm
4	Colebrook sqrt(fM)	=1/(-2*LOG10(eps/Di/3.7+2.51/Re/sqrtfM))		Re	10000	
5	fM	=Colebrook^2				

◀ **Figure 12.** To calculate the Moody friction factor, an iterative calculation must be used (a). The underlying formulas (b) show how the starting f_M value will be different than the final f_M value.

calculation, with the underlying formulas shown in Figure 12b.

This calculation has not converged because the $\text{sqrt}(f_M)$ does not equal the Colebrook $\text{sqrt}(f_M)$. So, we expand the spreadsheet to include the option to “close the loop” by a modification of the $\text{sqrt}(f_M)$ formula:

	Reset	TRUE
	fMstart	0.010
=IF(Reset,SQRT(fMstart),Colebrook)		
	Colebrook sqrt(fM)	0.196
	fM	0.038

Now, when Reset is FALSE, the loop is closed. However, Excel complains that there is a circular path:

	Reset	FALSE
	fMstart	0.010
	sqrt(fM)	0.100
	Colebrook sqrt(fM)	0.196
	fM	0.038

CIRCULAR REFERENCES: C3

To resolve this, set up the Iterative Solver via File \Rightarrow Options \Rightarrow Formulas:

☒ Enable iterative calculation

Maximum Iterations: 10

Maximum Change: 0.00001

The Maximum Iterations was set to 10 because, based on our experience with manual recalculation, this guarantees convergence of the circular calculation to the desired precision. The result is:

	Reset	FALSE
	fMstart	0.010
	sqrt(fM)	0.180
	Colebrook sqrt(fM)	0.180
	fM	0.032

The calculation also updates automatically if another parameter is changed, such as setting $Re = 50,000$ (Figure 13). So, as circular calculations arise in your chemical engineering problem-solving, embrace them and manage them with the Iterative Solver.

Some additional tips

It would be possible to elaborate on many more topics of interest to ChEs here, but space and time are limited. So, to conclude, we will mention in rapid fashion other considerations. These are dealt with in numerous references and in short courses offered through the AIChE Academy.

Consider using array formulas instead of copying formulas with relative addresses. A single array formula can replace many formulas that were generated, for example, by copying a formula down a column adjacent to other columns of data. Array formulas also allow for matrix calculations (transpose, multiply, inverse, determinant). They are inserted using the Ctrl-Shift-Enter key combination instead of just the Enter key.

Use templates to streamline chart creation. Creating charts can be a time-consuming activity in Excel.

Embed schematic drawings and typeset equations. Schematic drawings, created with such software tools as PowerPoint and Visio, can be copied and pasted into Excel workbooks. In addition, typeset equations, such as the Colebrook equation shown in Figure 12, can be embedded as objects (e.g., Insert \Rightarrow Text \Rightarrow Object \Rightarrow Microsoft Equation 3.0). These aid greatly in the understanding of spreadsheet calculations.

Modularize workbooks into separate worksheets and design individual worksheets with diagonal blocks. Don't allow your spreadsheets to grow in an amorphous, disorganized fashion. Calculations should be divided into modules that can be arranged on separate worksheets. Larger calculations on a single worksheet should be segmented into diagonal blocks to allow the row heights and column widths of those blocks to be adjusted independently for readability, and so each block can be reached quickly via a name associated with its upper left-hand corner.

Wade cautiously into VBA by recording time-saving macros. Developing skill and expertise in VBA programming for Excel is a big step to take. However, you can get a big return for a small investment by recording macros that replace a multistep procedure on the spreadsheet with a single shortcut command. Since Excel/VBA writes the macro after recording your actions, you can readily make modifications to the VBA code generated in the Visual Basic Editor (Alt-F11 to get there and back). This is facilitated

	Reset	FALSE			
	fMstart	0.010	Di	50	mm
	sqrt(fM)	0.155	eps	0.05	mm
	Colebrook sqrt(fM)	0.155	Re	50000	
	fM	0.024	$\frac{1}{\sqrt{f_M}} = -2.0 \log_{10} \left(\frac{e/D_t}{3.7} + \frac{2.51}{Re \sqrt{f_M}} \right)$		

▲ **Figure 13.** The iterative solver will update automatically if any initial parameters, such as the Reynolds number, are changed.

Back to Basics

because VBA code is verbose and easy to read but difficult to compose.

Consider user-defined VBA functions for standard engineering calculations and special needs on the spreadsheet. Engineering formulas can be packaged into convenient user-defined VBA functions, which allow you to efficiently and reliably implement the formulas. This is a bit more difficult than recording macros, but it is still possible with some practice. You can also package a collection of user-defined VBA functions into an Excel Add-In.

The topics reviewed in this article may help you improve your spreadsheet knowledge. The article is by no means comprehensive but may fill out a few gaps in your abilities with Excel.

Happy spreadsheeting!

CEP

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Nomenclature

A_{bin}	= bin area
A_{con}	= conical area
A_{cyl}	= cylindrical area
A_{top}	= top area
D	= diameter
D_i	= pipe inside diameter
f_M	= Moody friction factor
h	= liquid depth
h_{con}	= conical height
h_{cyl}	= cylindrical height
n	= moles of gas
R, r	= radius
Rd	= tank radius
Re	= Reynolds number
R_{gas}	= gas law constant
T	= absolute temperature
V	= volume
V_{bin}	= bin volume
V_{con}	= conical volume
V_{cyl}	= cylindrical volume

Greek letters

ϵ	= pipe roughness
θ	= conical angle

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Improve Your Spreadsheet Productivity with VBA

DAVID E. CLOUGH
UNIV. OF COLORADO

Excel includes a programming language that can improve your productivity, as well as the reliability of your spreadsheets. Simple programs in Visual Basic for Applications (VBA) can have a big impact on your work for little effort.

Most Excel users, including chemical engineers, have not ventured behind the curtain to leverage the Visual Basic for Applications (VBA) programming language that accompanies the spreadsheet program. Several reasons for this include: many chemical engineers have picked up the use of Excel on the fly; the availability and utility of VBA is not obvious, and its use is not required; and many chemical engineers have a disdain for programming languages, often instilled by an unpleasant experience in a computer programming course during college.

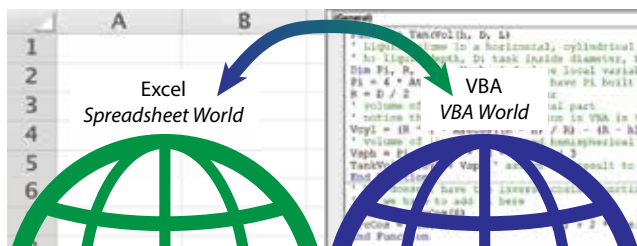
Because integrating VBA into spreadsheet problem-solving can bring many benefits in terms of efficiency, power, and reliability, the purpose of this article is to break the ice. Examples of a few elementary applications of VBA are presented. Using similar concepts in your spreadsheets can help make you more productive for little effort. This article builds on the concepts presented in the August 2016 *CEP* article “Use Spreadsheets for ChE Problem-Solving.”

Evolution of spreadsheet programming

Spreadsheet software was developed on personal computers, such as VisiCalc on the Apple IIe and Lotus 1-2-3 on the IBM PC, well before the advent of the graphical user interface and the mouse pointing device. The menus in the spreadsheet programs were operated using keystrokes. For example, in Lotus 1-2-3, the / key activated the menu, the arrow keys navigated the menu options, and the Enter key made a selection (pressing the first letter of a menu option, e.g., D for Data, was a quicker way to also make a selection). Submenus could be operated in the same way. We are now accustomed to using the mouse to make menu selections, although the keyboard (using the Alt key) can still be used to navigate the Excel interface. If memorized, the key sequence can be much faster than using the mouse.

Early in spreadsheet program development, the programs incorporated a “macro” feature that allowed the user to enter a series of keystrokes in a cell or a series of contiguous cells and identify it with a shortcut key combination, which enhanced efficiency for common menu sequences. Numerous competitors entered the spreadsheet market in the late 1980s and early '90s with macro language features that enabled the use of a limited programming structure, such as decisional branches and count-controlled loops. These macro languages evolved to a fairly complex level (e.g., Excel's Macro Language Version 4.0) but were never designed from the ground up as programming languages. They also allowed the recording of macro programs by following, and later mimicking, the sequence of keystrokes that drive the menus.

Microsoft overhauled Excel's programming capabilities



▲ **Figure 1.** The Visual Basic Editor opens as a separate window from your spreadsheet, making the two environments seem like different worlds that pass information back and forth.

Computational Methods

in 1993 with the introduction of VBA in Excel Version 5.0. VBA is an object-oriented programming language that is fully featured and is used across the Microsoft Office platform, including versions in Access, Word, and PowerPoint. With the launch of VBA, the programming capabilities became less integrated with Excel and, in essence, live in their own “world” (Figure 1).

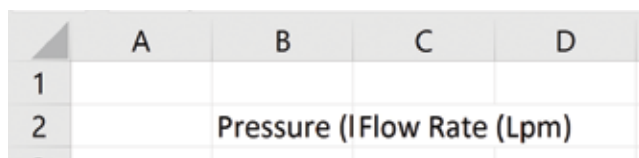
A fully featured, somewhat independent, programming language like VBA has major benefits but also has some drawbacks. When recording macros for a series of tasks, VBA observes what the user is doing on the spreadsheet and interprets it as a VBA program. Often, the interpretation is not exactly what the user intended and must be fixed. There are also difficulties associated with the exchange of information (e.g., data) between the spreadsheet and VBA environments. And, hundreds of useful built-in functions in Excel

are not directly available in VBA, which has a limited set of functions.

Despite limitations, chemical engineers can use VBA to:

- *record macros*. Macros that automate repetitive tasks offer the greatest opportunity to improve your efficiency when using spreadsheets.
- *develop custom functions*. Custom user-defined functions, especially for commonly used, formula-based engineering calculations, help streamline spreadsheet operation.
- *create VBA programs*. Stand-alone VBA programs that carry out more-complex calculations involving information contained in the spreadsheet are powerful tools.
- *make custom interfaces*. Custom user applications may include user forms and interfaces with other software, such as data acquisition tools and process simulators.

This article focuses on macros and custom functions. Chemical engineers who use Excel for day-to-day problem-solving can benefit greatly by leveraging these two simple tools. The latter two functions are introduced in this article but require more in-depth coverage. (Two courses in the AIChE Academy, available in both online and in-person formats, address creating VBA programs and custom interfaces.)

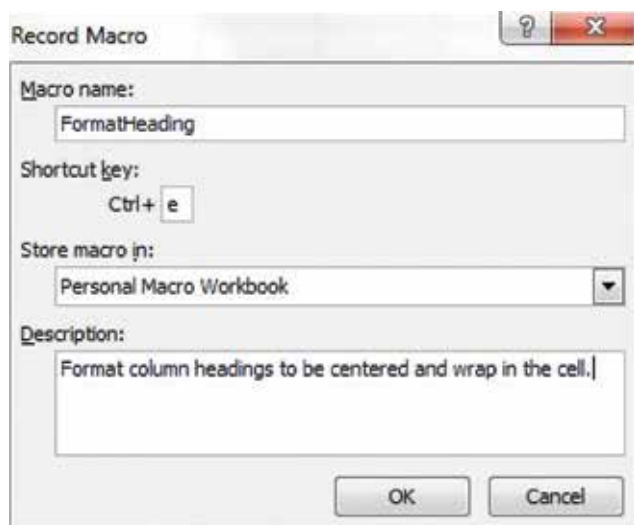


	A	B	C	D
1				
2		Pressure (kPa	Flow Rate (Lpm)	

▲ **Figure 2.** The complete headings in cells B2 and C2 — Pressure (kPa) and Flow Rate (Lpm) — are longer than the widths of columns B and C.



◀ **Figure 3.** After you select the Record Macro command button in the Code group of the Developer tab of the Ribbon or the Record Macro icon on the left of the status bar below the spreadsheet, VBA will record your actions in the spreadsheet environment.



▲ **Figure 4.** Be careful when assigning shortcut keys to macros because they will supersede any built-in shortcut key definitions. Most uppercase shortcut keys are available, but avoid F, O, and P. Many lowercase shortcut keys are already defined, although the e, j, l, m, q, and t keys are generally available. Third-party add-in software might occupy other shortcut keys.

The Excel-VBA interface: Moving between the worlds

VBA programs are developed, edited, and managed in the Visual Basic Editor (VBE) environment. There are numerous ways to move back and forth between the Excel spreadsheet and the VBE. (This article will cover the methods suitable for working with Microsoft Office 2016, and the associated version of Excel, for the Microsoft Windows 10 operating system. Earlier versions on Windows-based systems do not vary too much.) Keying Alt-F11 is the easiest way to open the VBE. Alternatively, you can select the Visual Basic icon from the Code group on the Developer tab of the Ribbon. (If the Developer tab does not appear on your Ribbon, activate it via File, Options, Customize Ribbon, and check the box next to Developer.) Once the VBE is activated, you can switch back to Excel by keying Alt-F11, by clicking the Excel icon on the left side of the toolbar, or by selecting the Excel icon on the Windows taskbar.

The VBE layout harkens back to pre-Ribbon versions of Office, which had a menu and toolbar at the top, a Project Explorer window on the upper left, a Properties window on the lower left, and the main area called the Code Window.

Record VBA macros: A big bang for a pocket-change investment

As we use spreadsheets in our daily chemical engineering work, we inevitably come across multistep procedures that we repeat again and again. In many cases, we can record

a macro to automate these simple but repetitive procedures. Each of us will have our own examples, but here are four of mine:

- centering and wrapping column headings that are wider than the numerical entries below them
- right-justifying a cell entry one space from the border
- transferring a label as the name on the adjacent cell to the right
- resetting the zoom setting of new, blank worksheets to 150%.

Consider the first repetitive task: I would like to center and wrap two adjacent headings that exceed their column width (Figure 2). To do this, select the two cells and then activate the Macro Recorder — either by clicking the command icon in the Code group of the Developer tab of the Ribbon or by clicking the Record Macro icon on the left of the status bar below the spreadsheet (Figure 3). Once activated, the Record Macro dialog box is superimposed over the spreadsheet.

Enter into the Record Macro dialog box a name for the macro and a shortcut key (Figure 4). Storing the macro in the Personal Macro Workbook makes it available to whatever Excel workbook is open. If you have not yet stored anything in the Personal Macro Workbook, it will be created for you when you record your first macro to be stored there. Finally, you should enter a few words in the Description field related to the function of the macro.

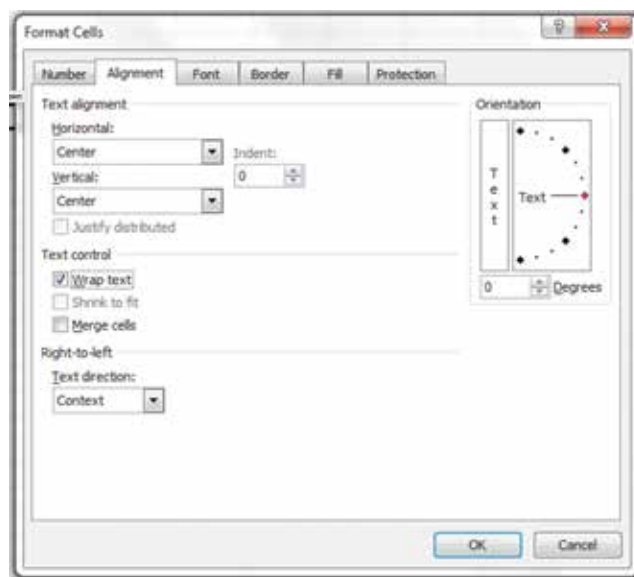
Click OK to turn on the recorder. From this point on, VBA observes what you do in the spreadsheet environment and attempts to compose code to replicate it. To center and wrap the text in the cells of interest, right-click the selected cells and select Format Cells. Navigate to the Alignment tab and in the dialog box select Center from the Horizontal and Vertical drop-down menus and 0 from the Indent menu, and check the Wrap text box, as shown in Figure 5. Click OK to format the cells as shown in Figure 6. To stop recording, select the Stop Recording command icon on the Ribbon or the Stop Recording square on the Status Bar, which is next to the Ready status (Figure 7).

Test the macro by typing another lengthy label, selecting the cell containing the label, and keying the shortcut combination. If the macro does not work, examine the VBA code. In fact, it is not a bad idea to look at the code anyway to see an example of the code or check for errors.

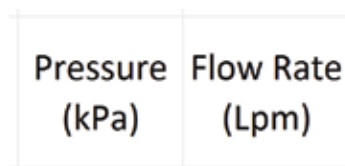
Key Alt-F11 to switch to the VBE. Double-click the code module in the Project Explorer under the Project associated with the Personal Macro workbook (PERSONAL.XLSB). The Code Window will open and should be populated with code (Figure 8).

If there are errors, they will probably show up as extra lines. The Sub (*i.e.*, Subroutine Procedure)

presented in Figure 8 is evidence of the relative readability of VBA program code. Comments are in green and set off by a leading apostrophe. The nine statements inside the With Selection ... End With structure refer to the options on the

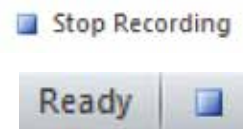


▲ **Figure 5.** Under the Alignment tab of the Format Cell window, specify Center for both Horizontal and Vertical text alignment and check the Wrap text box.



► **Figure 7.** When you are ready to stop recording your macro, select the Stop Recording command icon on the Ribbon or the Stop Recording square on the Status Bar (next to the Ready status).

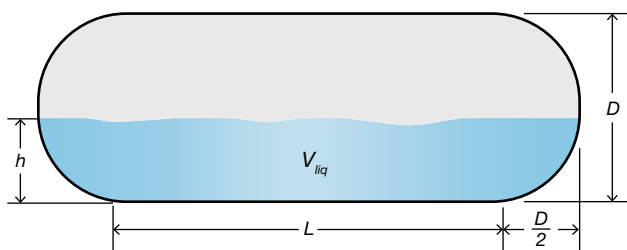
◀ **Figure 6.** The selections made in the Format Cell window format the column headings so they are easier to read.



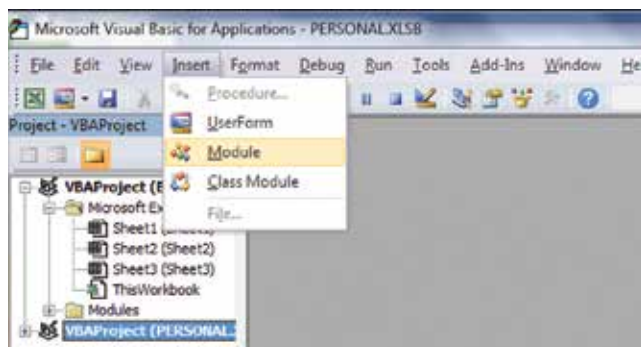
```
Sub FormatHeading()  
    ' FormatHeading Macro  
    ' Format column headings to be centered and wrap in the cell.  
    ' Keyboard Shortcut: Ctrl+Shift+e  
    With Selection  
        .HorizontalAlignment = xlCenter  
        .VerticalAlignment = xlCenter  
        .WrapText = True  
        .Orientation = 0  
        .AddIndent = False  
        .IndentLevel = 0  
        .ShrinkToFit = False  
        .ReadingOrder = xlContext  
        .MergeCells = False  
    End With  
End Sub
```

◀ **Figure 8.** Add a comment in your Sub by starting a line with an apostrophe. The text automatically turns green and will not be interpreted as code.

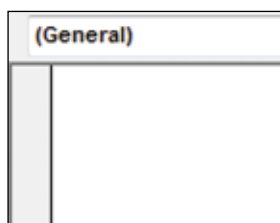
Computational Methods



▲ **Figure 9.** Create a user-defined function (UDF) to calculate the volume of liquid in this horizontal cylindrical tank with hemispherical sides.

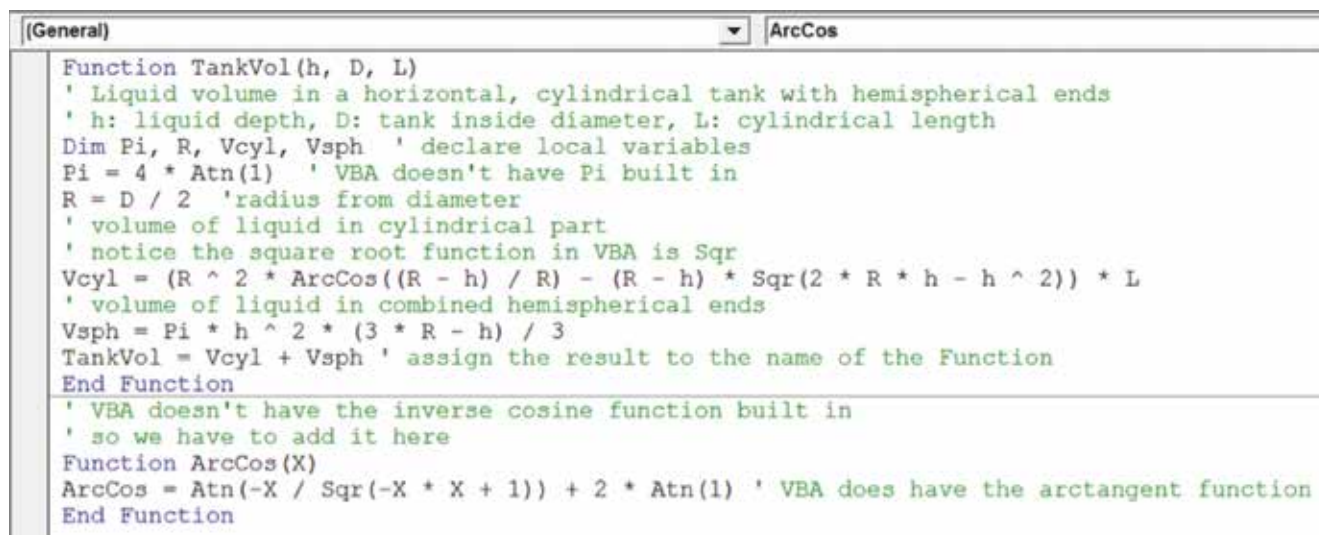


▲ **Figure 10.** After you select your project in the Project Explorer window, select Insert and Module on the VBE menu to open a blank Code Window.



◀ **Figure 11.** The blank code window in the VBE is where you enter your code.

▼ **Figure 12.** Comments can help make your UDF more easily understood by others, and they can help remind you of your reasoning when you revisit the code.



Alignment tab of the Format Cells dialog window. Selection refers to the cells that are selected, which identifies the object to which the code applies. Each item following a period is a property associated with that object, which is assigned a value via the equals sign.

Coding the word Selection in front of each period of the nine lines, absent the With Selection ... End With, accomplishes the same thing as the With Selection ... End With statement; however, the latter is more concise.

Only the first three lines of the macro correspond to the selections made on the Alignment tab. The last six are default values that can be deleted to make the code more compact and easy to understand.

This short time investment produces a simple macro that will likely be used dozens, perhaps hundreds, of times. Similar short macros can just as easily be recorded and provide a big payback.

User-defined VBA functions: Build your arsenal of engineering formulas

Chemical engineers occasionally use formulas for calculations that are relatively complex. These formulas can be incorporated into a user-defined VBA function (UDF). A UDF:

- allows the formula to be invoked in numerous locations on the spreadsheet without you re-entering or copying it
- improves reliability because it ensures only one version of the formula is used in the spreadsheet
- provides the ability to package the UDF into an add-in, possibly with other UDFs, and share the add-in with a work group or company organization (even commercialize it) to improve consistency of application.

To see how formulas can be incorporated into UDFs, consider the volume of liquid in a horizontal, cylindrical

tank with hemispherical ends (Figure 9). The total volume of liquid in the tank (V_{liq}) can be calculated by summing the volume of liquid in the cylindrical portion of the tank (V_{cyl}) and the volume of liquid in the hemispherical ends (V_{sph}) as defined by:

$$R = \frac{D}{2} \quad (1)$$

$$V_{cyl} = L \left[R^2 \cos^{-1} \left(\frac{R-h}{R} \right) - (R-h) - \sqrt{2Rh-h^2} \right] \quad (2)$$

$$V_{sph} = \frac{\pi h^2 (3R-h)}{3} \quad (3)$$

$$V_{liq} = V_{cyl} + V_{sph} \quad (4)$$

where R is the radius of the tank, D is the diameter of the tank, h is the depth of the liquid in the tank, and L is the length of the cylindrical portion of the tank.

To create a UDF with the format `=TankVol(h, D, L)`, enter code directly into the VBE. Select the appropriate project corresponding to the Excel Workbook in the Project Explorer window, and then select Insert and Module on the VBE menu (Figure 10) to open a blank Code Window (Figure 11).

Figure 12 shows the Code Window populated with the appropriate code. A good practice is to include ample comments to describe the calculation. The next step is to test the function on the spreadsheet (Figure 13).

Other formulas can be implemented in UDFs but might require program structure, such as decisions (If statements) and iterations (For-Next and Do-Loop statements). Books

► **Figure 13.** The variables h , D , and L are the necessary input for the function `=TankVol()`. In this spreadsheet, the cells have been renamed h , D , and L , rather than retaining their original coordinate names (*i.e.*, B2, B3, B4).

	h	1	m
	D	3	m
	L	6	m
Liqu	<code>=TankVol(h,D,L)</code>		
			m^3

	h	1	m
	D	3	m
	L	6	m
Liquid Volume		16.04	m^3

that cover the details of writing VBA code are available; a good one is *Excel 2016 Power Programming with VBA* by M. Alexander and D. Kusleika (John Wiley & Sons, Inc., Feb. 2016).

Streamline and format data: Save time and improve reliability

Data sets often need to be cleaned up and formatted to improve their readability and usefulness. If you find yourself doing this repeatedly, consider developing a VBA program to streamline the effort.

A small-scale example of data in need of formatting is the output of Excel's Analysis Toolpak feature. The Analysis Toolpak has a Descriptive Statistics option that generates a statistical analysis of a data set. If you use the Toolpak option for Descriptive Statistics for a small set of data (Figure 14) and designate its output for a separate, new worksheet, the Toolpak provides a table summarizing an analysis of the data set such as in Figure 15.

To make this table more readable manually, we would adjust column widths and number formats, and we could record a macro to see the code composed by VBA for these operations (Figure 16). I cleaned up the code in Figure 16 by removing superfluous statements, and I specified a particular numeric format for each cell. This would be a limitation for a generic macro but would be sufficient if the data sets we treat are consistent. Adding code to display a certain number of significant figures, independent of the scale of

Yield (%)
95.3
94.1
92.1
96.4
88.2
86.4
74.6
84.9
87.3
89.6

◀ **Figure 14.** We could analyze this set of data manually. However, Excel has an automated analysis feature that is particularly useful for large sets of data.

	A	B
1	Yield (%)	
2		
3	Mean	88.89
4	Standard E	2.013204
5	Median	88.9
6	Mode	#N/A
7	Standard [6.366309
8	Sample Va	40.52989
9	Kurtosis	1.999748
10	Skewness	-1.15169
11	Range	21.8
12	Minimum	74.6
13	Maximum	96.4
14	Sum	888.9
15	Count	10

► **Figure 15.** Excel's Analysis Toolpak includes a Descriptive Statistics option, which provides statistics about data sets in the form of a table.


```
Sub FormatDescriptiveStatistics()
' FormatDescriptiveStatistics Macro
Columns("A:A").EntireColumn.AutoFit
Columns("B:B").EntireColumn.AutoFit
Range("B3").Select
Selection.NumberFormat = "0.00"
Range("B4").Select
Selection.NumberFormat = "0.00"
Range("B5").Select
Selection.NumberFormat = "0.00"
Range("B7:B8").Select
Selection.NumberFormat = "0.00"
Range("B9:B10").Select
Selection.NumberFormat = "0.0"
Range("B11:B13").Select
Selection.NumberFormat = "0.0"
Range("B14").Select
Selection.NumberFormat = "0.0"
Range("B15").Select
Selection.NumberFormat = "0"
Range("A1").Select
End Sub
```

	A	B
1	Yield (%)	
2		
3	Mean	88.89
4	Standard Error	2.01
5	Median	88.90
6	Mode	#N/A
7	Standard Deviation	6.37
8	Sample Variance	40.53
9	Kurtosis	2.0
10	Skewness	-1.2
11	Range	21.8
12	Minimum	74.6
13	Maximum	96.4
14	Sum	888.9
15	Count	10

◀ **Figure 16.** The number of decimal places for each cell in the range can be individually specified in the code (top).

the numbers, requires more effort.

Another elementary application of VBA is to remove blank cells from a set of data. Compressing a data set with a few blank cells (Figure 17) requires a VBA Sub with a little program structure (Figure 18).

User interfaces: Applications to be used by others

If you would like to develop a spreadsheet to be used by others, such as operators and technicians, consider creating a user interface as part of your application. An efficient and well-designed spreadsheet interface for a common calculation that must be performed by those who are not spreadsheet-savvy can be worth the effort.

A user interface (Figure 19) requires the design of objects, such as forms, message boxes, input boxes, buttons, and switches, which are generally linked to VBA event handler code segments. Designing and programming these applications takes time and the learning curve is steeper than, for example, recording a macro.

Spreadsheets can also be integrated with other software packages, including math software (e.g., Matlab), process simulators (e.g., Aspen Plus), optimizers (e.g., What'sBest!),

Yield (%)	Yield (%)
95.3	95.3
94.1	94.1
	92.1
92.1	96.4
96.4	88.2
88.2	86.4
	74.6
86.4	84.9
74.6	87.3
84.9	89.6
87.3	
89.6	

▲ **Figure 17.** VBA can condense data sets that contain blank cells.

▼ **Figure 18.** You can discover statements like .Delete Shift:=xlUp by recording a short macro to delete a cell. You can use this information to then write a custom Sub.

```
Sub Cleanup()
Dim nRows As Integer, RowCount As Integer
nRows = Selection.Rows.Count ' how many cells are selected?
RowCount = 1 ' start at the top
Do
If IsEmpty(ActiveCell.Offset(RowCount - 1, 0)) Then ' is the cell empty?
ActiveCell.Offset(RowCount - 1, 0).Delete Shift:=xlUp ' if so, delete it
nRows = nRows - 1 ' discount the number of rows left
Else
RowCount = RowCount + 1 ' if not empty, move down one
End If
If RowCount = nRows Then Exit Do ' if at the end, time to go
Loop
End Sub
```

and data acquisition software (e.g., LabView, distributed control systems [DCS]). It is also possible to link spreadsheets with programs written in other programming languages, such as C/C++ or Fortran. In most cases, the bridge between Excel and these other packages is VBA.

Some software vendors provide Excel-based add-ins that facilitate intercommunication, such as the Excel Link add-in for Matlab and the Pi software from OSI. However, for the most flexibility and power, it is frequently necessary to write object-oriented VBA code.

Concluding thoughts

Most chemical engineers will not be able to carve out the time to get heavily involved in VBA application development. However, it is well within the reach of practicing professionals to take advantage of the small-scale features of VBA, such as macros and user-defined functions, and reap substantial benefits in time-savings and spreadsheet reliability. If you haven't tried these features, venture into the VBA world to see what it can offer.

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▲ **Figure 19.** Selecting the Solve Case button produces the desired output, which can appear in a Message Box or be placed on a Worksheet.

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Make Your Minutes Count

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BSI ENGINEERING

Distribute minutes for project team meetings to ensure the scope is recorded and communicated. Use the format outlined here to get all the benefits of minutes without the drawbacks.

Our ideal selves keep our desks organized, meet or exceed deadlines, and answer every email. In the real world, however, few of us consistently and simultaneously achieve these goals. Taking and distributing meeting minutes is one such goal that often falls by the wayside. Perhaps it is unrealistic to compile minutes for every meeting on your calendar, but you should consider taking and distributing minutes for any project team meeting. This article provides a format for meeting minutes that eliminates the shortcomings and increases the benefits of minutes.

Why use minutes?

Minutes are important to project team meetings because the project scope is often generated during these discussions, and the best way to document it is through minutes. Projects of all sizes can benefit from minutes, but they are especially important for large projects — some large-project team meetings generate eight or nine pages of minutes. When a scope is that complicated, documentation is imperative.

The project manager needs to make sure the scope is complete, documented, and communicated, which may involve meeting with appropriate experts. The scope informs your overall responsibility, which is to ensure that the project achieves the intended goal and that it is completed correctly, on time, and under budget. Accurate minutes can help you accomplish these goals.

I was the project manager responsible for a large project involving the design and construction of a new process building that included new controls, raw material handling equipment, two large roll dryers, packaging equipment, and support equipment. Although this was a high-profile assignment, I received it verbally from my manager. He said that he wanted to add a second roll dryer and build a new facility to take advantage of lessons learned about the process.

I formalized the verbal directive by forming a project team and scheduling meetings to develop the scope. Over the course of the many project team meetings, the scope changed dramatically. Originally, the new building was to be placed on the east side of the existing packaging warehouse and an existing railroad spur. That would have required the finished product to be conveyed about 150 ft to the packaging warehouse, where it would be packed by new equipment, and the new process building would have needed a new control room. The final scope located the new process building just a few feet west of the packaging warehouse, which eliminated the long transfer line and allowed the packaging warehouse's control room to control the new process building.

Clearly documenting these changes and the rest of the scope was imperative. The scope lays the foundation of a project, and it is vital that it be documented and communicated. Inherent in the scope of a project is its

limits. For example, in this project, we had to decide whether we wanted to leave room for another roll dryer in a future expansion and determine minimum and maximum processing rates. Minutes must detail these limits, which, when combined with the rest of the scope, should be incorporated into drawings and other project documents.

Meeting minutes, however, do have shortcomings. You

might take minutes and distribute them, only to have them go unread. In addition, projects typically require many project team meetings, and it may be difficult to understand the entire scope when it is distributed across various documents. Minutes may also have inconsistencies because project teams frequently change their minds. What was agreed to in one meeting may differ from what was agreed to in another.

Although minutes have problems, they also offer many benefits. In addition to documenting the project scope, minutes can be used to ensure that assignments are completed. Even assignments of people not on the project team or not attending the meetings can be tracked. For example, a high-ranking manager not on the team who committed to an assignment verbally can be held accountable through minutes.

Project managers must often influence colleagues they do not manage; without minutes, it can be difficult to ensure assignments are completed on time. Minutes can be used as a tool to influence without authority. They can even be used to build relationships. Used correctly, minutes can increase a project's chances of success.

Ensure minutes are read

Minutes are useless if no one reads them. You can increase the likelihood that the minutes you distribute are read by calling or visiting meeting attendees. Ask if they have any questions about the minutes or highlight important points. When you start doing this, people will be more likely to read the minutes in anticipation of your call or visit. I have found that once people start to read minutes, they see their value and look forward to discussing them. Most engineers enjoy following a project unfold and finding ways to contribute.

Although you should plan to check in, always state that no response to meeting minutes indicates agreement, such as Note 2 in the Minutes Template on the left. This type of note helps to discourage last-minute changes, as well as impart a sense of discipline to stakeholders. Your in-person check-in will help to gather any late comments, especially those from high-ranking managers.

In one project that I managed, for instance, I held ten project team meetings before moving on to detailed design, and distributed minutes after every meeting. After the design contract was issued and the design started, I received a call from the head of process engineering. Although he was apologetic for being too busy to read the minutes in time, he had some serious issues with the design. His comments included big changes to the scope, which delayed the project and cost money.

Personal checks to gather meeting minute comments are also your opportunity to use minutes to build relationships

Minutes Template	
To: <u>Venture Manager, Pertinent Dept. Heads, Project Team Members, Other Stakeholders</u>	
From: <u>Project Manager</u>	
Date: <u>Nov. 22, 2017</u>	
Subject: <u>Powder Processing Team Meeting Minutes</u>	
Attendance	
_____	_____
_____	_____
_____	_____
Minutes	
<ul style="list-style-type: none"> • All agreed the last minutes were correct. • The new process building will be located west of the packaging warehouse. • Roll dryers must be removable for maintenance. • Sanitary fittings must be used. 	
Minutes from Past Meetings	
<ul style="list-style-type: none"> • The new process building will be located east of the packaging warehouse. • The existing roll dryer will be transferred to the new process. • The existing process building will be demolished. 	
Action Items / Assignments	
Description, Responsible Party, Due Date, Status	
Next Meeting's Agenda	
Date: _____	Time: _____
Location: _____	
Notes	
<p>Note 1: A highlighted item in the Minutes section signifies a change from something agreed to in the past. (See also highlights in Minutes from Past Meetings.)</p> <p>Note 2: No response to the minutes by the next project team meeting is considered agreement with the minutes.</p>	

and your network. After discussing the minutes, take some time to get to know your fellow project team members. Do not let the relationship stop after the project is complete. Look for opportunities to connect and chat about the installation, any current projects, or even a favorite sports team. With each project, your network will grow.

Close action items

Minutes can ensure that assignments get done. In your minutes, list the action item, as well as its due date, status (*i.e.*, incomplete or complete), and owner. The owners or responsible parties must commit to the action item and its details. You will have no doubt that the owners are aware of their responsibilities by communicating it through minutes.

By distributing minutes, responsibilities will be communicated to some of the most important people in an organization. This helps to get the proper resources allocated to close items, as well as hold owners accountable.

Owners of action items not on the project team or not attending project meetings can also be held responsible through minutes. During a project meeting, mention the commitment, even if it was made in passing, and incorporate it into the meeting minutes. When distributing the minutes, be sure to copy any individuals mentioned.

Track changes

Keeping track of multiple, sometimes contradictory, minutes can be a problem. Use the format illustrated by the Minutes Template to compile a single, evolving set of minutes that captures all project team meeting events. Meeting attendees and other stakeholders only need the latest version to be up-to-date. Any inconsistencies between versions are highlighted to reduce confusion.

This summary format allows individuals to read the latest minutes and see everything that has been accomplished and agreed to by the project team at all the meetings. Having all of the information in one document keeps everyone up-to-date without needing to examine multiple files.

This format also eliminates contradictions between minutes of different meetings, creating a single coherent picture of the project and status. When an item changes from one meeting to the next, highlight the item in the Minutes from Past Meetings section and also in the Minutes section. In the next version, remove the highlighting and move the information from the previous Minutes section to the Minutes from Past Meetings section. At this point, take out any incorrect statements and eliminate any duplicates.

This method keeps minutes as concise as possible and clearly indicates any contradictions. Maintaining a log of changes for as long as it is useful lets everyone know of the changes and that they have been agreed to. After the final

As the first order of business at each project team meeting, verify that the latest minutes are correct.



project team meeting minutes are distributed and all parties have verified the information, send a final set of minutes that summarizes everything that has been agreed to and delete the Minutes from Past Meetings section.

Head off complaints

Send the final minutes to everyone on your project team, project stakeholders, other interested parties, and anyone who is notorious for making changes. Communicating the project scope through minutes as it is being developed can head off complaints before they grow to be real problems that affect timelines or deliverables. It is much easier to incorporate a change during the preliminary design stages than out in the field. Capturing changes at this stage can help keep the project on budget and schedule.

Use the attendance lists on the minutes when you need to argue against unreasonable change requests or criticisms by project team members who do not attend meetings. It is easy to point to lack of attendance as a reason for not incorporating a change. The attendance list is also a useful tool for persuading members to show up to the meetings.

As the first order of business at each project team meeting, verify that the latest minutes are correct. If not, redline the minutes and ask everyone to sign the document. It is extremely important that the information captured in minutes is considered reliable. Then, simply list the items that the team has agreed to.

Looking ahead

What is not in the minutes is just as important as what is. Include all major points in minutes, but do not list the back and forth that took place to come to a conclusion. Take notes during the meeting to create a draft. At the end of the meeting, summarize any major points aloud to the team. Ask the team to verify that you have captured all the major points and list those you may have missed.

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Speaking Up in Meetings

Meetings are an inevitable part of the workweek for most of us. Whether it is a department staff meeting, senior executive briefing, or even an informal breakroom chat, we must interact with our coworkers, bosses, clients, and others. Knowing how to communicate in these settings can be important to career advancement, but some individuals would rather have a tooth extracted than speak up in a meeting.

Those who are shy or introverted may be uncomfortable expressing themselves in a group setting. They may prefer to listen quietly and not make eye contact, which can come across as a lack of interest in the meeting topic. New employees or team members may also hesitate to participate in the group discussion. “The newest person on the team may be trying to get the lay of the land and therefore not speak up,” says Eileen Sinett, President of Speaking that Connects, a Plainsboro, NJ-based communications coaching firm. “Unfortunately, to the boss, this can look as if they are mentally absent from the meeting.”

Sinett has coached individuals for whom English was not their primary language, who were reticent in meetings. “These employees had been hired to analyze data. For that role, it was permissible to converse in Japanese. But then they were thrust into a setting where they were expected to update senior managers who only spoke English. The employees’ English skills were poor, so they were too embarrassed to communicate,” she notes.

Even those with good English skills who are from different cultures may be uncomfortable communicating in meetings. “In some Asian countries, for instance, employees may only speak up when asked directly for their input. They are not used to jumping in when they have questions or comments,” says Ray Henson, management consultant and author of the book, *Successful Global Leadership*.

If you are someone who has difficulty speaking up in meetings, the good news is you can take steps to improve your participation.

Prepare in advance. When you are invited to a meeting, find out its purpose and who will be attending. Ask the meeting leader if there is anything specific they want you to cover. “I ask for an agenda in advance. As an introvert, I need that time to think through the meeting topics,” says Mark Wollum, senior process engineer at W. L. Gore & Associates (Elkton, MD).

Take baby steps. Start with a lower profile meeting — perhaps one with a few supportive colleagues rather than senior executives — and plan to participate in a small way. “Your goal in this meeting is to ‘anchor’ someone else’s opinion. This means that all you need to do is express agree-

ment with someone else’s statement,” says Sinett. “When you start with anchoring it’s less personal and takes the pressure off you.” Your next step might be to ask a clarifying question. These tactics can help you get better at speaking up but are still low risk. Then, when you are more comfortable, you can use these skills in a more difficult meeting setting.

Listen actively. Listening is an equally important part of communication. Demonstrate your engagement by taking notes and looking in the direction of the speaker.

Take a public speaking course. Speaking in meetings is a form of public speaking, so consider signing up for a public speaking course at an adult education center or local community college. Clubs such as Toastmasters can help you gain confidence and build your skills in a supportive setting. “There is time in every Toastmasters meeting where a member is called to ‘speak on their feet’ on a subject of little importance,” notes Glenn Shivelor, application specialist at Sulzer Chemtech USA, Inc. (Tulsa, OK).

The responsibility to participate does not fall solely on meeting attendees. Meeting leaders have an obligation to run an effective meeting, where all attendees feel comfortable talking. Here are some tips for leaders:

Minimize meeting stress. “I have found that the more relaxed the group is, the more everyone — quiet ones included — will contribute. Anything the meeting chairperson can do to engender calm is beneficial,” says Angus Keddie, Director of Process Safety Matters (Bracknell, U.K.). He finds it is also constructive to ask everyone during introductions to include a statement about how they feel they can contribute to the meeting. “This gives the chair some clues about where the reticent members’ competencies overlap with the subject.”

Ask questions to draw people out. As a meeting leader, David Eckhardt, project manager at Irwin Engineers (West Boylston, MA), encourages participation by asking open-ended questions. At the end of every meeting, he asks each participant directly if they have anything else to add.

Keddie, who is a HAZOP chair, phrases questions to acknowledge a participant’s expertise. He comments, “Let’s say we were discussing if operators had enough time to respond to initiate a safeguard. I’d say something like, ‘Jim, you know the facility well. Do you think the guys would have enough time to push the button before X happened?’”

Keddie offers this final insight, “When you do receive a contribution from a reticent member, whether solicited or spontaneous, make sure you generously explore the point they’re making and thank them before you move on to another team member.”

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Listen Up!

It may seem easy, but good listening requires effort and practice. Follow these tips and learn to listen like a pro.

BRUCE D. SMITH
EMERSON ELECTRIC CO.

NIKKI BISHOP
SIEMENS

Observe any conversation, and you might think that the person speaking is the one in control of the exchange. After all, the speaker is the person stating information, sharing opinions, issuing orders, and generally making noise. A speaker, however, can talk to four walls in an empty room or to the stars in the night sky, but without a listener, it is not a conversation.

Listeners control conversations, and good listening is vital for efficient and effective communication. However, being a good listener can be challenging.

Why is listening so difficult?

Hearing is not listening. Hearing is a purely physical act: the speaker's vocal chords make vibrations, which are altered by the tongue, teeth, and lips; barring disability or interruptions, the vibrations travel through the air into the listener's ear canal, where they are converted into nerve impulses in the brain. Hearing is a prerequisite for listening, but it is a passive action. Listening is an additional layer on top of hearing that requires active engagement and critical thought.

Lag time. Words move from the speaker's mouth to the listener's ears, and then are processed by the listener's brain. There are lags between the mouth's ability to enunciate

words, the ears' ability to receive sound, and the brain's ability to process information. Although the entire process can feel almost instantaneous, each of these actions takes time.

The brain works considerably faster than the mouth and ears. While a speaker pronounces words, the listener's brain waits to process the sound. During that time, thoughts may wander to extraneous ruminations, such as "What's for dinner tonight?" "Is that spinach between her teeth?" "I hope the commute home won't be bad tonight." It takes effort to reel in our brains and maintain focus throughout a conversation.

Filters. Because the brain works so fast, it has time to place its own filters between the speaker's message and intent and the listener's conclusions. Filters may be based on the listener's culture, language or linguistic patterns, expectations, or biases. For example, the listener may interpret the way that a speaker uses certain words or references as nonsensical or offensive. This fast, usually subconscious perspective may cause the listener to interpret the message and form opinions, answers, and assumptions even before the speaker has finished making a point.

Filters are often the cause of miscommunication because they cause the listener to misinterpret the intent or meaning of the speaker's words or the speaker to misinterpret the listener's reaction. For example, a listener may disagree with

This article is based on a presentation at the 2016 Emerson Global Users Exchange that was recognized with the Best-in-Conference award.

better communication and retention of information.

The behaviors related to active listening take time, energy, and effort to master. They involve controlling your mind to deliberately focus on the other person. Passive hearing is like driving a car without your hands on the steering wheel — the car will move, but not in the direction you intend. Active listening gets you where you want to go. If you encounter obstacles or traffic jams, you can brake, turn, or double-back to points where you need more clarification in the conversation.

Start with empathy. Good listeners are empathic. Entering into a conversation with empathy shows that you acknowledge the speaker's emotions, experiences, needs, perceptions, and interests. Passive attention will not capture the information required for an empathic response. Empathy demonstrates that you value the speaker and are willing to invest your time with him or her.

Express empathy with simple phrases that show you acknowledge the speaker's point of view and emotions. Simply recognizing the speaker's positive or negative feelings about a problem, coworker or customer, new product, or general issue can motivate him or her to share more, which can help to inform your next steps.

Attend the concert. When speakers are talking, they are putting on a concert. The music is the speaker's message and it has nuances that you could easily miss if you are not fully focused. Listen for dissonance between word choice and tone, which might indicate sarcasm or insincerity. Pay attention to crescendos and decrescendos in the speaker's voice. Remember that a concert is also a visual experience;

analyze body language and facial expressions for their impact on the message.

Verbal, vocal, and visual signals are all necessary to understand a speaker's message (8). To pick up on verbal cues, pay attention to the speaker's words. Although words will not give you the entire message, they are a critical element. Consider why the speaker chose specific words, and focus on the words within the context of the whole message.

Vocal signals, which are communicated through the speed, tone, and volume of the speaker's voice, often express emotion and passion. These signals may also vary, depending on the speaker's cultural background. In most western cultures, rapid speech combined with high tones and loud volume indicates excitement, whether from surprise, fear, or elation. Conversely, slow delivery with low tones and volume could reflect feelings of menace, threat, resignation, or conspiracy. Assess these cues to determine the speaker's emotional state.

Visual factors, including the speaker's posture, gestures, and facial expressions, complete the picture. Body language adds more meaning to the speaker's message and emotional state. Good listeners watch for changes in body language and sequences of movement. Observing body language can help listeners ask relevant questions to gain deeper levels of understanding and avoid misunderstandings.

Get started now

Listening is difficult and requires practice. You may not become a good listener in time for your next conversation or even the one after that, but you can start practicing.

Are You a Good Listener?

Read the following statements and score yourself on a scale of 1 to 5 — where 1 is *almost never* and 5 is *almost always*.

When another person is speaking, I:

- ☐ Focus my complete mental attention on the speaker
- ☐ Concentrate on what the speaker is saying, even if I'm not particularly interested
- ☐ Ask questions to get additional information
- ☐ Do not interrupt and let the speaker finish
- ☐ Notice and respond to the speaker's nonverbal signals
- ☐ Take notes if the information is detailed
- ☐ Acknowledge and empathize with the speaker's feelings
- ☐ Ask the speaker to clarify if I'm uncertain about the message
- ☐ Paraphrase what I have heard to confirm my understanding
- ☐ Summarize what I heard and what actions, if any, should be taken at the end of the conversation

Now, total your ratings for all of the statements. A score of more than 40 means you practice very good listening habits, 30–40 means your habits are about average, and below 30 means you may need some work. Next, get someone else's perspective. Let someone you know use the questionnaire to rate your listening skills, and compare your scores.



**TOTAL
SCORE:**

ing now. The next time you are listening, withhold your opinions or statements, and instead respond with a relevant question. Try to paraphrase what the speaker told you. Use simple phrases such as “What else?” and “Tell me more” to draw out more information. Once you begin sharing your opinions, thoughts, and reactions, you have stopped active listening. When you do feel compelled to give your own perspective, first ask yourself: “Why Am I Talking?” (remember the acronym WAIT).

Because listening is so crucial to understanding, set aside time to review your listening skills to keep it at the forefront of your mind. Make a calendar appointment for five or ten minutes to set aside time to review techniques. The internet is full of good ideas, articles, and blogs on effective listening. Or, you could keep this article at arms reach for a quick review.

As you work toward becoming a better listener, ask for feedback. It is helpful to share your goals with others to keep yourself accountable. Taking intentional steps toward improving your listening skills and breaking bad habits will set you apart.

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Become a Better Writer

ROBERT W. BLY
MARKETING TO ENGINEERS

You may call yourself an engineer, but you're
also a writer. Follow these 10 tips
to improve your writing.

When it comes to accelerating your career success, increasing your chances of getting a job or promotion, and even making more money, technical writing skills are highly valuable. Conversely, weak communications skills can hinder your career progression and even make it difficult for you to get hired. For example, some business units at Rockwell Automation, a Milwaukee-based automation vendor, specifically evaluate candidates' writing ability, reports Susan Schmitt, a senior vice president of human resources (1).

In a survey conducted by the College Board, a nonprofit organization, about half of the companies surveyed said they consider writing ability when promoting employees, and nearly all said they would hold poorly written job application materials against candidates (2). A recent survey by the National Association of Colleges and Employers (NACE) found that the ability to create or edit written reports was one of the top 10 skills employers look for when hiring new college graduates (3). According to an article published by the Institute of Electrical and Electronics Engineers (IEEE),

engineers spend 20–40% of their workday writing, and the higher they move up the corporate ladder, the more writing they do (4).

Engineers are often tapped to write, help write, or work with editors and technical writers to produce reference, product, marketing, and educational materials, including technical articles, press releases, instructions, datasheets, reports, manuals, proposals, emails, newsletters, blog posts, web page content, white papers, books, and presentations.

It is important for engineers to write and edit publications skillfully, quickly, and correctly. Clear, concise, and persuasive prose could prevent a safety incident, make a project proceed more efficiently, convince others of the merits of your ideas, reduce calls to customer support, and improve user satisfaction. In addition, good writing can help establish your reputation as an expert in your field, gain wider acceptance of your company's technology, get your work published, and even generate more leads, inquiries, and sales of your products and services.

"Publish or perish" doesn't just apply to scholars, writ-

ing can help your star rise higher and faster within your organization and in your field. “The reverence people have for the printed word is amazing. Simply because a man [or woman] appears in print, the public assumes that he [or she] has something authoritative to say. This applies on every level,” writes Edward Uhlan in his book *The Rogue Of Publishers’ Row: Confessions Of A Publisher* (5).

The proliferation of personal computers and increasing use of email — which enables us to write more and more often — makes writing an undeniably important skill. When I entered the corporate world as a technical writer in the late 1970s, the only people using typewriters were secretaries. All the technical writers in my department wrote in longhand with a pen and pad, and gave their work to a secretary to be typed up. When I told my boss I needed a typewriter, he thought I was nuts and discouraged me. But I insisted and found a clunky old electric typewriter in storage.

Back then, the average manager or executive did not have a typewriter, so they wrote very little. But now, thanks to computers and email, everyone is a writer. The average engineer spends about one-third of their time writing. If you spend a full third of your day doing something, wouldn’t you want to do it well?

What does it take to get your writing skills to the next

level? Surprisingly, less effort than you may think. In fact, you can significantly improve your writing with minimal time and effort just by putting into practice the 10 tips presented in this article.

#1. Be technically accurate

A U.S. Occupational Safety and Health Administration (OSHA) bulletin explains that the atmosphere we breathe must have 19.5% oxygen content or higher to sustain human life. If OSHA had made a typographical error and typed 9.6% instead of 19.5%, an engineer referring to this document while designing an automated fire suppression system might calibrate the nozzle to dispense an excessive volume of the fire-extinguishing agent. The excess volume of agent could lower the oxygen level in the room far below 19.5%. Although the fire will likely be extinguished, the inhabitants of the closed space may suffocate.

Compare this error to, for example, a Sunday newspaper mistakenly citing the distance between the Sun and Earth as 920 million miles instead of 92 million miles. Embarrassing? Yes. But no one is going to burn to a crisp flying their rocket too close to the sun, even if our rockets could fly that far, because scientists and engineers fortunately do not plan space flights based on popular science articles.

Accuracy in technical writing is more important than in perhaps any other type of writing, because people act on the information. If the content is inaccurate, everything from a product defect or structural weakness in a bridge, to a toxic chemical spill or an explosion, could result.

#2. Write clearly and conversationally

Readers — even those who are highly technical — appreciate documents that are clear and concise. In my nearly four decades as a technical writer, I have never once heard an engineer complain that a document was too easy to read. Use these methods to make your writing a pleasure to read:

- *Omit needless words.* Say what you have to say, but do so in the fewest possible words. Avoid redundant and wordy phrases. For instance, “plan in advance” is redundant, because all planning is done in advance. Simply write “plan.” The expression “RAM memory” is also redundant, because the M in RAM stands for memory.

- *Choose an informal, conversational style.* For instance, instead of “The data provided by direct examination of samples under the lens of the microscope are insufficient for the purpose of making proper identification of the components of the substance,” write “We can’t tell what it is made of by looking at it under a microscope.” The second sentence is written in a more informal, conversational style than the first; it flows more smoothly, is easier to understand, and sounds more natural than the first sentence.



GETTING STARTED

You wouldn’t undertake an engineering or design project without developing a plan, so don’t start writing without a set plan either. No matter the extent of the document, make sure you always:

- identify your audience and their expectations
- know the purpose of the document; refer back to this often while writing so you don’t get off track
- understand the material you will present
- do your research, whether that’s reading the latest articles on your topic in scientific journals, talking to leading scientists in a particular field, or performing experiments
- think about potential visual aids that could help deliver your message
- organize your thoughts and materials
- choose a relevant organizational structure
- budget time to write, review, and edit.

If the document will be long, such as a report on a new equipment installation, consider creating a structured outline as part of your plan.

- *Use the active voice.* The active voice expresses an action directly, as opposed to the passive voice, which expresses an action indirectly. Instead of writing, “Control of the bearing-oil supply is provided by the shutoff valves,” write “Shutoff valves control the bearing-oil supply.” The sentence that employs the active voice directly attributes the verb to the noun performing the action, which makes the sentence more clear.

- *Select an easy-to-follow organizational scheme.* The way you organize the information in your writing should logically fit your content. Organizing your material in chronological order or by stating the problem first followed by the solution is often best for a case study. Alphabetical order makes sense for a booklet on vitamins (e.g., vitamin A, B1, B12, C, and so on) or an employee directory. Use sequential order for work instructions and process descriptions to make each step easy to follow and reference.

#3. Put the reader first

The difference between mediocre writers and good writers is that mediocre writers start with the subject, while good or excellent writers start with the reader. We often begin writing by thinking about what interests us first — which, for engineers, is often the process, machine, experiment, or technology — rather than our readers. But all professional writers, as well as all engineers and scientists who are good writers, put the reader first.

The more you tell your readers about what they want or need to know about your topic — how it relates to their problems, concerns, goals, project, job, or company — the more interested they will be. To do that, you must understand three things about your readers: who they are, how much they already know about your topic, and how they would benefit from knowing more about it.

Let’s say you are writing an article about when, where, why, and how to use motionless mixers for laminar flow applications in chemical plants. You of course know what motionless mixers are, how they work, their applications, and the advantages of using them, so your natural tendency is to assume everyone else does too. But they don’t. Many chemical engineers graduate without having seen a static mixer in operation. Even ChEs who have worked in industry may not have seen a static mixer in operation. Your article should educate both the experienced and inexperienced reader.

Answer these questions about your reader before you sit down to write an article, report, or paper on a specialized or technical subject:

- Are my readers chemical engineers, engineers or scientists in other fields, technical managers, nontechnical senior executives, or even laypeople?
- What do they already know about my topic?

The difference between mediocre writers and good writers is that mediocre writers start with the subject, while good writers start with the reader.

- What do they want and need to know about my subject?
- How important is my topic to them and their work?
- How will they use the information in my article in their work?
- What do I want them to believe, think, or do after reading my article?
- How can the methods I describe make or save money, increase yield, improve product quality, or deliver other desirable results?

#4. Write in the second person

Writing in the second person means addressing the reader as “you.” Doing so directly addresses the reader, thereby putting them first (as suggested in tip #3).

Using “you” engages the reader in a way that using the third person (*i.e.*, he, she, it, etc.) does not. Instead of writing in the third person, “Chlorine flow may be easily regulated by the operator through use of the control panel,” write in the second person, “You can easily regulate chlorine flow using the control panel.” The second sentence is more engaging, because it speaks to the reader directly.

Successful advertising writers — those who write primarily to persuade — will tell you that “you” is one of the two most persuasive words in the English language. People care about themselves first, and your products, technology, application, or project second. Therefore, when you write “you,” you are talking about the subject that matters most to them and it gets their attention.

(As an aside, the other most-persuasive word is “free.” If you put up a landing page on your company website for downloading your latest white paper, make the headline “Free White Paper on Managing Large Data Centers” instead of “White Paper on Managing Large Data Centers.” Adding “free” to the headline has been proven in numerous tests, in which response rates are precisely measured, to increase conversion rates.)

#5. Motivate the reader with benefits

Motivate the reader? Use benefits? That’s for advertising executives on Madison Avenue trying to sell soap, right? Don’t engineers simply inform and instruct, not persuade?

Quite the opposite is true. People are busy, and sometimes you need to sell them on an idea you want them to believe, an action you want them to take, or even a document you want them to read. Consider these introductory paragraphs of a manual on how to use a particular type of

workstation as an exercise in persuasive technical writing:

The operator's workstation acts as the interface between the operator and the processes being monitored and controlled. It is often referred to as the human interface to the process. The workstation consists of devices that allow the operator to perform his or her duties in an efficient manner.

Utilizing all available documentation, the student will be able to use each of the devices provided with the operator's workstation to access displays, overlays, and environments; determine if display objects are pickable; and perform various windowing operations.

There is nothing particularly wrong with this text, but it could be improved. For starters, it is boring.

Many users do not bother to read manuals and this gets them into trouble from which technical support must then rescue them. By adding a benefit, you can motivate users to read the manual and operate the system properly, which can help reduce operator error and call volume at your help desk.

Here is the same text rewritten to make it clear to the reader the benefit of reading the document:

Your job is to monitor and control processes in your plant. The operator's workstation can help you do that job better and faster.

In this module, we'll explore all of the parts of your workstation, including the monitor, touch screen, keyboard, annunciator, keypad, mouse, trackball, and printer. In addition, you'll learn how to:

- *access displays, overlays, and environments*
- *determine whether a display object can be selected*
- *perform windowing operations.*

#6. Do one (or two) more drafts than you normally would

In writing, as well as many other activities, the law of diminishing returns applies. The more time you put into the work, the smaller the incremental improvement of the results for each additional hour of labor. The biggest gains occur in the beginning of the work, but as you continue, the return on your effort gradually shrinks (Figure 1).

Many of us work on our writing assignment until we get to Point A in Figure 1. Then, because we are busy, or prefer to move on to other things, we stop and hand in what is essentially our first draft. This is the kind of unpolished copy that makes you as the author cringe when you revisit and reread it. These types of rough drafts leave many readers scratching their heads and wondering, "What is the author trying to say?"

Mediocre writers stop at Point A, but they could make their writing better, stronger, and clearer by putting in a

little more time and effort. How much better can the document get, and how much time will be required?

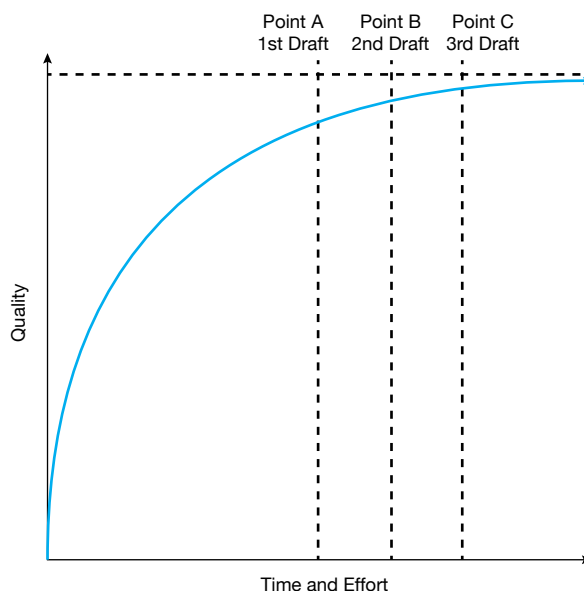
For the average engineer working in industry, I suggest you push forward to Point B even though you might feel like stopping at Point A. To move from Point A to Point B, you need to do one more draft, which usually includes careful editing and rewriting problematic sections. At this somewhat-early stage of the curve, the extra time you put in yields a quality improvement substantial enough to justify the added effort.

If you're an engineer who writes, you can stop at Point B. Many of the engineers in your organization that you consider decent writers, but who are not professional technical writers, probably write at the Point-B level. If, however, you are a professional technical writer or editor, or the document you are working on is of critical importance, you should do yet one more rewrite or edit, which will get you to Point C.

I would advise you to stop at Point C. Rewriting any more will provide too little incremental improvement and too little return for the extra time invested. It simply doesn't pay off.

#7. Be consistent

Use consistent and correct grammar, spelling, nomenclature, symbols, units of measure, style, etc. The reason is simple: If you are inconsistent, you are automatically wrong at least part of the time. For example, do not use "USA" and "U.S.A." in the same document.



▲ **Figure 1.** When you develop your first draft into a second draft, the added effort pays off with vast improvements that make your document easier to read and more useful. As you develop the document further, the incremental improvements will gradually taper off.

Table 1. Check for these common errors to ensure your writing is clear.

	Incorrect	Correct	Why
Subject and Verb Disagreement	In reference to your recent letter, your address on our files are correct. An order form, as well as a post-paid envelope, are enclosed.	In reference to your recent letter, your address on our files is correct. An order form, as well as a post-paid envelope, is enclosed.	The subject of the sentence is “address,” not “files.” The subject is “order form,” which is singular and so the verb should also be singular.
Problematic Pronouns	John, George, and me met to discuss the job. We met with Mr. Brown, Mr. Smith, and yourself in New York.	John, George, and I met to discuss the job. We met with Mr. Brown, Mr. Smith, and you in New York.	Read the sentence with each subject one at a time, you will discover that “me” should be replaced with “I,” and that “yourself” should be replaced with “you.”
Dangling Modifiers	After finding the missing report, the search was ended by the administrative assistant.	After finding the missing report, the administrative assistant ended the search.	The modifier, “after finding the missing report,” modifies the assistant and not the search.
Displaced Modifiers	The payroll teller recommended First Carrier over Federated, whose delivery service is very prompt.	The payroll teller recommended First Carrier, whose delivery service is very prompt, over Federated.	If First Carrier is recommended, it must be the prompt company, not Federated.
Run-On Sentences	Your projected cost for fiscal 2017 is \$650,000, however, this figure may vary because of a variety of factors.	Your projected cost for fiscal 2017 is \$650,000. This figure may vary because of a variety of factors.	The “however” is the start of a whole new thought with its own subject and verb.
Unparallel Structure	Operators should carry out maintenance activities safely, carefully, and in a detailed manner.	Operators should carry out maintenance activities safely, carefully, and thoroughly.	Use the same pattern of words to show that ideas have the same level of importance.

Be consistent in your use of styles, such as boldface, italics, underlining, indenting, highlighting, type size, and font. For instance, if in chapter one of a technical book, the chapter title is in 14-point boldface flush left, the subheads are 12-point boldface flush left and underlined, and the sub-subheads are in 12-point italics centered, this schemata should be used consistently in every chapter.

Some readers hold even minor inconsistencies and errors, such as typos, against you. It distracts them to the point that all they want to do is point out the mistake to you rather than concentrate on the valuable content your document provides. Even a flub as seemingly inconsequential as “Farenhite” instead of “Fahrenheit” can give the impression that you are careless, needlessly distract the reader from your content, and raise doubts about the accuracy or validity of your entire document — unfair as that may seem. You do not want your efforts to be wasted and your technical prowess overlooked, so be mindful of details and be consistent.

Table 1 lists some of the most common grammatical errors businesspeople and engineers make and how to correct each.

#8. Keep it short

The quickest and most effective way to make your document less intimidating is to keep it short. Not the document itself; it should be as long as is necessary to include all pertinent information. Rather, keep the components of the document short.

Use small words. Mark Twain famously said, “I never write metropolis when I get the same nickel a word for writing city.” Similarly, do not write “utilize” when “use” means the same thing but is shorter and less pompous.

Keep sentences short. Use the “breath test.” Read the sentence aloud at an even speaking pace. If you run out of breath before you get to the end, it is too long. To fix long sentences, find a place where a new idea begins, and divide the one long sentence into two shorter sentences at that point.

Break up paragraphs. Long paragraphs are visually intimidating, tiring to read, and can be confusing. Break long paragraphs when you begin a new idea.

Organize information into short sections and sub-sections. Make your writing easier to scan and digest by using headers, subheads, numbered lists, and bullets. If you must include material that seems to interrupt the flow of the document, such as a long form or checklist, put it in an appendix. In a book of 200 pages, readers prefer 20 chapters that are 10 pages each over 5 chapters of 40 pages each.

Bullets and numbers help make lists more readable. If the order in which you present the points does not matter, use bullets. When information is sequential, such as in an article on the seven steps to specifying the right motionless mixer for your process, present the points in order and number each point.

When using a numbered list to structure an article, consider putting the number in the title or deck of your

Using gendered words and phrases is a sure way to make yourself appear dated and risk alienating your reader.

document to pique the reader's interest and grab their attention. Readers will be compelled to read your document to find out, for example, the seven steps necessary to specify a motionless mixer.

Although bulleted and numbered lists are easy to write and easy to read, do not overuse them. Documents that are page after page of bullets and numbers become monotonous, and many readers will simply not read the lists.

#9. Use gender-neutral language

Decades ago, engineering was a male-dominated profession, and in the 1980s, only 5.8% of engineers in the U.S. were women. However, this is no longer the case — today, about 18–20% of engineering students are female (6).

Because of this change in demographics, as well as the need to foster an inclusive work environment, engineers must avoid the use of sexist and gendered language. Using gendered words and phrases is a sure way to make yourself appear dated and risk alienating your reader.

Do not use words with the suffix “man,” such as policeman, weatherman, mailman, etc. Instead, use police officer, meteorologist, letter carrier, etc. This will make your writing more inclusive, as well as more accurate because these positions are held by both women and men.

When a sentence structure seems to force you to use gender-specific language, an easy solution is to rewrite the sentence to make the subject plural. Instead of “The customer pays no interest on his account balance,” rewrite this as “Customers pay no interest on their account balances.”

You may also use “he or she” and “him or her,” instead of indicating an individual gender in cases where you cannot simply make the subject plural. *CEP* follows the Associated Press (AP) style guidelines (with some modifications), and accepts the use of the singular “they” as a gender-neutral singular pronoun instead of using “he or she” and “him or her.”

#10. Use visuals and captions thoughtfully

Many engineers and technical writers use graphics from source documents to add visual interest to a white paper or technical article. If you do this, you must understand the contents of the graph, chart, or diagram well enough to write a meaningful and clear caption to accompany it. If you do not understand what the graphic is showing well enough to do that, either ask someone who does know or do not use it.

Always include meaningful captions that are full sen-

tences. According to industrial writer John Cole, captions get twice the readership as the main text. Capture important points in visuals with captions to help get your message across (7).

A good caption communicates more information than the image alone. If you show a photo of a horse, for example, including “horse” under the image is a label, not a caption. Offer an interesting piece of information instead, such as “The average horse weighs over 1,000 lb.”

Be aware that much of the content on the Internet, text as well as graphics, is copyright-protected. You cannot simply lift a graphic from the web and drop it into your document. You need to get the publisher's or author's permission in writing.

While text and artwork can be copyrighted, copyright law does not typically protect data and information. You can use data that you find online and draw your own graphs, bar charts, or pie charts. As a courtesy, list the source of the data in a footnote or endnote.

I am not an attorney, however, so the safest bet is either to get written permission to use someone else's material, and if you can't, then do not reprint it at all.

CEP

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NEILL WALLACE
ELEVEN 249

Shirk conventions and express your individuality.
You and your employer will benefit.

More than ever before, organizations need to continually adapt to remain viable. A company's ability to adapt is made possible by employees who are forward-thinking and capable of proactively implementing innovative ideas and solutions. To hire and retain this type of employee, many organizations have embraced innovative workspace formats to promote collaboration and creativity, as well as technology tools to improve communication and enable flexible work schedules. Organizations now realize that to succeed, they need personnel who are willing and able to break from established employee conventions.

From infancy, we are conditioned to accept and adopt conventions for behavior that blaze a path to a functioning society. Conventions serve as signals along the trail that give us clarity and keep us safe, but can also eliminate the need for individuality and creativity. This path is one of least resistance that only promises to lead us safely from childhood to adulthood and into the workplace.

Conventions in the workplace, including protocols for leadership, career management, and employee behavior, have undergone a dramatic makeover in recent decades. In many cases, employees are encouraged to take the unconventional path and offer an original perspective. As a result, standing out has become the new fitting in.

The evolving workplace

A generation ago, employees were expected to adhere to conventional workplace rules and norms — show up on time, do your job, do not disturb the status quo. In return for their obedience, conformity, and trust, employees were typically rewarded with job security, and after some number of years of dedication, a promotion. Career success came from fitting in (being loyal) and not from standing out (being a troublemaker).

The advent of computer technology has shifted workplace expectations, because employers now expect employees to work differently. Computers, the Internet, email, and smartphones increase access to information as well as the speed at which it is obtained. The ability to research and share information in seconds has overhauled workdays, and helped to make companies more global.

It is no coincidence that as computer technology has changed the way employees work, so, too, has employee behavior changed. The thought that an employee should sit obediently and quietly from 8 a.m. until 5 p.m. performing routine tasks in a cubicle under the surveillance of a supervisor now seems rather ridiculous.

Progressive employers have pulled back the curtain on company strategic decisions, and often ask employees to vocalize their opinions. The goal is no longer to get the job

done at all costs, but rather to accomplish reasonable goals that do not drain staff of energy or motivation. Employees are trusted and expected to manage their own workload. Working hours are more flexible and the work environment has been expanded to include remote locations (e.g., home, coffee shop, etc.).

Perhaps the biggest change to the workplace has been increased collaboration. Organizations have embraced a team-oriented approach that enhances communication, improves decision-making, and reduces errors. The added benefit is a more engaged and empowered workforce that is motivated and invested in the organization, which is vital

to a successful and competitive business.

The celebration and encouragement of employee individuality is a win-win for employees and companies. Employees gain valuable personal satisfaction, and their enhanced engagement enables companies to adapt, evolve, and profit.

The unconventional employee

An unconventional employee needs to understand his or her values, motivations, skills, strengths, and weaknesses, as well as have the courage to admit mistakes and learn from them. With this personal foundation, an unconventional employee can successfully function and collaborate as a member of a team, confidently challenge assumptions, and contribute to a creative and positive work environment.

Know yourself. Your personality — quirky and odd as it may be — is who you are, and to fight it is futile. More importantly, there is no reason to fight it. First though, you must know yourself — your strengths and weaknesses — to harness your individuality and use it as your greatest asset. Self-awareness allows you to shed restrictive career rules and conventions to rely on your individual judgments.

Part of self-awareness is also knowing what motivates you. For example, why do you go to work everyday? One practical answer is a paycheck to afford basic necessities like food and shelter. But beyond paying the rent, what inspires you to go to work? Discussions of inspiration are often reserved for creative pursuits, but inspiration is just as important for technical careers. It drives us to grow and find fulfillment in what we do, and as a result find success.

The foundation of being unconventional in the workplace is built upon your key strengths and values. Online self-assessments are available to help you discover your core values and strengths. Your human resources department should be able to direct you to reliable self-assessments, and if they cannot, explain why you think they should make this a priority. Companies want and need employees who know their strengths.

Overcome fear. Conventions are comforting because they mark a safe and

WORKPLACE TRENDS



Trend 1: Distribution of organizations

Organizations are becoming more widely distributed as functions are outsourced to service providers, work is relocated to lower-cost locations, responsibility is pushed lower down the organizational ladder, and pressure to reduce indirect costs increases.



Trend 2: Availability of enabling technologies and social collaboration tools

Technological tools for communicating, storing, and managing shared data are not new, but the ubiquity and low cost of these capabilities and devices are. These tools have been updated to allow workers to collaborate asynchronously to accommodate varied and flexible schedules.



Trend 3: Shortage of qualified workers

As the Baby Boomer generation retires, there may be a dearth of younger people available to replace them. These projections are controversial, as some believe that the Boomers will work longer to make up for losses to their portfolios during the Great Recession and because of extended life expectancies.



Trend 4: Demand for work flexibility

In the near future, organizations will have to compete for the best workers, so they will need to be more sensitive to the preferences of potential employees. Research reveals that workers desire more work flexibility, e.g., to choose how, when, and where to work.



Trend 5: Pressure for more sustainable organizations and workstyles

Consumers, employees, and governments are pressuring organizations to pay more attention to environmental sustainability because of increasing climate change regulations and heightened media attention on the topic. Organizations are responding through improved building efficiencies, revised product designs, recycling, and reuse.

Source: Ouye, J. A., "Five Trends That Are Dramatically Changing Work and the Workplace," Knoll Workplace Research (2011).

well-traveled path. We are conditioned to conform, so to suddenly abandon convention and embrace individuality is naturally frightening. In addition, despite changes at many organizations, some companies still rigidly cling to the past, making going against the grain even more difficult. Do not relinquish yourself to this fear, because falling short of your full potential is what is truly terrifying.

Conventions are also comforting because they protect us from blame, and sometimes responsibility. When you follow conventions and make a mistake or a poor decision, conventions are an easy scapegoat. Were you not just doing what your company expected you to do? The fear of accepting blame, perhaps more than anything else, is what keeps many of us from being ourselves in the workplace. Unfortunately, this shield from blame also separates us from our personal identity.

Instead of fearing the possibility of making a wrong decision or a mistake, be realistic and know that you will. Own it, learn from it, and become a better employee because of it. This is part of knowing yourself and being able to acknowledge your weaknesses. Be honest about your abilities, as well as your shortcomings, with your boss, your peers, and yourself. It will likely be the most liberating experience of your professional career.

Work collaboratively. Most people view upper management and supervisors as company leaders, and in many scenarios, this is true. Typically we assign leadership to those in charge, but leadership is also something displayed through a willingness and ability to guide and influence. All employees can be leaders in creating a culture of collaboration.

An unconventional individual who is a collaborating team player may sound like a contradiction, but it is certainly not. Think of a company's staff as a soccer team: The defenders prevent the opposing team from scoring, the midfielders transition play from defense to offense, and the attackers assist and score goals. The individual team members, with their unique skills and talents, form a single team capable of accomplishing a strategic goal. They are able to achieve that goal by applying their skills and collaborating.

To improve your organization's collaborative culture, ask your manager to create

goal-oriented workgroups and let the workgroups manage the tasks, rather than assign individual assignments to each employee. A collaborative workgroup can be formed to improve cross-functional work processes and to enhance involvement in the company's social responsibility efforts.

Look for new opportunities to collaborate. For example, form a workgroup focused on external environments that evaluates what is happening politically, socially, and technologically in your industry. This group will have to engage and collaborate with stakeholders, including clients, vendors, and contractors. This will extend the reach of your collaborative culture, and also provide your business

IMPLICATIONS OF WORKPLACE TRENDS



Implication 1: More collaborative workspaces

Offices are emphasizing collaborative workspaces and shared workstations, rather than solo work environments, such as cubicles and offices. Central offices will likely remain but may be repurposed as meeting or collaboration centers for critical face-to-face meetings and social events.



Implication 2: Challenge to keep workers engaged and connected

As workers become untethered to the office environment, it is more difficult for them to engage with colleagues, work groups, and organizations. Informal collaboration areas, video conferencing, and social media will be important tools for building the social trust necessary for team collaboration.



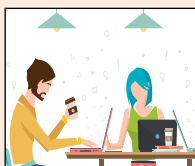
Implication 3: Difficulty of a changing culture

How we relate and use space is a part of our culture, so as workspaces change so does the culture. Organizations should involve workers in the planning process leading up to changes and allow them to have input on when, where, and how they work.



Implication 4: Adopting new work practices

A distributed workforce calls for new work practices to accommodate new and existing needs. It may not be possible to communicate informally or casually, such as stopping by a colleague's desk, so organizations need to formalize good working practices.



Implication 5: Emergence of alternative workplaces

Workplaces have diversified to include non-assigned workspaces, mobile furniture systems with wireless connections, satellite offices, and telecommuting, and they will likely continue to evolve. One emerging trend is the popularity of co-working centers that offer a community of similarly minded workers, as well as other benefits.

Source: Ouye, J. A., "Five Trends That Are Dramatically Changing Work and the Workplace," Knoll Workplace Research (2011).

leaders with valuable strategic information.

To maintain a positive collaborative culture, it is important to understand what collaboration is not. Collaboration is not attending countless meetings, being copied on every email, and constantly checking on the status of each task — that is micromanagement. A team member who micromanages in effect takes control of all the decision-making, which undermines collaborative efforts, destroys trust, and, rather than improve company culture, creates a more hostile work environment.

Don't act busy. Our workspace reflects how we want to be and are perceived. A busy workspace lets others know that we have a lot going on. Looking busy also elevates our sense of importance to the organization, and, by convention, busyness is job security.

However, a messy desk is just that — a mess. It does not illustrate how invaluable you are, but instead, is a visual indicator of a disorganized mind that is incapable of completing tasks. More importantly, all of the clutter projects a giant do-not-disturb sign, which is particularly detrimental to creating a culture of collaboration. At best, clutter communicates disorganization, and at worst, it says its owner is not a team player.

The hard part

Achieving a level of self-actualization that allows you to be unconventional in the workplace is the easy part. The hard part is doing this while accepting that there are still workplace rules to follow, tasks to accomplish, and mistakes that will happen.

Focus on the job. Your personal change does not suddenly make the workplace all about you, so do not expect to be promoted, get a pay raise, or not be admonished for making mistakes. Unconventional employees do not get to do whatever they want, whenever they want. You must still follow corporate policies and procedures and industry laws, and, ultimately, get the job done. Ignoring policies is not unconventional, it is foolish.

Say yes. In a collaborative environment, day-to-day activities generally involve a team, and in the interest of collaboration and teamwork, you may be asked to do things that are not necessarily part of your defined job

description. Assuming it is legal for you to do these tasks, do them. If you work by the mantra “doing that isn’t my job,” then you are not being a team player and should not expect others to step in and help you with your job.

Do it for the right reasons. If the only reason you are trying to stand out in the workplace is to get ahead, then you are setting yourself up for disappointment. As much as you might think you deserve more power, pay, or recognition, no employee is entitled to these things. Go to work because you are inspired by your job and enjoy it. If you do not actually enjoy your job and also are not getting the power, pay, and recognition you believe you deserve, then ask for it. If you still cannot advance, then leave.

Mistakes will happen. Even as you become more confident in your individualism, you will still likely make mistakes. You will totally miss the mark on an assignment, arrive late for an important meeting, or say something inappropriate. Know that mistakes will happen, and do not allow them to rattle you and derail your goals when they do.

Depending on the severity of your gaffe, it may get you reprimanded, embarrassed, or both. Do not take the consequences personally because it is not about you but about something you did. Simply acknowledge the mistake, learn from it, and move on.

Lead the change

You may work at an organization that is resistant to change. A lot of companies, especially those in conservative industries, operate with a conventional ethos. Often this stagnation occurs because of leadership who are reluctant to accept the reality of a changing world and workplace. Despite their reluctance, even companies in the most conservative industries will need to change and adapt to stay relevant. You are aware of this reality, so help lead the change.

Your new and unconventional approach to work will make you stand out. As you and your colleagues start to lead and your workplace begins to evolve, you will soon realize that what you are actually doing is fitting in. Fitting in will no longer mean suppressing your individuality, but instead, expressing yourself and utilizing your strengths as part of a team. You will fit into a dynamic and engaging organization — a success for both you and your employer.

CEP



AN UNCONVENTIONAL LEADER

Read the author's book, *An Unconventional Leader*, for an extended discussion of the benefits of abandoning convention in the workplace, as well as personal anecdotes and experiences from the author.

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www.neillwallace.com; Twitter: @neillwallace), a company that helps organizations establish and implement strategic goals. He is the author of *An Unconventional Leader* (2014), a best-selling career management book that rewrites the rules of office politics and leadership in the contemporary workplace.

Complete Your Capital Project Efficiently

GLEN ROSENTRATER
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Capital projects are complicated and can be fraught with all sorts of issues. Follow these guidelines for safe and efficient work — to avoid problems, maintain relationships, and ensure your success as a construction manager.

Many chemical engineers will find themselves responsible for managing a project and/or the construction of a capital project at some point in their career. Engineers who assume these roles may not have formal training in project management or construction management, and must instead rely on intuition and experience. This article provides guidance that will help you fulfill the role of construction manager for a capital project.

The role

Whether dealing with new construction on barren land (*i.e.*, a greenfield project) or the modification of an existing facility, a construction manager's responsibility is to ensure that the installation corresponds with the design. To accomplish this goal, the construction manager serves as a representative of the project team's intentions when interfacing with contractors, and must be prepared to answer questions that will invariably arise.

The in-house project team typically consists of: a construction manager; project manager; process engineer(s); environmental, health, and safety (EHS) engineer(s); maintenance representative(s); and production representative(s). The type, size, and importance of the project determine the team composition. Where appropriate, representatives from purchasing, research and development (R&D), and other departments, as well as representatives from other plants, may be included in the project team. For smaller projects, the project manager may assume many of these roles —

including that of the construction manager.

The in-house project team may be supplemented by a design firm team consisting of a project manager and various design leads from mechanical, electrical, structural, automation and control, and drafting disciplines. The design firm creates the drawings and technical scopes of work that govern the construction project.

With all of these parties involved, it is vital that the construction manager and project manager communicate. Although the construction manager is primarily concerned with the daily activities in the field and the progress of the contractors, it is important for the project manager to inform the construction manager of the overall intent of the project. Agree on a method to obtain and distribute the information necessary for the construction manager to represent the project team in the field. Establish a direct contact for questions and information, and a uniform method of communication (*e.g.*, phone, email, memo, etc.). One efficient communication method is for the construction manager to contact all parties directly via email and copy the project manager on this correspondence to maintain a written record.

Get organized

The project manager should clearly delineate the construction manager's duties. If this is incomplete or not provided, present a written construction management plan that includes duties, responsibilities, reports to be written, and reporting frequency to the project manager and other parties

involved. Request their suggestions and approval to confirm the plan.

The construction manager needs to have a comprehensive understanding of the project to be able to effectively relay information between the project team and the contractors. Collect any project information available, including the scope description, project plan, drawings, schedule, contractor scopes of work (SOWs), contractor quotes, equipment and contractor purchase orders (POs), etc.

To gain an overall understanding of the project, become familiar with these documents. For example, it is important to understand the project drawings, but it is equally important to understand their intent and purpose. A piping and instrumentation diagram (P&ID) depicts the hardware associated with a control scheme, but it does not show the actual control scheme or how the operators will interact with the system. Instead, the control scheme is explained in the automation specification document. Memorizing the information and drawings associated with a project is unrealistic, but knowing where to locate information is essential.

Additionally, familiarity with the project and documentation will help you visualize the practicality of the installation. This includes the purpose and uses of the area and equipment, and how operators will work and move throughout the area. New equipment and structures will need to safely accommodate operators and equipment. The hardware and programming for control equipment will also need to be available and accessible to operators.

To avoid last-minute surprises, become well versed in the schedule and scope details two weeks in advance of deadlines. This expertise can help you anticipate problems in the field. Bring these issues to the attention of the project manager for a discussion, suggestion, or resolution.

Conduct coordination meetings

Hold coordination meetings with contractors and, if the project takes place at an existing facility, plant personnel. The first meeting should be the project kickoff meeting. All of the contractors should be present to discuss their work and how they plan to interact with each other. The primary goal of this meeting is for the contractors to be aware of who else will be working near them, what work will be done, and how

that work may affect them. Contractors are typically used to working side-by-side, but will appreciate the opportunity to share information.

After the kickoff meeting, hold regularly scheduled coordination meetings to keep contractors aware of current work plans, as well as to introduce any new contractors. Include pertinent plant personnel as necessary.

The frequency of these meetings is determined by the size and complexity of the project, or by personal preference. A daily coordination meeting with the contractor foremen can be helpful when held at an opportune time, such as after the contractor's regularly scheduled morning break. Request a brief description of the work that is planned for the near future to ensure that the appropriate work permits are obtained. There may be little information to relay, but it is important to provide parties a convenient platform to discuss any issues, no matter how small. On most days, this meeting might last 15 min or less, but it will highlight issues that could cause slowdowns or stoppages.

Maintain a request-for-information log

Coordination meetings present an opportunity for questions. Some of the questions will be technical and will require consultation with an expert, such as an engineer, designer, production manager, or maintenance personnel.

Create a request-for-information (RFI) log by organizing the questions in a spreadsheet (Table 1). Include the date of the query and who asked the question, as well as the name of the individual queried and the date of the inquiry. Distribute this list to the project team and any other responsible parties each week. This weekly reminder is a powerful organizational tool that ensures questions are answered and not forgotten. When a question is answered, record the date and move this entry to a separate page documenting closed items.

Many questions can be answered by examining the job materials, SOWs, and drawings. Inspect the appropriate document with the contractor to ensure there is no miscommunication of the question or answer. If the answer cannot be found in these materials, then there is a shortcoming in the documentation that needs to be addressed. This should be recorded in the RFI log.

Table 1. Maintain a request-for-information (RFI) log to document questions that arise and their answers.

Questioner, Affiliation	Submission Date	Question	Responder, Affiliation	Response Date	Response
John Doe, BTS	4/14/2014	What piping spec should be used for potable water?	Glen Rosentrater, BSI	4/15/2014	Spec 120
Jane Doe, FBC	4/16/2014	Does pump P-2064 get a concrete pad?	Glen Rosentrater, BSI	4/16/2014	Yes. Use the details of pump P-2065's pad
Jordan Doe, IEC	4/17/2014	Who will supply the pump starters?	Glen Rosentrater, BSI	4/18/2014	IEC

Inform facility personnel

If the project is at an existing plant, production and maintenance representatives should be kept informed of contractor plans. Some work permits will require special procedures that could impact them. Any potentially affected parties should be notified in advance to allow them to adjust their work plans.

Although most permits will not affect operating procedures, it is still prudent to inform plant personnel of the work by attending production meetings and by sending out a daily email that details the work to be done the following day. The emails should include the location of the work, number of contractors, equipment to be used, permits required, permit issuer, and any other pertinent information.

Use these emails as a detailed construction log. Annotate these in the field as work progresses, and log them as a daily record of the work performed.

Understand work permits

Most plants have six types of permitting: safe work, hot work, line break, confined space, lockout/tagout, and elevated work. Some plants may combine two or more of these into a

single permit, while others issue them separately.

The construction manager is usually not responsible for issuing or signing work permits. However, it is important to become an expert in the company's permitting procedures. Consult the EHS department for information and guidance.

Production and maintenance foremen are generally responsible for issuing permits, but may not be knowledgeable about the trade receiving the permit or the details of the work to be performed. This discontinuity can result in an accident if it is not properly managed. The construction manager should serve as an expert, and provide the foreman with any necessary information about the work or the contractors to ensure that the permit is correctly and appropriately issued.

Enforce site safety

The construction manager is expected to enforce site safety. Contractors who are not familiar with site-specific safety requirements look to the construction manager to set the tone, and generally work to the level of safety expected by the construction manager.

Become an expert in the site's safety policy and make

TYPES OF WORK PERMITS

Safe work involves mechanically coupling or bolting equipment, as well as moving equipment at grade, either manually or with the aid of equipment. For example, a contractor installing threaded pipe or running conduit requires a safe work permit.

Hot work is defined differently by different facilities. Most plants consider any process that can create a spark or heat to be hot work, including welding, torching, cutting metal, grinding, drilling, or live electrical work. An area where hot work is to be performed needs to be checked with a gas detector to ensure that no explosive vapors are present and that flammable and combustible materials are stored sufficiently far away. Plan this type of work well in advance, and, when necessary, present the plan to production and maintenance personnel for verification.

Line break involves breaking a line by unbolting, unscrewing, or cutting. The most important factor is the contents, or previous contents (if the line is thought to be empty), of the line. Was the material hazardous? Is the line empty? If so, how has this been verified? These questions need to be answered in a meeting with production, maintenance, and EHS personnel. These groups should help in formulating a work plan and recommending the proper personal protective equipment (PPE) for the scenario.

Confined space is any work that removes the worker from the ambient environment — for example, work inside a vessel or in a trench that is more than 4 ft deep. This type of work requires extensive planning to minimize risk, and should be identified well in advance of the scheduled date. A temporary ventilation system may have

to be designed and installed to ensure a breathable or nonexplosive atmosphere. Special cleaning procedures may need to be carried out prior to entry. A rescue team must be assembled or identified, and incorporated in any planning meetings.

Lockout/tagout requires isolating hazardous energy sources and disabling equipment to prevent unintentional startup or a release of energy that could result in injury. This permit is typically required as part of line break or confined space permitting.

Elevated work is work above grade or work that uses a crane. Jobs that are performed from a scaffold, erecting a scaffold, and working from a lift are examples of elevated work. Any mobile equipment, such as cranes and lifts, must be operated by certified personnel. Some plants require a lift analysis prior to crane use.



Career Catalyst

sure it is completely clear to all contractors. Require each contractor to have a short safety meeting at the beginning of each day. Attend at least one (preferably more) of these meetings daily, and each week try to be involved in at least one meeting of each of the contractors that will perform work that week.

Visit the construction site at least four times a day, and vary the times of your visits. Inspect for adherence to the safety policy. Also use this time to check on construction progress and adherence to the design. Call attention to even minor infractions, because these small issues can grow into larger problems.

Monitor the schedule

The schedule should be accepted by the project manager and the contractors. Weekly schedules that have clearly defined tasks and goals are useful for tracking and monitoring progress.

A detailed schedule for each contractor should include project line items each week. The contractors should provide these schedules. If they do not provide a schedule, work with the contractor and project manager to create one. It is easiest to obtain these schedules before the PO is issued.

Work with any contractor that is not progressing in accordance with the weekly schedule to determine why there is a discrepancy. Determine the cause and devise a solution to get the work back on track to meet milestones.

Help contractors work efficiently

By reviewing drawings and plans two weeks ahead of construction and by communicating with contractors regularly, potential problems should surface well in advance. Problems can be resolved easily on drawings and in plans, but are difficult to remedy after construction has begun and will undoubtedly lead to slowdowns or stoppages. Thorough planning ensures that work is conducted as efficiently as possible, without frequent stops and starts.

To help contractors work more efficiently, check on equipment deliveries and compare them to the bid. If they differ, make sure an expediting program is established — negotiate for better delivery, or, if necessary, pay an expedition premium. Once deliveries are confirmed, notify the contractor.

When the equipment arrives, compare the equipment manuals with the installation design to ensure that they correspond. If they do not, notify the parties responsible to remediate any discrepancies as soon as possible.

Identify tie-in points and other issues that will require shutdowns or coordination with production and maintenance. Electrical and mechanical tie-ins require that the appropriate facility personnel and sometimes the utilities be notified of the work two weeks or more in advance. It is judicious to

schedule all tie-ins at the beginning of the project.

It is also the responsibility of the construction manager to discuss and receive approval for the placement of heavy equipment, scaffolding, laydown areas, fabrication areas, trailers, and the use of company restrooms and lunchrooms by the contractor(s). This should be done during the job bidding process, but, if it was not, resolve this as soon as possible.

Coordinate with the project manager

Notify the project manager of progress during a daily phone call or meeting. Discuss any additional work or materials that are required, and present a time-and-materials-not-to-exceed (T&MNTE) price, which is an agreed-upon maximum time and price that should not be surpassed during the project.

Do not personally authorize any work without the project manager's approval. Even if the construction manager is cleared to authorize work for a certain dollar amount, check all additional costs and work with the project manager to gain approval. Daily contact with the project manager should present a suitable opportunity to receive authorization, and will not slow down work.

Keep a record of changes and share this record with the project manager. Create a numbered list in a spreadsheet of each change order, submission date, description, cost, status, and approval date. When the scope of the contract is changed (e.g., a concrete pump pad is widened by 1 ft to accommodate a larger-than-expected pump) and additional funds are requested, record this in the change-order log.

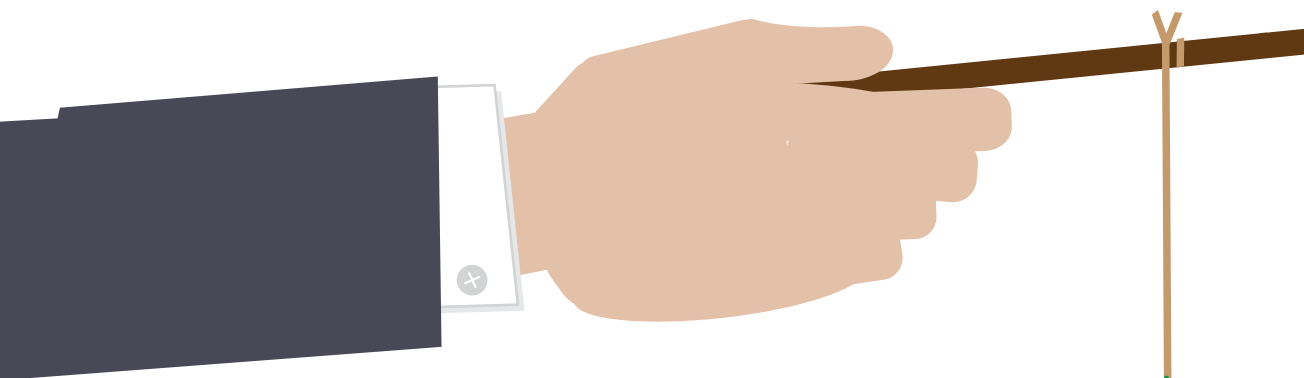
To formally record and communicate progress, write a monthly status report. Include a description of the work to be performed in the following month. Issue this report to the project manager and other key stakeholders.

Foster morale and a professional attitude

All projects are processes that are being done for the first time, which means problems will arise and mistakes will be made. Focus on solutions rather than problems. This will help to foster morale and a professional attitude among the project team members and the contractors. It will also help complete the capital project efficiently and maintain colleague relationships.

CEP

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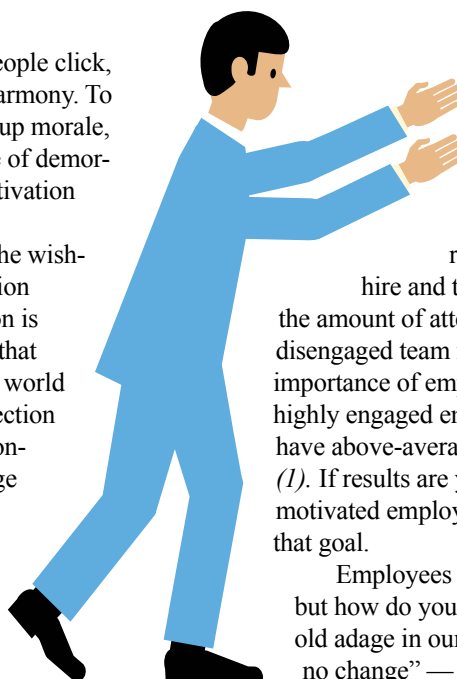
Cultivate and Sustain Motivation

Motivation can be nebulous, appearing and then simply disappearing. In a team environment, it is vital that you ensure it stays put to drive results and reach goals.

CHRIS HELBLING
EXPERITEC, INC.

Something almost magical happens when people click, ideas flow, and results surge — a perfect harmony. To the contrary, lack of team synergy, low group morale, and no tangible outcomes breed a palpable sense of demoralization within a team, and often signal that motivation has been lost.

As a leader, you might be inclined to check the wish-washy, philosophical jargon at the door. Motivation may not feel relevant or practical. But, motivation is critical to achieving a harmonious team balance that produces results. Project teams, especially in the world of engineering, often comprise a diverse cross-section of stakeholders. It can be difficult enough to reconcile incompatible cultures and overcome language barriers, but managing conflicting personalities and communication styles presents an entirely different set of challenges. The team will look to you for clarity and direction. This article discusses why motivation matters and offers guidance on how to achieve it with your team.



What is motivation?

More than 70% of employees become disengaged every day — even to the point of contemplating quitting (1). Considering the resources and energy required to hire and train just one individual, let alone the amount of attention required to offset just one disengaged team member, it is easy to see the importance of employee engagement. Furthermore, highly engaged employees are 38% more likely to have above-average productivity than their peers (1). If results are your goal, deeply engaged and motivated employees are your capital for achieving that goal.

Employees must work to achieve results, but how do you get employees to do that? An old adage in our sales department is “no pain, no change” — implying that without sufficient

reason to alter the process, a customer will not spend money to make a change. This maxim can be generalized to encompass all human behavior: “no motivation, no action.”

We are continually evaluating our behaviors against needs, wants, desires, obligations, and neural forces (some of which are beyond our immediate control). Maslow’s Hierarchy of Needs (2) has informed the basis of motivational psychology for nearly 60 years and attempts to define a path that people take to fulfillment (Figure 1).

Maslow was on the right track with his contention that people are inherently predisposed to provide for their most basic needs (e.g., physiological needs, security, etc.). However, he did not account for a fundamental oddity of human nature — we are irrational and illogical creatures. If Maslow were correct, people would not run into burning buildings, jump out of airplanes, or leave high-paying jobs. This critical fault undermines the model and challenges academics and leaders to find new ways to address motivation.

The hierarchy misses the mark on two significant points:

- the journey to self-actualization is not necessarily linear
- yes, people can be selfish, self-serving creatures, but

we will undergo some degree of suffering to accomplish a goal for which we are dedicated.

These flaws are telling. They make it clear that to encourage the right behaviors, we need to first understand the values of each individual and then establish the right environment to use those values as a motivational force for success. They also suggest that the mark of successful leaders may reside in their ability to leverage both internal and external factors that shape employee behavior.

Motivation 1.0

It is clear that we have been relying on a flawed approach to motivation, but how has that manifested in the workplace? A carrot-and-stick method has been used as a motivational tool for generations and, unfortunately, still permeates business culture.

This traditional view of motivation — let’s call it Motivation 1.0 — is predicated on the notion that the primary function of resource managers is to ensure that every part of the organization is performing at or above its required potential to ensure collective success, and that managers have an array of bureaucratic tools (e.g., quotas, bonuses, demerits, performance reviews) at their disposal to ensure compliance. In practice, this means that results are achieved or not

achieved, and personnel are either rewarded or punished.

This model has worked. Tycoons made fortunes running their empires in precisely this manner. But, success comes at a price, and Motivation 1.0 also had some unintended consequences. It can prove difficult to quantify, in hindsight, the opportunity losses in terms of employee burnout, distraction, and inefficiency that result from this management style, but the dollars are real. Given an opportunity to work for an employer offering more accommodating conditions or a nominal pay increase, personnel will jump ship. Environments managed in this way are also characterized by a void of empowered accountability and creative and critical thought, which are vital in a competitive world driven by innovation.

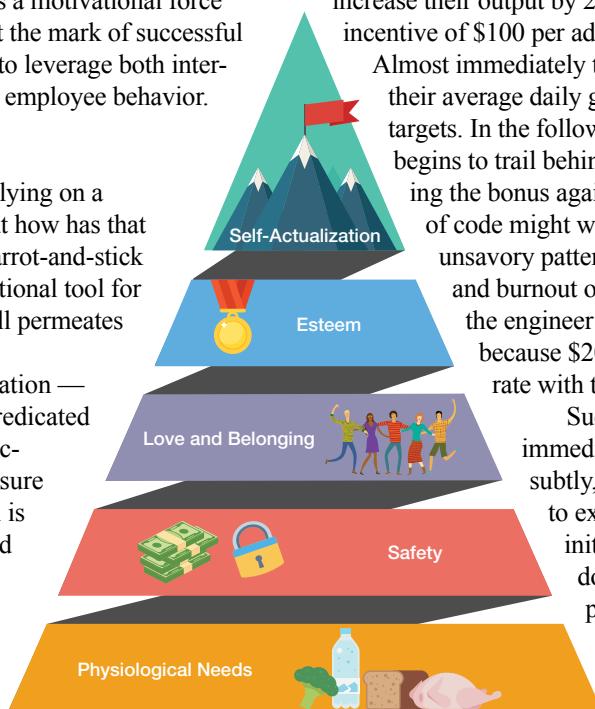
The advent of distributed control, digital transformation, and machine learning requires a new managerial style. Monotonous, dehumanized, and decentralized tasks will be less and less the responsibility of personnel as automation advances. These actions are easy to motivate with the carrot-and-stick method, but those that are nuanced and empirical are less so. As business management has evolved, we have learned that very little human behavior transpires without emotional rationalization.

To understand how Motivation 1.0 fails today, consider an electrical engineer who enjoys software programming, from which they gain immense satisfaction and pride. To increase their output by 20%, the programmer is given an incentive of \$100 per additional 10 lines of code per day.

Almost immediately the programmer begins to exceed their average daily goal, helping to boost overall targets. In the following quarter, however, their output begins to trail behind past peak performance. Raising the bonus again to \$200 per additional 10 lines of code might work initially, but it perpetuates an unsavory pattern of monthly declines in output and burnout of a star performer. Eventually, the engineer will stop increasing their output because \$200 will no longer seem commensurate with the amount of effort.

Such incentives almost always afford immediate surges of activity. But, more subtly, this system conditions employees to expect payment for work that they initially enjoyed or were motivated to do for other reasons. A newly forged precedent to associate purpose and gratification with a rewards system has replaced pleasure that organically fueled their technical work.

As we continue to uncover the damaging effects of mis-



▲ **Figure 1.** Maslow’s Hierarchy of Needs is depicted as a pyramid. Each source of motivation must be satisfied before the tier above it can be tackled. Image adapted from (2).

applied rewards systems on individual performance and team morale, it has become clear that a new era of intrinsic motivation is necessary to achieve sustainable results and promote employee well-being and creativity.

Motivation 2.0

Self-determination theory (SDT), which considers inherent growth tendencies and innate psychological needs, offers a lens for looking at intrinsic and extrinsic motivators. Sovereignty over our time (autonomy), perceived success and growth in a given task (mastery), and the overall meaningfulness of that task (purpose) strongly correlate to how intensely we desire to continue and grow that behavior. When we have control over our own time, are in a position to develop and feel fulfilled, and are able to do so under a charter that aligns with our own values and beliefs, we become intrinsically motivated beyond the boundary of extrinsic rewards (Figure 2).

Motivation 2.0 is inspired by SDT in the same way that Motivation 1.0 was built on the Hierarchy of Needs. This new guiding principle requires looking at the individual, the leader, and the team to fully understand motivation.

The individual

Getting the right people in the right seats on your bus, and diligently removing the wrong ones at every stop, allows you to forget about creating motivation and instead focus on cultivating and sustaining it. Personnel can be taught many things such as discipline of process and procedure (which is critical), but things such as discipline

of character, ethics, and beliefs are not easily taught. These characteristics form the basis of a trustworthy individual who can be granted autonomy and the resources to intrinsically seek success.

An intense and rigorous hiring process may be cumbersome, but the true price of a hastily vetted employee is not fully realized until it dissolves. Hiring is the most opportune time to manipulate the constitution of your team. At this critical point, you have the power to control how that individual will integrate into the team.

Make it a priority to hire top talent who also fit the functional role. Unproductive and disengaged employees can dilute overall team performance, so hiring should be a shared responsibility. Ask human resources and talent management how candidates are recruited and onboarded. Find out what initially attracted the candidate to the company, and what questions are being asked to discern a mutually beneficial business fit.

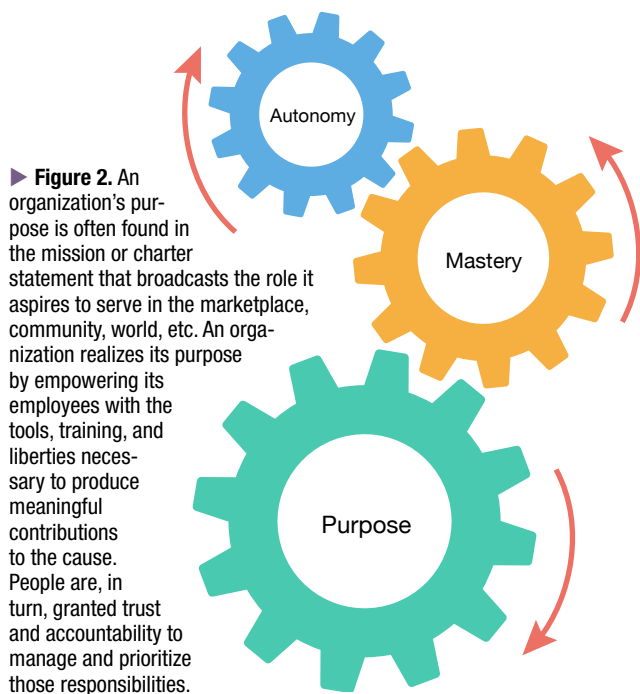
Encourage your team to share aspects of the company that inspire them to help build profiles of top performers. Each employee should be an ambassador and practitioner of the company's mission statement, which will help attract more talented and motivated contributors. Provide employees with the resources and materials that support their ability to aid the organization's goals. The most impactful thing that individuals in a team and company can do to sustain motivation is to be engaged and outspoken.

The leader

Keeping the distinct personalities that form a team working in unison is the function of the manager or team leader. Leaders are also responsible for shepherding motivation within their respective teams. This might involve being the voice of the team to ensure ready access and investment in the tools and training necessary for mastery and autonomy, and ultimately success.

The modern leader guides their team through a visualized path to success by helping to prioritize tasks, eliminate obstacles, and encourage progress through rewards, rather than realizing performance and setting goals (3). This tenet informs the situational leadership approach, which gives managers a robust template for moderating their leadership style based on each employee's stage of development to reflect the dynamic nature of the workplace (4).

When leaders base their professional relationships on this model, interactions can proceed with clarity and discipline, allowing employees to achieve the desired output and maturity level. Leaders are able to more effectively solicit behavioral improvement through directing, coaching, supporting, or delegating (Figure 3). As employees become more confident and competent in their functions, leaders are able to mirror that progression by shifting from a



training instructor role to that of a mentor persona. Trust and autonomy are exchanged as employees mature in their craft and accountability.

The situational leadership model implies that leaders must constantly adjust to different situations, sometimes even employing a combination of techniques, to deal with different personalities and team conflicts. The model provides a framework for managers to counsel their team. As people enter and exit the organization and employees progress, leaders have a tool to assess skillsets and adjust the environment to persistently motivate the team.

Leaders need the right information to map employees' skills and strengths against the situational leadership curve. On-the-job competency evaluations, personality assessments, and strengths and aptitude tests can provide invaluable insights into team interactions and inform leadership approaches suited to each employee.

Acknowledgment of desired behaviors and results in the form of direct, timely, and relevant feedback is a powerful motivator. Such feedback is essential for employees to know how their interpretation of team goals manifests in their output. Feedback becomes the primary conduit to communicate performance versus expectations and personnel development plans. Keep in mind that the more that you practice it, the better you will be at doing it.

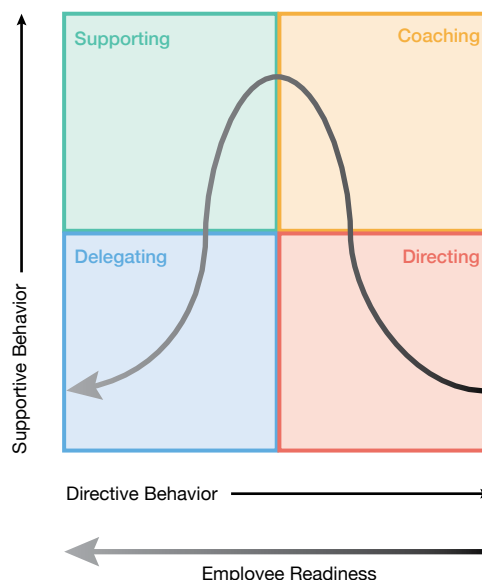
The team

Culture, core values, and mission statement are the responsibility of the entire team and/or company, but these vital aspects of motivation require buy-in from individuals and leaders. The relationship between the team, leaders, and individuals follows a cascading model. Internal drivers pass through leaders' situational management styles and the team environment, while external drivers that govern employee behavior (e.g., policies, procedures, financial incentives) propagate back down through the organization (Figure 4). This model accounts for the individual's degree of choice for their behavior. It illustrates that the primary role of a team or organization is to formalize the social and cognitive rules agreed to by individuals and leaders (5).

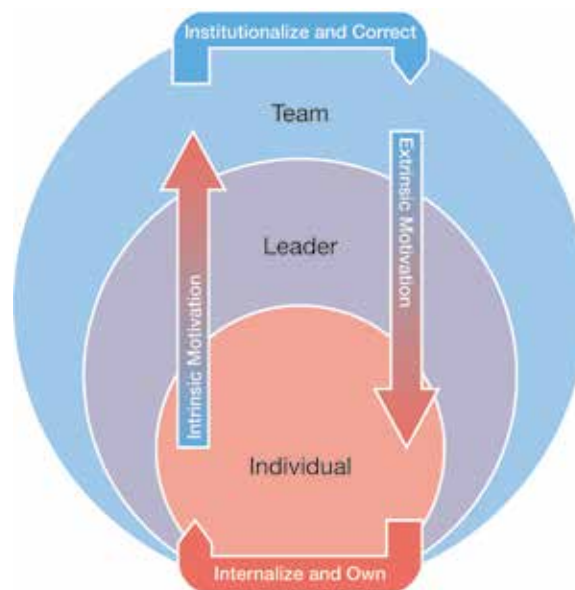
Extrinsic motivators that propagate down to individuals can be regulated in either a controlled or self-determined way. These two fascinating concepts close the loop between intrinsic and extrinsic motivators. When people encounter pain or strife when working toward a goal (e.g., complying with an external request), cognitive dissonance permits that person to internalize some sense of ownership for the outcome to rationalize the experience. People also possess an inherent tendency to internalize the regulation of a behavior that was originally under an external control. Humans crave control and will relentlessly seek to regain it.

The team that follows the tenants of Motivation 2.0

challenges and empowers individuals with training and additional responsibilities, and then gives them the freedom to pioneer and add value. There is a stark difference, however, between catering to and nurturing individuals. Leaders should avoid being too impressionable by the compulsions



▲ **Figure 3.** Successful leaders adapt their methods relative to the person or group being influenced, as well as the task at hand. Leaders can determine the appropriate approach for a given situation based on the maturity of the employee.



▲ **Figure 4.** The relationship between individuals, leaders, and the team can be represented by nested circles. Leaders manage internal motivators of each individual, which propagate to the entire team environment. External motivators that govern the team cascade back through leaders and affect employee behavior and motivation.

of the team. Leaders who overly indulge their staff may find themselves at the precipice of a slippery slope of false precedents and misapplied rewards.

Putting it together

It takes the right individuals, leadership skills, and team environment to foster motivation. Whether you are a leader or a team member, follow these guidelines to help motivate your team.

Communicate, communicate, communicate. It is amazing how many problems in life and work can be solved by effective communication. Open dialogue eradicates misunderstandings and allows people to deal objectively to circumvent the need for assumptions. Communication signals intent, and it also helps to align purpose and function, as well as boost morale. Alignment to personal motivators is pivotal in building intrinsic motivation.

Say yes to happy hour. Technology has become a vital part of the workplace, but it is a tool, not an end. A step counter does not guarantee you will lose 20 pounds, but it empowers you with information and a means to track progress. Technology can unite people, transcending organizational, geographical, and even cultural divides to enable elevated levels of workforce collaboration. Nevertheless, technology is no substitute for human contact.

Find as many excuses as possible to bring together your team in a fun and meaningful way. Breakfast clubs, luncheons, book clubs, and happy hours all help to unite people and build rapport. Employees feel more motivated to help individuals and teams that they trust, where they feel a personal connection and a vested sense of accountability. Trust is the bedrock of a productive and successful team, and without it, there will be no healthy exchange of ideas (6).

Make work fun. The fictional character Tom Sawyer was able to convince an entire band of children to assume his chore of whitewashing a picket fence. He was a genius motivational psychologist because he appealed to the joy and self-actualization of the task, passing something completely mundane off as playful and desirable. Like Tom, find ways to bring fun and energy back to the workplace by appealing to the reasons individuals originally joined the team or profession. The work, not the financial or social recognition, becomes the reward. If you find this challenging because there are no underlying intrinsic motivators, find small ways to make the job more rewarding through competitions, games, or camaraderie.

Do more with more. When motivated employees compete and thrive at work, a culture of star performers instills more engagement, more collaboration, and more productivity. Motivated employees experience intense feelings of belonging and pleasure in their work, and they work to advance the team's overall goals.

Your strongest defense to engagement attrition is a formidable offense of onboarding quality candidates and training star performers with programs and benchmarks. After you have the right people on the bus, ensure employees know the realities of the job and are equipped with the tools, training, and coaching necessary to build autonomy and mastery.

Embrace diversity. NASA recruits skillsets ranging from musicians, theater majors, political scientists, and biologists. People from different backgrounds and dispositions bring varied perspectives and new ways of solving old problems. They also have more diverse intrinsic motivators. The more diverse a group is, the more rewards the team will reap in cultivating that team's intrinsic motivation.

Reward thoughtfully. Actions have consequences, but so do rewards. Bonuses, trophies, sales quotas, after-school snacks, etc. are all appropriate means of recognizing effort, and each has its place in life. Smart leaders understand that sustainable results hinge not on the incentive itself, however, but rather on the individual's capacity and desire to excel. Leaders must consider the expectations and impressions set by any reward system. Small, random, and genuine rewards that convey appreciation are a healthy way to augment performance goals based solely on output.

Ring the bell. Start thinking about value as more than just commercial return on investment, and praise individuals

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that add value in a range of ways. Be liberal with feedback and praise, and never miss an opportunity to recognize a team member's contribution. For any type of recognition or praise to be effective, it must be timely, specific, and sincere. Be honest and phrase your remarks carefully, because poorly delivered remarks can actually serve to make others feel less motivated.

Reinforce job fit, satisfaction, and purpose. People are not profit-maximizing machines. Hence, most of our major life decisions are usually prompted less by income and more by happiness, satisfaction, and fulfillment. Early attention to employee basic needs and financial motivators can prevent employees from feeling dissatisfied and underappreciated. Do not, however, rely solely on this to instill intrinsic motivation. Remember that purpose, mastery, and autonomy are more reliable supports for motivation. Reinforce job fit, satisfaction, and purpose to make employees feel secure and invigorated by their work environment.

Practice what you preach. Evaluate your own work styles and strengths. This understanding can help you to anticipate how you will react to coaching from superiors or

mentors, as well as how you will influence others.

You owe it to yourself and to your team to know your own competencies and intrinsic motivators. Maintain a personal development plan that models the format and cadences of your employees to ensure that accountability transcends organizational lines and establishes credibility and trust.

In closing

Employees with high intrinsic motivation possess an innate passion for their work, embrace challenges and new experiences, remain optimistic in the face of failure, and inspire others to reach new heights. Motivation plays a critical role in not only keeping employees mentally engaged in their work, but also feeling more productive and fulfilled in their personal lives. The evidence is clear that this is a venture worthy of your time and focus. The task now is to indoctrinate those around you in the merits of workforce motivation. By presenting it in a pragmatic and tangible way, you can help your colleagues move beyond an esoteric understanding of the concept and start practicing it at work.

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Globalize Your Career

Globalization has become unavoidable for businesses, organizations, and even individuals who must now extend their reach internationally to be successful. Political entities around the world are split on the idea — either decrying or heralding its implications on trade, supply chains, and efficiency. This discord can be intimidating to students and young professionals. However, globalization is inevitable and young people need to consider how it affects them.

Fortunately, my involvement in AIChE and other organizations exposed me to the concept of globalization while I was still in school. As I began my job search during my senior year, I searched for positions with companies that valued this trend and were active participants on the global stage. I eventually accepted a position with a German specialty chemicals company that boasts over 35,000 employees worldwide. At the time, I did not expect that my global philosophy would escalate as far as it did. After being with the company less than three years, I was offered a transfer assignment to a site in Germany. Fast-forward two years into the transfer, and I have no regrets about the move.

Sprichst du Deutsch, oder? Ja, klar! Or, well, at least now I speak German. It is undeniably daunting to move to a country where you do not speak the official language, and surviving a workday in said language is exhausting at first. You may worry that you don't know how to say something, but in time you'll realize that you should not get hung up, but simply phrase the thought differently. For example, you might want to say to your colleagues: "The other week I took a road trip between Munich, Vienna, and Prague with a childhood friend." However, the sentence is too complicated for you to construct. Instead of staying quiet, express it in a different way, such as: "Two weeks earlier a friend was visiting Europe. We drove by car between Munich, Vienna, and Prague. We have been friends since kindergarten." Focusing first on content and later on style is the key to immersive language learning success, and you may find it is far more effective than classes.

Most large cities have contingencies of expats that can be a great source of friendship and guidance. In fact, hours after landing in Düsseldorf, I passed a sign in the center of town advertising an English-speaking expat social event. At the time, and even now, it seemed a little too convenient, but it was exactly what I needed, and I still have

friends I met that evening. Your fellow expats can be a helpful source of information for navigating unfamiliar local protocols, from visa paperwork to train pass subscriptions.

Be sure to also branch out from the comfort of an English-speaking social circle. You can unlock a new dimension of living and working internationally by improving your language skills to a point where you are comfortable exchanging thoughts with a native speaker. Give yourself time to speak, rather than feeling unnecessarily rushed.

Citizens of the internet. Thankfully, in 2018, the internet has removed most of the hurdles and barriers once associated with moving to a different country or continent. You can stay connected to friends and family, mostly for free, through resources such as Whatsapp, Google Voice, Google Hangouts, and, of course, Facebook. Beyond your social spheres, banking, paying bills, and transferring currency can all be accomplished for little to no charge online, with resources like OFX and Google Wallet.

Live spherically. The Italian director and screenwriter Federico Fellini is quoted as saying, "You have to live spherically — in many directions. Never lose your childish enthusiasm — and things will come your way." If you are considering working abroad but are feeling hindered by hang-ups and reservations, take this advice! As a young professional or recent graduate, you are better poised than ever to take on the challenge. As your career and life progress, you'll inevitably become more tied to specific places, people, or services, making moving across the world even more challenging.

Relocating through a company also removes many unknown factors. Residence and work visa applications are handled internally, housing search assistance is often provided, and services for filing your taxes are typically available. Keep in mind that U.S. citizens must file taxes in their country of residence and the U.S. (this rule is unique to only the U.S. and Eritrea).

While I don't know exactly where my path will lead after my assignment in Germany, the skills, new ways of thinking, and exposure to the global community have positioned me for exciting new opportunities. Living and working in Germany has given me the confidence to look forward to any challenge and declare, as the German Chancellor Angela Merkel would, "Wir schaffen das!" (Yes we can!).





Should You Pursue PE Licensure?

Becoming licensed as a Professional Engineer (PE) takes dedication. Having a PE after your name signals to employers and clients that you have competence in your field and helps set you apart from your competitors.

Although the requirements to become a PE vary from state to state, the basic steps remain the same throughout the U.S. First, you must earn a four-year degree in engineering from an accredited college or university, and then you must pass the Fundamentals of Engineering (FE) exam. You must complete four years of engineering experience under a licensed PE before you can take the Principles and Practice of Engineering (PE) exam. If you pass the PE exam, you can then obtain a license from your state's licensing board. To retain that license, PEs must maintain and improve their skills by fulfilling continuing education requirements.

"I have been a PE for 14 years, and I believe that the PE license is a very important credential to be aware of and pursue," says Jean Andino, an associate professor of chemical engineering at Arizona State Univ. (ASU). "Licensing provides that 'stamp of approval.' I doubt that anyone would consider going to a doctor that was not board certified or a lawyer that had not passed the bar exam," she says. "Thus, it follows that the engineering profession, a profession that impacts lives, would also have a licensing option."

The National Council of Examiners for Engineering and Surveying (NCEES) administers the exams and keeps records of those engineers who are licensed. You can purchase and download exam prep materials — such as practice exams and the supplied-reference handbook — directly from the NCEES website (www.ncees.org). Reviewing the handbook before you take the FE or PE exam can help you become familiar with the charts, formulas, tables, and other reference information provided.

Why become a PE? A PE license may be required for some engineers, but for others, obtaining PE licensure is a personal goal. Only a licensed engineer may prepare, seal, and submit engineering plans and drawings to a public authority for approval. For this reason, many chemical engineers believe that having a PE license is only valuable for those in the design or consulting fields.

However, there are many ChEs who believe holding a PE license sets you apart from other engineers. Many employers view having a PE on staff as a benefit. Going through the rigorous testing process shows that you have put time and effort into understanding the responsibilities and implications of your role as an engineer.

You never know when having a PE license could be beneficial, so many engineers recommend starting the

process by taking the FE exam as early as possible. This was the approach taken by Mikel Goldblatt, Senior Engineering Consultant at Solenis. "While I was in school, the prevailing thought was that ChEs don't need to be licensed — that was for civil engineers," he says. "One professor encouraged seniors to take the FE exam, just in case. I took that advice. That turned out to be very fortunate for me, as twenty years into my career, I found myself starting my own consulting business," he says. "The PE, while not used to stamp engineering drawings, provided a sign of credibility to clients."

Take the FE exam early. The first step toward obtaining your PE is to take the FE exam. It is best to do this while you are still in school or soon after — but even if you graduated more than a decade ago, it's never too late.

Adam Crosswhite, a process engineer for Applied Chemical Technology, Inc., believes that all chemical engineers should take the FE exam after graduating. "Taking the FE exam immediately upon graduating, while most of the information is still fresh in your mind, is much easier than waiting until years later to do so," he says. "I did not take the FE exam upon graduation, and a few years later I decided to obtain my PE license. If I could do that over, I would have taken the FE exam immediately after graduating to save myself some trouble," Crosswhite says.

It's important for all graduating seniors to take the FE exam, because it's impossible to know the future — you may be required to attain a PE for a job down the road.

Andino is a volunteer for the NCEES, and is on the committee that writes the environmental FE exam. She feels so strongly about licensing that she incorporates a small module on engineering licensing in the freshmen engineering orientation class she teaches at ASU. "I try to remind young engineers that licensure is helpful to distinguish them from other candidates," she states.

"I recommend that seniors take the FE exam as the first step towards being licensed," says Andino. "I absolutely do not hold review or study sessions for the exams, but I do encourage my students to download the free electronic FE reference manual from the NCEES website and learn to work with a simple scientific calculator. This helps prepare students for the FE given the strict calculator rules," she says. To protect the integrity of its exams, NCEES limits the types of calculators you may bring to the exam; only certain types of scientific calculators are allowed.

If you are a recent graduate, or you are approaching graduation, you should think about taking the FE exam. You may not ever need to become a PE, but it's good to have the first step out of the way, just in case.

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Happy Hour Etiquette: How to Behave at After-Hours Functions

The end of the year is fast approaching, which means countless office holiday parties are just around the corner. Attending a work holiday party or happy hour can be a fun way to engage and network with coworkers in a relaxed setting. However, if you imbibe too much, it's also a good way to torpedo your career. No matter how festive the atmosphere, remember that your actions affect your professional reputation.

You should view an office outing as an ideal opportunity for others to see another side of you — your social side. Use this to your advantage by getting to know distant coworkers, introducing yourself to your supervisor's significant other (if he or she is in attendance), and making connections with your immediate team.

If you are a young professional, a social function can be a great forum to politely introduce yourself to upper management and get to know the more-seasoned engineers on staff. It may even help you find a mentor within your organization.

Attending a holiday party or happy hour does not require you to consume alcohol. Although many of your coworkers may be drinking, don't skip an event just because you don't drink — your absence will be noted. You can still generate lively discussion and enjoy yourself with a soda or water in-hand. If some of your colleagues get a little too tipsy and you feel uncomfortable, it is okay to leave early.

Before you go, follow these simple guidelines to ensure you are socializing with style:

Finish your work first. If you are running behind on a major deadline, or you have not completed your assigned tasks for the day, hold off on attending an office happy hour. It's better to arrive an hour late — or miss out entirely — than neglect your responsibilities.

Dress to impress. Although the social outing may take place after work hours, make sure you are dressed professionally. Look your best — but keep your outfit tasteful and appropriate for the event.

Make a plan. Before the party, think of a few smart conversation starters. Stay up-to-date on community events, new developments in your industry, or a popular television show — all of these topics make great icebreakers. If you will be drinking, decide beforehand how much you want to drink and how you will get home. If you have to work the next day, plan to leave the event at a reasonable time and make sure you stick to your plan.

Work the room and make connections. Use the event as an opportunity to mingle and network with all of your coworkers — not just your immediate team members. Strike

up conversations with people from different departments. Be congenial and open up about your hobbies and interests, but avoid talking only about yourself or about work. Ask your colleagues about life outside the office — appropriate questions include: "What are your holiday plans?" and "How are your children doing?" Strive to keep the conversation polite and positive.

Don't overshare. Although personal conversations are not off-limits, don't bring your personal baggage to the party. Socializing with your coworkers is vastly different from getting together with your friends — at any work function, your professional reputation is on the line. Think before you speak, use your best judgment, and don't share anything that you wouldn't want *all* of your coworkers to know.

Pace yourself. If you choose to drink, you should eat a snack before you arrive at the happy hour, or be sure to partake of the hors d'oeuvres that are served at the start of the event. Never drink on an empty stomach. Have a glass of water after each alcoholic beverage to stay hydrated and pace yourself. If you know that you can't handle your liquor, or if you have had adverse reactions in the past, abstain from all alcohol. You are not in college anymore — nobody will mind if you don't drink, just as nobody will praise you for downing the most beer. And remember, even if your supervisor or coworkers are drinking heavily, that doesn't give you permission to do the same. Drink in moderation.

Avoid office gossip. Although it can be difficult, refrain from participating in — or initiating — office gossip. This isn't the time or place to voice complaints about your boss or company policies. In a bar setting, it's easy for others to catch snippets of your conversation. You don't want the wrong person to overhear you trash talking your program manager.

Be respectful of office boundaries. At all times, view the holiday party or happy hour as a relaxed business meeting. Act as though you are still in an office setting and that the usual HR rules still apply. Even though you may be sharing a glass of wine (or two) with your boss, remain professional and treat him or her as you would in the workplace. Show your ability to make good decisions by maintaining proper decorum.

Know your limits. Make your exit at an appropriate time and be sure to thank whoever organized the outing while saying your goodbyes. If you imbibe too much and begin to feel tipsy, leave. It's better to miss out on the end of the party than to embarrass yourself. Being drunk at a work event will reflect negatively on your professional persona.

Most importantly, have fun! (But not too much fun.)

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