Use of Excel Graphics for Enhanced and Interactive PFDs

Course No: H05-003

Credit: 5 PDH

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Chapter 1. INTRODUCTION

This course will introduce you to the potential of the under-used features of your Excel software, to produce impressive graphics for insertion in your **Process Flow Diagram (PFD)** and any other spreadsheets. You will learn how to unleash your creativity and make your mundane engineering spreadsheet a work of art.

“A picture is worth 1,000 words.” So says a proverb generally attributed to Confucius. This is certainly true in engineering, whether in internal communication or in final design documents.

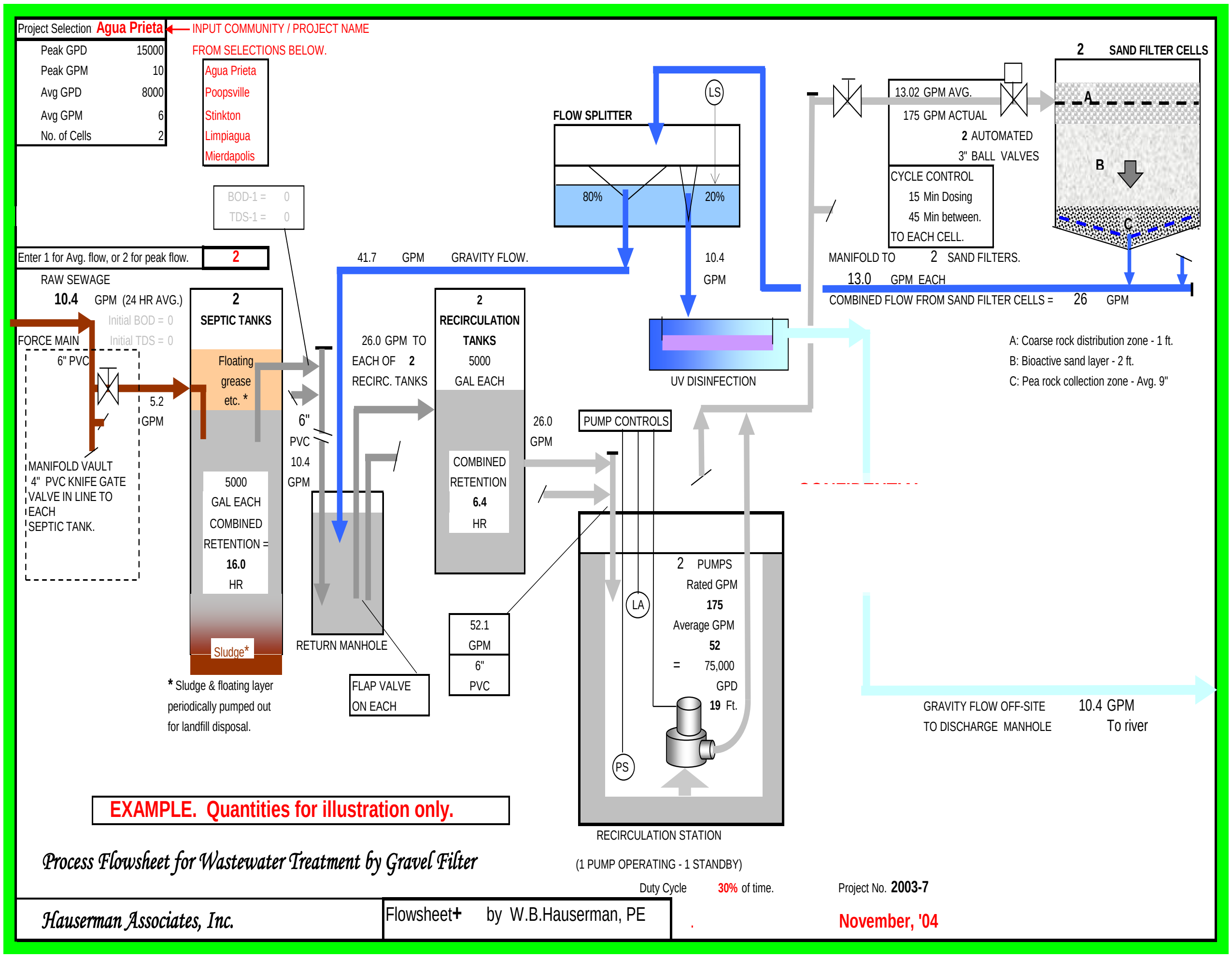
In chemical process design, this most certainly applies to any PFD which is the essential one-view introduction and final summation to any plant design project. This kind of “flow sheet” consists of at least a diagram showing lines for all flowing materials, connecting pieces of equipment, which are drawn using “standard” symbols for all items with all flow lines numbered. This picture is usually combined with a table showing all flow parameters (flow rates, temperatures, pressures and composition) for each stream. This creation was traditionally drawn manually, but is now done using AutoCAD or other drawing software with standard symbols, including the table. Any revision or change of parameters requires that the PFD be redrawn for release or presentation. This requires man-hours and limits the immediacy of communicating changes.

As a qualification to benefiting from this course, it is assumed that the reader is a graduate engineer (primarily chemical), with average spreadsheet proficiency in Microsoft Excel. For supplementary reading, one might consult the two volumes of “Excel for Dummies,” but those do not contain anything on the use of the powerful drawing feature which will be discussed in this course.

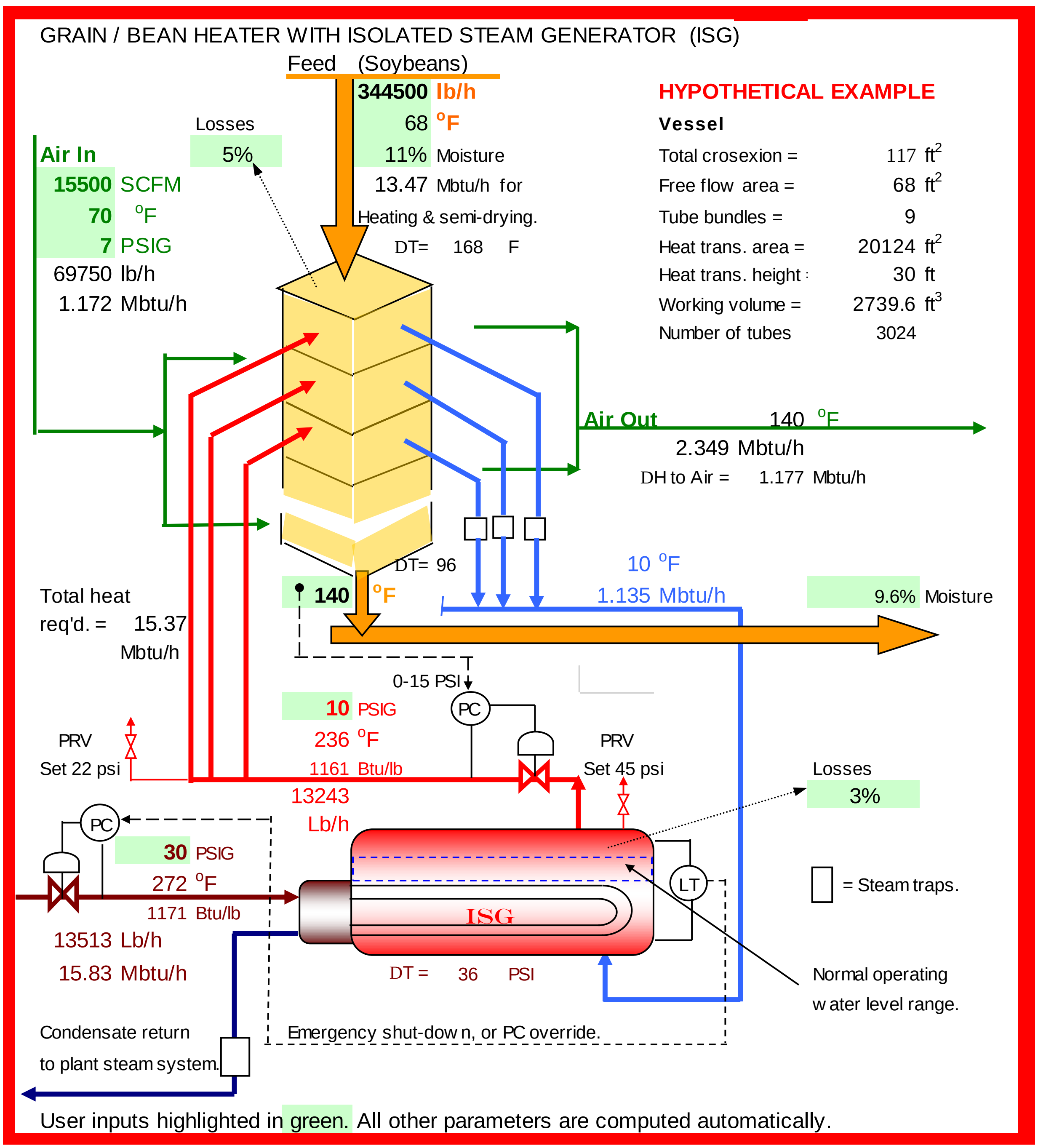
Scope of Application: There are drawing software packages such a Visio, that provide flowsheet symbols according to a “standard” format that can be inserted into a spreadsheet and show all process calculations. There are expensive process simulation packages, available for licensing, such as Aspen HYSYS, which can presumably do most of a process design for you, including minimal standard flow diagrams. This course, however, is intended for the do-it-yourself chemical engineer, needing only a laptop with MS Office Excel, which everyone has. Some employers and clients may require flow sheets to be done in Visio or other such systems in the name of “uniformity” or “professional appearance.” However, where you are allowed to make the best effort to deliver a flowsheet as visually explanatory as possible, such as to sub-technical management. Remember that “You are the *artiste”*. Your flow sheet can be a masterpiece, and creating it can be fun!

Here are some examples of what anyone can easily generate.

Example 1. This was a preliminary design for a small sewage treatment plant, using a trickling sand bed filter as the main bio-oxidation step. It was designed in multiple capacities for different communities. By selecting a community in the upper left corner, all of the process parameters change accordingly. Pending the owner's requirements of formatting details and the certification of all numbers, this would be an impressive presentation of the product.

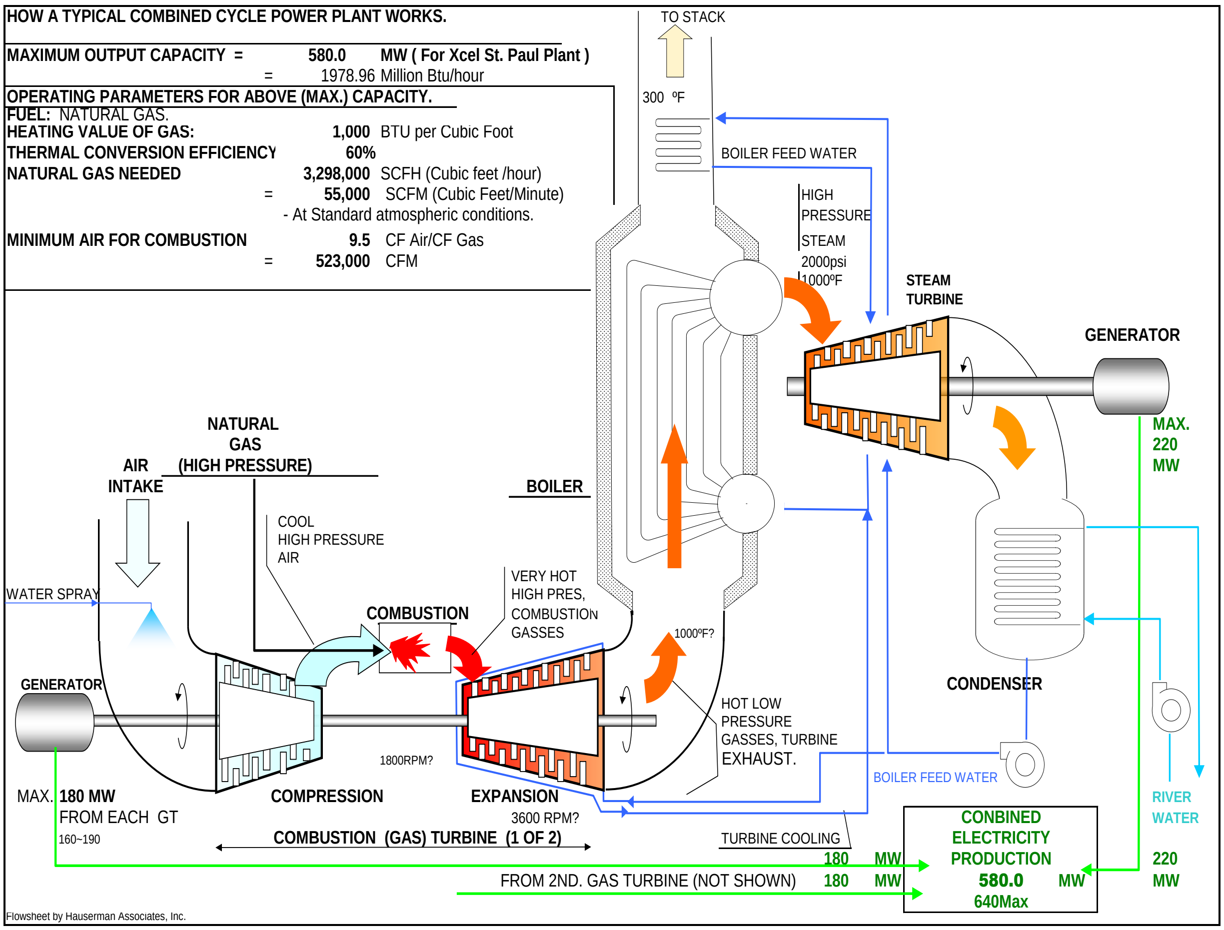


Example 2. This was a conceptual design for a rotating, multi-hearth heater, for pre-roasting various oil seed products, as pretreatment for oil extraction. The feed stream of beans/grain flows radially inward and outward, across a rotating steam-heated surface, with streams of ambient air flowing across each hearth/pan, to carry out the vapor. It uses plant steam at 30 psig, to generate lower pressure steam for carefully controlled heating of the solid product stream. As a result of being part of the process design spreadsheet, any change in user inputs (highlighted in pale green) updates all of the other parameters.



While artistically refined enough for final presentation, these were created initially as internal working documents, pending refinement of calculations and approval for release.

Example 3. This example was put together rather quickly as a tutorial for some non-technical visitors to a new combined cycle power plant in St. Paul, MN, showing its typical operating conditions.

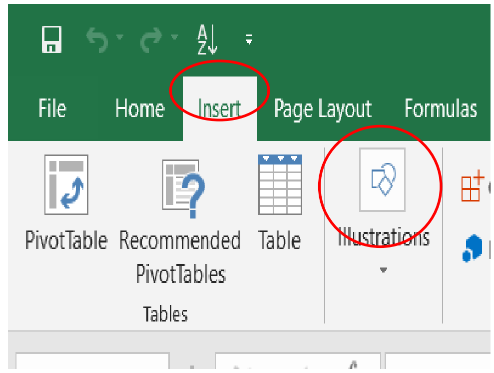


With these examples of what is possible with Excel Graphics, we will now proceed with the basic details of the creation process. Unlike most online courses, this one is of necessity a “hands-on” learning process. You will do exercises to duplicate given graphic “creations,” and then save them for future reference. Fully mastering these techniques requires following a manual and trial-and-error learning. Initially, you will be experimenting with your capabilities, so be generous with practice time and have patience.

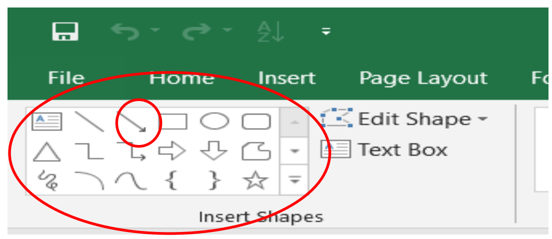
Chapter 2. EXCEL GRAPHICS BASICS

Navigating the Excel Tool Bar

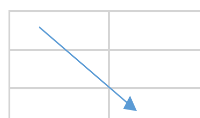
As background for this course, it is assumed that everyone is thoroughly familiar with most functions of Excel spread sheets. We will begin here with the less-well-known commands essential for creation of simple and complex graphics. To start, open an Excel spread sheet and look at your tool bar. If you have a recent version of Excel, click on **Insert** and then on **Illustrations,** and then, on the mini-drop-down, click again on **Shapes.** If yours is an older version of Excel, like 1997, you will click directly on Shapes, without the Illustrations step.



You will now get a long list of options, in multiple boxes, of which the most useful are shown here. To use these, click on your selection and insert on your spreadsheet. For example, select the arrow. It will appear in pale blue, as shown below.

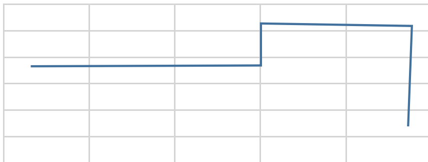


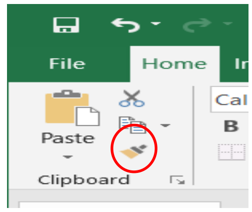
The arrow will have dots at each end (not shown here). These are handles, or grab points. Click and hold on either end, to swing the line around to whatever angle you may need it, and stretch it as needed.

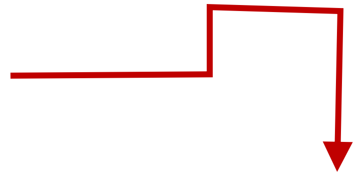


Then click on any part of the line to drag it around on your spreadsheet. Then click again on the arrow, to see a **Format Shape** drop-down menu, from which you will see **Line** and **Fill.** Select **Line.** Then select the type of line, color, type of arrows and size of arrows, as applicable. For example, select: 2 pt., and dark red, for the result shown above. To hide the spreadsheet grid lines, > **Home Tab** > **Font** > the little pouring pitcher icon for cell background color, then select white. <u>(As used in this course, "**>**" means "go to and click on.")</u>

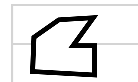
Now, back to **Insert** > **Illustrations** > **Shapes**, select the multi-line ( ) from the drop-down menu. You are now installing a long run of pipe on your PFD. Using the grids on your spreadsheet for alignment, click a series of corners to make the line go around any obstacle to arrive where it is going. At the end of the run, double click. Here you have your "raw" line, in blue, below. Now, you can click on the line, click on **Format Shape**, and select the appropriate line type, weight and color – depending on what's flowing through the pipe on your flow sheet. If the arrow above is right for your selection, then <u>double</u> click on it, then click the format paintbrush in the **Home** tab, then click on your new blue line, with the result shown below. When next clicked on, use the mid-point handles to stretch it to fit on your flow sheet.

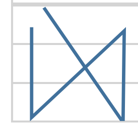




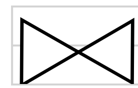


When working on a PFD, you will need valves: > **Insert** > **Illustrations** > **Shapes** > in the lines box on the drop-down, again click on **----**

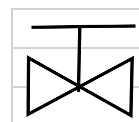




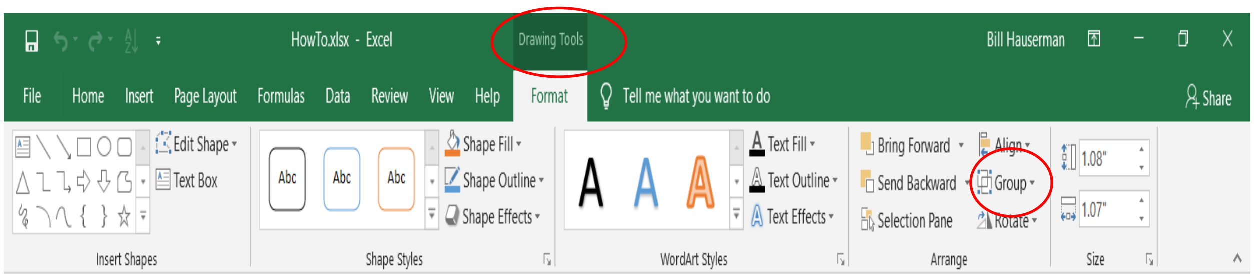
This command is simply a multiple of the simple Line command. You click on any sequence of points, anywhere on your worksheet, to draw a series of connected straight lines. To end the series, double click on the last point.



Repeating this, with the final click point back on the point where you started, will close the object, which automatically takes a solid fill. Now, using the grid of your worksheet for corners, draw the shape that you need. Then, click anywhere on your new object, and select line weight & color, and fill color. Now it is starting to look like the standard symbol for any valve.



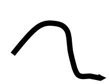
To make this a simple hand-operated valve: > **Insert** > **Illustrations** > **Shapes**. Select the plain line (do it twice). Then, using the handles at each end, arrange the lines to form a T shape, along with your valve. The valve and each line are now in position, but as separate objects. To convert it to a single object, simply click on it, and observe a change in the tool bar. Then click on the **Drawing Tools Tab** to see the tool bar below. In the arrange block, see **Group,** to see a mini-drop-down, with 3 choices: **Group, Ungroup and Regroup**.



Click on your completed valve, and notice separate boxes around each of the three objects. Click on each one of them, then click on **Group.** Click again on **Group** on the mini-drop-down. Notice that your valve with the handle is now one object that can be moved around, rotated, and formatted as one. Copy it onto a new spreadsheet to start your collection of standard objects.

But for this project, a simple manual valve won't do! We next assume that we need a pneumatically operated control valve.

Back to **Insert** > **Illustrations** > **Shapes**, and select the smoothly curved line. It works like the sequence-of-lines command used above, except that all

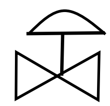


points are connected along a smoothly curved curve.

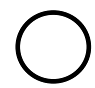
Using this command, click points, to create and upwardly bowed line.

Another way to do this would be to use the Arc command, from the **Shapes** drop-down. You will get a blue arc. With handles on both ends, you can extend the arc to any part of a full circle. Do this to make one that looks like you want for your valve actuator. Then > **Format** > **Line** > **Weight** > **Color**, as above.

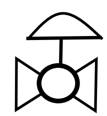
Adjust this curve so the ends match those of your T valve handle, drag and drop it in position. Then, holding down Shift key, click both this curve and your valve. Now > **Drawing tools tab**, > **Group** > **Group** on the drop-down. Now you have the standard flow sheet symbol for a pneumatically positioned valve. Save it to your separate sheet of "standard" symbols for future use.



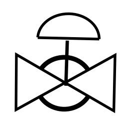
Looking at the flow-sheet table below the picture you are drawing, you see that the flow through this valve has a high coarse solids content, and thus needs a full-bore ball or plug valve. To make the standard symbol for a ball/plug valve, again > **Inserts** > **Illustrations** > **Shapes** and select the circle/oblong from drop-down. It is a circle or oblong, depending on how you stretch it. Format it with a solid white fill.



Now size the circle until it looks right and place it over the center of the valve. Notice that the valve is still 2 objects with separate boxes. Hold down shift and click both boxes. Then > **Drawing Tools** > **Group** > **Group** and click. Then add this one to your collection of standard items for future use.

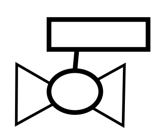


Then, back up a step, separate these objects, and move the valve to the circle. This doesn't look right at all, so do not save it! So before you Group, click on the circle and right click to show another long menu. In about the middle of it, click on "**Send to front.**" This puts the circle over the valve as above. Then again, > **Group** > **Group** to combine. The "**Send to Front**/**Back**" are critical when grouping objects.



The dome-shaped top on the standard symbol for pneumatic control valve was conceived to suggest the usual diaphragm for vertical motion of the valve stem in a simple lobe or needle valve. But for pneumatic operation (rotation) of a ball or plug valve, a more complex actuator is needed, including a pneumatic piston and lever enclosed in a rectangular housing.

You might want your symbol to look more realistic based on your professional experience with such complex valves. To achieve this, > **Shapes** and select a rectangle. Now, take apart your pneumatically operated valve using the **Ungroup** command on the drop-down. Then delete the curved dome and replace it with your rectangular pneumatic piston housing. Then re-assemble (Group) your valve.



Summary

- So far, you have mastered the most important basic procedures (sequences of commands/clicks) to do simple Excel graphics. These are:
- On **Insert Tab** > **Illustrations** > **Shapes**, select shape of your choice.
- Use handles (yellow dots) to stretch, shrink, expand, contract or otherwise change your selected **Objects**. Grab (click on) your Objects, but not by handles, to drag around as needed or to superimpose in other Objects.
- Use **Group** and **Ungroup**, from the drop-down to combine multiple objects that can then be formatted, dragged around, rotated or re-scaled as a single Object.
- Click on your creation (yellow handles showing on corners of identifying boxes), right click for a drop-down menu, then **> Format Object** at the bottom of the menu. From the new pop-up menu, use **Line** and **Fill** menus to select the line types, weights, colors, and other details to make the desired object.
- To match formatting, double click on a completed object, then on **Home** Tab, double **click** on the little **paintbrush** icon, use it to click on every object you want to match your completed object.

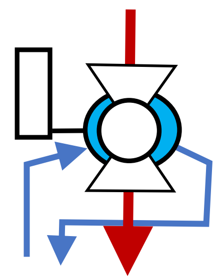
Summary

Insert > Shapes > Select Object(s) > Format > Assemble/Arrange > Bring to Front/Back > Group.

Semantics: Each symbol/thing you create using the above techniques we shall define as a **creation**. The complexity of each creation can be defined by the number of different **selections** from the **drop-down** menu and the number of different **fills**.

Exercise 1.

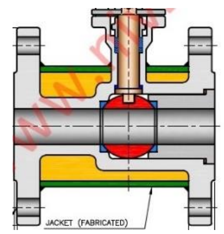
You check the process conditions on the table just below your flow sheet on the same page and see that the content flowing through the valve you just created is over 400ºC! Few or no valve seals and packings will survive very long at such temperatures. So, you must upgrade your valve selection by adding a cooling water jacket. There is probably no “standard” symbol for this so you must create one that will clearly indicate how this contraption works. Do this using what you have learned so far. The diagram to the right is a suggestion on your main process stream with cooling water connected. Do you think it will work? Try to improve on it.



(This **creation** so far required 5 **selections** from the drop-down and 2 **fills**.)

Hint: When arranging/combining shapes on a worksheet separate from your product flowsheet, it easier to position things accurately if you do it on a large scale and then shrink your final grouped item to copy to your flowsheet. But when you substantially shrink an item, you will notice that the line size des not shrink. When formatting a complex grouped object, you may find that some of the formatting choices do not respond. So your final product may have much bolder lines than you intended, as in the above suggestion. To avoid this, format each pre-grouped object with finer line width. Similarly, line weights and arrow sizes may not respond to formatting after grouping.

If you want to – or are required to – keep your flow sheet brief and simple, you can simply import “standard” symbol for everything. You can quickly find tables of these via the Internet to download and copy. To customize your flowsheet, making it even more illustrative/realistic for the reader, you can also insert complex illustrations or even photos easily copied from external sources. But with this skill, remember that you are the *artiste*. The flowsheet is your masterpiece and the degree of realism depends on how much information you are transmitting.

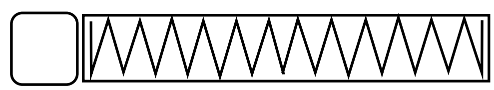


Chapter 3. DRAWING PROCESS EQUIPMENT SYMBOLS

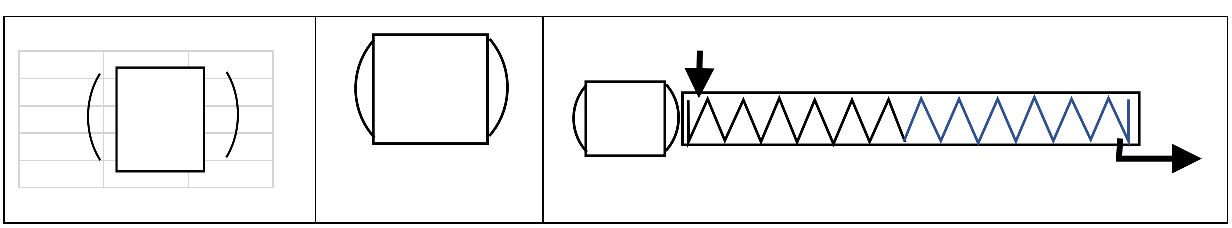
With Excel, we do not aspire to do precise scaled drawings. It's only designed for schematic, symbolic, or illustrative representations.

But for neat and precisely aligned drawings, we use the worksheet's normal grid. For example, your flow sheet needs a screw conveyor. To start, select again the multi-line shape and allow plenty of room on your grid as shown below.

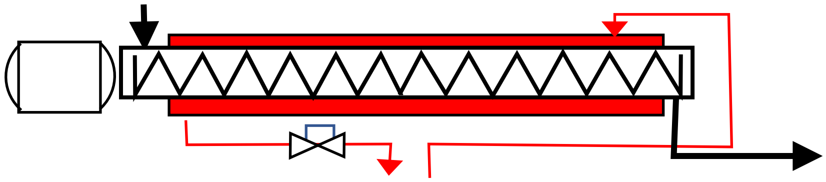
Next, using the handles on the box around it, which cannot be inserted into Word documents, shrink it down to a more convenient size. It now looks too short. Simply copy it, then invert the copy. To do this, grab a handle in the middle of either side of the box and drag it completely through the object and out the other side, turning the object inside out and making a mirror image. Do this with the copy both horizontally and vertically as shown below. Then, using the **Group** procedure, join them together as a single long screw. Then, from **Shapes**, select a box and place it snugly around your combined screw, then **Group** as a single object.



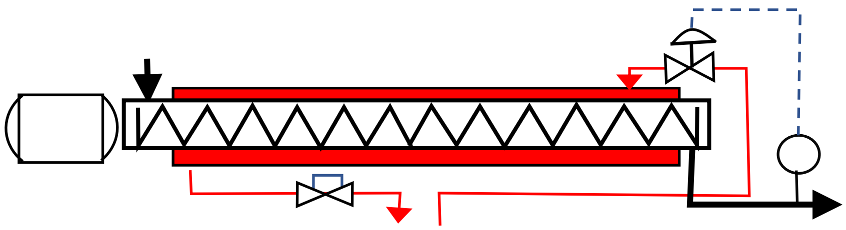
Since a conveyor must have a motor, we look through the **Shapes** drop-down and find the box with rounded corners, (as shown above) to group with rest of the product. While this quite adequate for usual/standard flow diagrams, we are considering presentation to sub-technical management and would prefer a little more visual realism. So, we next select from **Shapes** a plain rectangle, then again the arc shape that we used for the top of the pneumatic valve. Grouping these with the conveyor above, we now have what looks more like the actual machine.



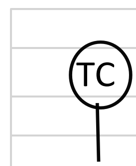
Now, consulting your initial process description or the table on your spreadsheet below your flow diagram, you are reminded that the content being conveyed also needs to be heated. Therefore, this conveyor is also a steam-jacketed heater. For this, you can simply select the rectangle shape, format the fill to red (since steam is hot), overlay it with the conveyor, send to back, and group. (So far, this creation has used 4 selections and 2 fills.)



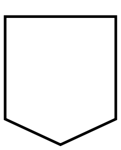
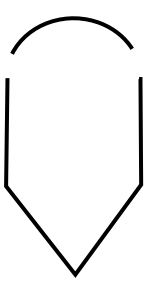
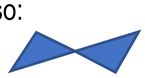
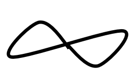
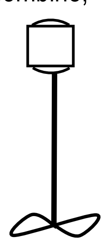
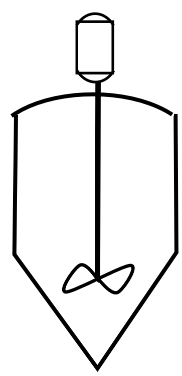
As a necessary afterthought, we have also added the steam supply line and condensate return line with a steam trap. Now all your conveyor/heater needs is a temperature control loop on the steam supply. Exercise: Add a temperature control loop as shown below.



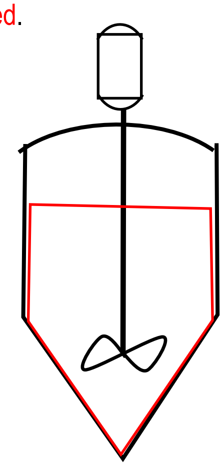
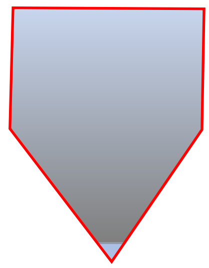
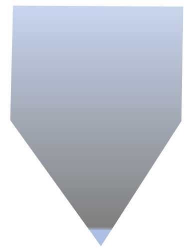
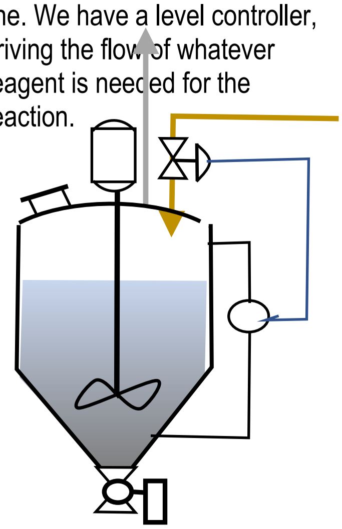
Hint: In the example above, the standard thermocouple symbol is blank. For your finished drawing, it should be labeled TC. Excel graphics does not include letters, except in “**Callouts**” described later. So on your spreadsheet the TC will be simply typed in a space with the circle positioned over it.



In your **Shapes** drop-down, you will find some simple shapes especially in the Flowchart block that are often used in simple PFDs. These are quite adequate for minimal identification of valves or vessels, for instance, where vessels are merely to contain something temporarily. But in our process design, we need an enclosed vessel to contain a slurry and some noxious vapors, and an agitator to keep the solids from settling while blending a batch of several components. Below, left-to-right are the series of steps to assemble such a vessel on your flow sheet.

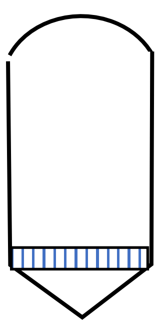
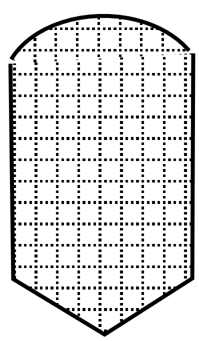
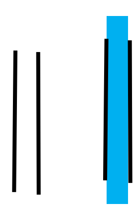
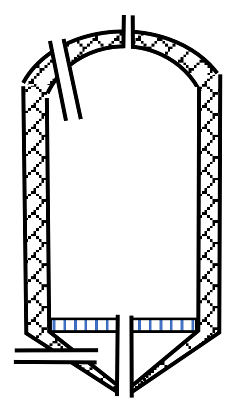
Minimal symbol for a vessel, direct from Shapes drop-down. 	Select multi-line and arc shapes. 	With (multi-line) can do 5-point shape like so:  Instead use shape with the same 5 points to make a convincing propeller: 	Copy the motor from your screw conveyor, add a shaft and combine, 	Now, put the lid on your tank and insert the mixer.  This creation has used 3 selections from the drop-down, plus the motor designed earlier.

So far all of the closed shapes used in this liquid with settling solids tank/mixer/reactor are all formatted as “no fill.” To fully indicate the purpose of this device, you can show something about its contents, which only partially fill the vessel. To do this, starting left-to-right below,

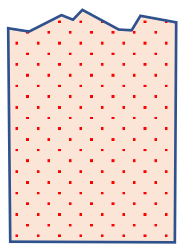
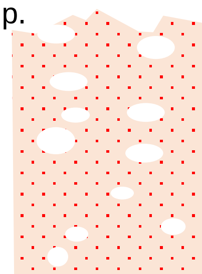
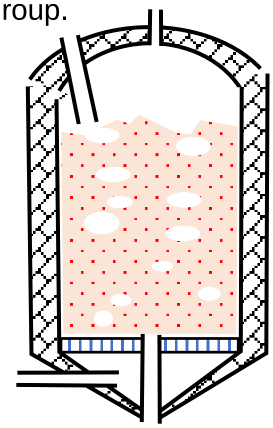
Using multi-line to manually copy the partial shape of your tank, up to the liquid level, shown in red.	Then to format, select gradient fill. Explore gradient options, selecting direction, position & colors of your choice, for the liquid and settling solids.	The format “no line,” and put the liquid neatly back in the tank.	Besides a ball valve drain, a man-hole for filling and a vent line. We have a level controller, driving the flow of whatever reagent is needed for the reaction.
			
	This will take some experimentation with the gradient options available,	You can now start adding all the essential details for a stirred reaction vessel.	

Exercise 1.

Now let’s design an insulated fluidized bed reaction vessel which is as complicated as a vessel can get. Again, using the same basic steps as above, proceed from right to left as shown below.

Use multi-line and arc to create a vessel, with white fill. For a perforated floor plate, use a rectangle, and from patterned fill, select on that looks like holes through a thick plate. Then group.	Before adding the plate, copy vessel and enlarge by 10~20%. Select patterned fill that look most like insulation.	For adjustable penetrations through a vessel wall or insulation, show 2 lines. Add a rectangle between, with “no line” and white (invisible) fill. Then group.	Finally, superimpose vessel on insulation, and then add penetrations as desired for the following result.
			

So far, this creation has used only 4 selections from the Shapes drop-down and 3 different fills. Now, to show the fluidized bed in operation, proceed as below, left to right.

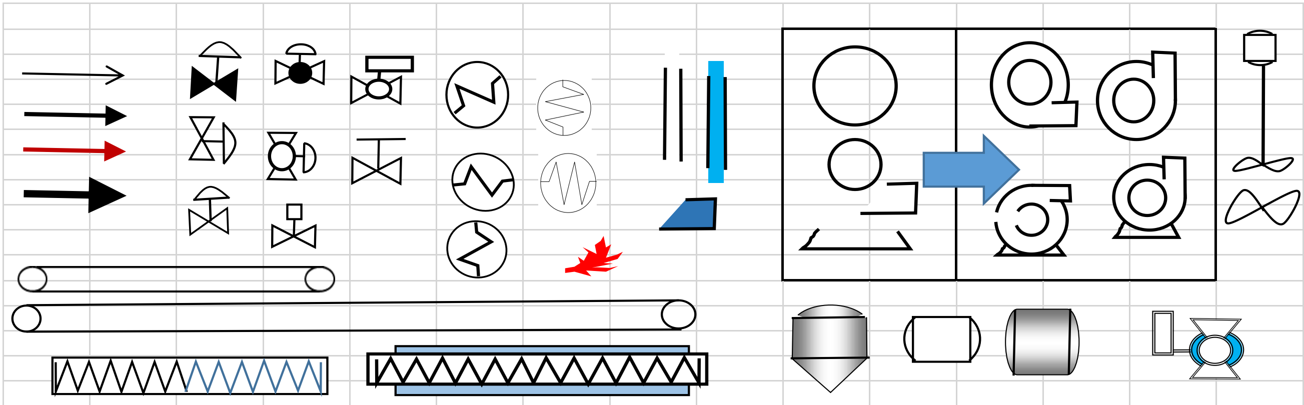
Again, using multi-line, partially trace the fluid bed to whatever depth you want to fill the vessel.  From pattern fill, select whatever looks to you like the bed material. The available fills may vary with your version of Excel.	Select no-line. Then, select the circle/ellipse to draw a bubble, with white fill and no line, so it's invisible. Then superimpose on the bed. Then copy and paste as many as desired with various sizes and shapes. Then group. 	Finally, put the bubbly fluidized bed into your vessel, adjusting all dimensions to fit. Then group. 

Here we have used only one more selection from the drop-down, plus one more fill.

Now that you have a detailed-looking symbol for a fluid bed reactor in your archives, take a look at the description of a design project you're about to start. It calls for partial gasification of a slurry of sand and used drilling mud in crude petroleum and brine – a common pollutant found in puddles around oil fields. Using air for fluidization, it will burn enough of the oil to vaporize the rest plus all the water. Field tests report peak bed temperatures of 1000ºC to 1200ºC, with hot gas/vapor going to a waste heat boiler to generate clean steam. So, the above symbol means that outer surface is your steel tank, with a thick layer of refractory brick on the inside. Do you want to use this "standard" symbol for 2 different process units – or create a different one for the high-temperature refractory-lined vessel?

Exercise 2.

Start assembling your own chosen menu of "standard" symbols to use in tour flow sheets. Start creating your own Excel sheet of these symbols. It may take you several minutes, to create some of these symbols, but once created and saved it only takes seconds to copy and paste onto a flow sheet. Using the simple techniques you have just mastered, create some generic heat exchangers from the following table and save them. For simple centrifugal pumps, see below how a range of configurations are simply created from 4 basic shapes. Your Excel reference sheet will the immediate useful tool acquired from this course.



Summary.

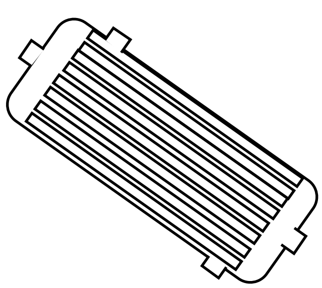
Select simple shapes > Arrange to build equipment items > Send to front/back > Group.

Your “menu” sheet should include a few, simple arrows pre-formatted in most useful weights, colors and arrow size and kind so that the process lines on your flowsheet can be quickly formatted by sampling using the paintbrush icon on your Home tab.

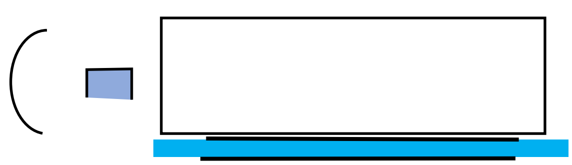
On your **Format Shape** drop-down, the selection of **Pattern Fill** and **Gradient Fill** options may vary between different versions of Excel. In the current/recent version, gradient fills are more complicated and less user-friendly than in earlier versions.

Exercise 3.

Here is a simple, shell-and-tube, low-shell-pressure heat exchanger made of only 3 items from the Shapes drop-down. Improve it for higher pressure use using the 4 components shown. Format nozzles and tubes with white/invisible fill. The nozzles can be arranged depending on the intended application: heating/cooling or condensation. Formatted nozzles and tubes should be on your reference sheet.



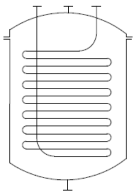
This creation will use 5 selections from the Shapes drop-down and 2 fills.



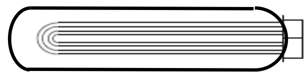
For single tubes, use a line, of weight 10 or higher, framed by 2 lines of weight 2 or 3. Then color the wide line white (invisible) after grouping.

Exercise 4.

Here are two more common symbol to create for heat exchangers, plus a cyclone separator. You can/should consider whether to use different line weights for the shell and tubes.

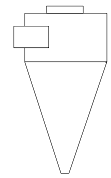


This creation, though complicated, should use only 2 selections from drop-down and no fills.



This creation requires 3 Selections, one extra wide line weight and one fill.

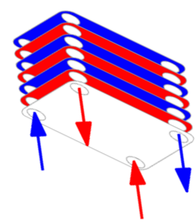
This quick, simple *Creation requires only 2 selections And one fill.*



Reminder: Add all results of these exercises to your Excel reference sheet for potential future use. Make variants of each and tinker with them for improved neatness. **Practice!**

Exercise 5.

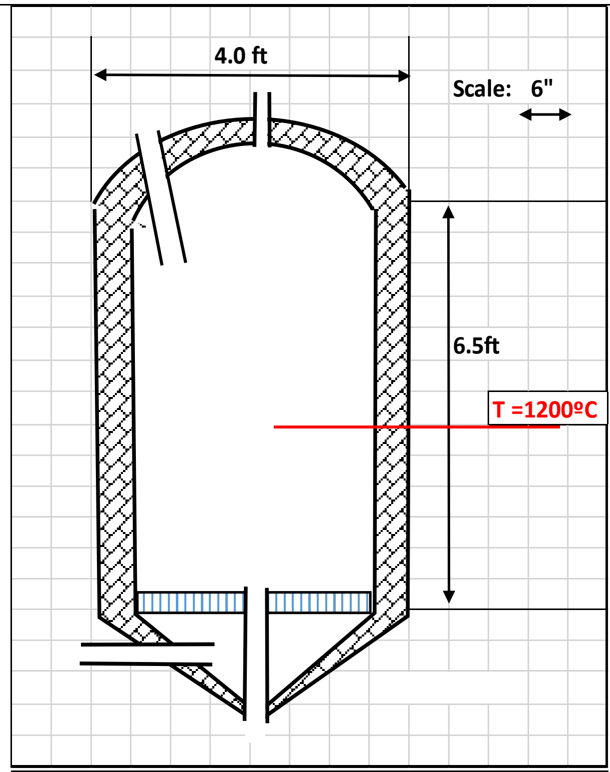
Now for some real creativity:
From your extensive process design experience, you know what a plate type heat exchanger looks like and how it works. But how do you show one as a simple symbol on a flow sheet? **Invent one!** To this, there is no “correct” answer.



Dimensioned Drawings in Excel?

Exact dimensioned drawings are not possible in Excel. For these, you normally use AutoCAD, SolidWorks or other equivalent software. If you are unable to use those software, you can do near-accurate freehand drawings that are quite adequate for presentation and preliminary layout of equipment whose dimensions are established. This is quite simple.

1. Start with a new worksheet. Stretch the horizontal scale of cells to match the vertical scale, so all cells are exact squares. Define your scale.
2. Copy-paste your equipment symbol into the new worksheet.
3. Then stretch/shrink its dimensions to selected values, as defined by your scale.



Individual square cells may be too small to show working numbers. When you enter actual dimensions, they must be preceded with an apostrophe: ‘6.5 ft. The numbers and units can thus span multiple cells. Alternatively, you can merge several cells, to make a single cell long enough to accommodate a “live” number or equation result, linked from your process calculations on other sheets in the same project workbook. An example is the reactor temperature, shown in red above.

Chapter 4. ASSEMBLING THE FLOW SHEET.

Until a plant is built, operated, and signed off by engineers, the design is in a continuous state of revision. The traditional flow sheet is created by drafters, with frequent (sometimes daily) manual revision as process calculations are refined and engineers proceed from estimates to firm/final numbers. Whether they are done by hand or on AutoCAD, revisions take time and man-hours. As equipment specs are developed, selections vary as minor details are refined. In conventional practice, a PFD will normally contain the following items:

- Major equipment items
- Principal process control functions (e.g. pressure, level, flow control)
- Connections with other systems
- Major bypass and recirculation (recycle) streams
- Operational data (temperature, pressure, mass flow rate, density, etc.), often by stream references to a mass balance.
- Process stream names

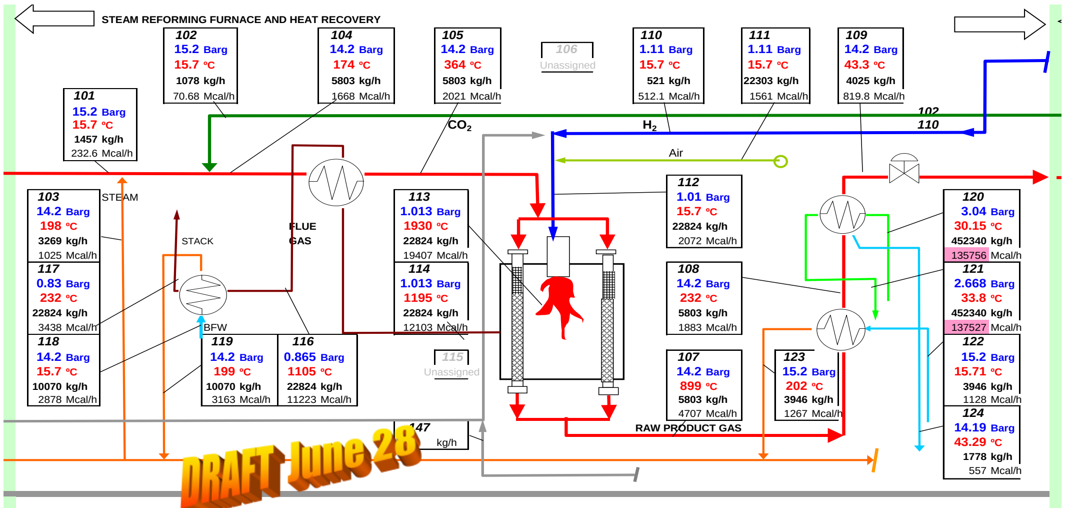
Process flow diagrams generally do not include:

- Pipe classes or piping line numbers
- Instrumentation details
- Minor bypass lines
- Isolation and shutoff valves
- Maintenance vents and drains
- Relief and safety valves

But within the scope of this course, what is normally done is of little concern. The intent here is for you – the Artiste – to make a flowsheet look however you want it to, but to be as informative as possible to any viewer.

Example 1.

The following is Page 2 of 8 pages (panes), of one big preliminary spreadsheet. Page 2 is part of a process to make high-purity carbon monoxide. The carbon monoxide was to be used to make phosgene, which, apart from its infamy as a military weapon, is in turn used to make polycarbonate plastic. The first step was the catalytic reforming of purified methane from natural gas by the desired reaction: $CH_4 + O_2 = CO + 3H_2$, with undesirable side reactions yielding CO_2, and dilution by N_2 from air. Page 2 shows just the steam-methane reformer and some exchangers to recover the heat of reaction, while subsequent pages (not shown) deal with separation/purification of the product CO. This flow sheet was the initial/preliminary process design used for weekly or even daily communication between several engineers working at separate remote locations. For heat exchangers, it uses the simplest generic symbols for as-yet undefined equipment selections. For the catalytic reforming reactor using recycled hydrogen for heat, some ingenuity with Excel graphics was used in the absence of a "standard" symbol. Note that for each line, temperature, pressure and flow rates are shown in boxes linked to the table below. At this point, assuming engineers' joint confidence in their calculations to date, this flow sheet would provide data for an equipment list and initial (for estimates) equipment specs. It is shown here as a good example of linked graphics and flow sheet data as a quick and easy communication tool. All data shown on the graphic portion is automatically up-dated with every minor design calculation.



Methane - Steam Reformer

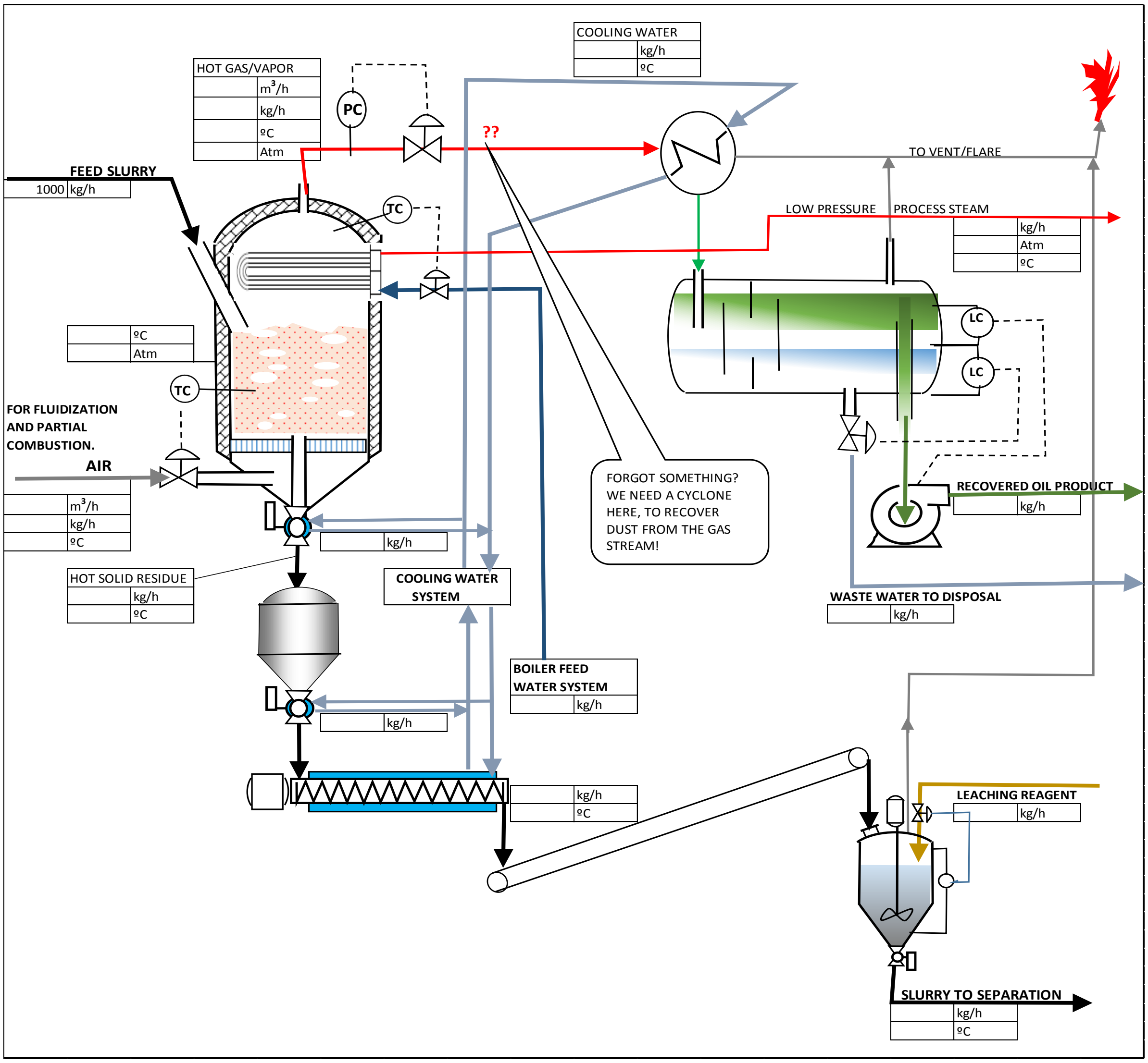
Basis of Sesign: 10% loss of CO in dowmstream purification operations and 20% overdesign

2,252 Kg/Hour (4,964 lb./Hour) Carbon Monoxide in stream # 109 going to CO2 Absorber

Stream #		101	102	103	104	105	107	108	109	110	111	112	113	114	116	117	118	119	120	121	122	123	124	122	123	124
Description		Methha	on	Steam	to	Reform	from	t from	**t from**	(H2) to	refor	Air	stion	on gases	stion	ustion	Feed	(From	CWS	CWR	r	m	r	Feed	(From	r
ID in Aspen		101-CH	102-(	103STE	104FDI	105FDH	107HOT	108CLD	**109DR'**	110-H2	111-AI	112H2	113CME	114FLUOI	116FLU	117FL-	118BLF	119STE	120-C\	121-CWR		123ST	124H2O		123STEA	124H2O
Stream From		Header	Strip	Heade	Header	Prehea	er	2	**ct**	ream	r	r/	er	Shellside	Prehea	Boiler	feed	Boiler	Head	mer	r	2	rmer	feed	Boiler-2	rmer
Stream To		Feed	Fee	Feed	Feed	Reform	Boiler-2	Produc	**CO2**	Reform	Refor	Refor	Reform	Feed	Boiler	Comb	Boiler	Steam	Reforr	CWR	Boile	Stea	Sewe	Boiler-2	Steam	Sewe
Phase:		Vapor	Vapo	Vapor	Vapor	Vapor	Vapor	Vapor	**Vapor**	Vapor	Vapor	Vapor	Vapor	Vapor	Vapor	Vapor	Liquid	Vapor	Liquid	Liquid	d	Vapor	d	Liquid	Vapor	d
Component					Mol. Wt.																					
CH4	kg/h	1455.4			1455	1455.4	148.4	148.4	**148.4**																	
H2O	kg/h			3268.6	3269	3268.6	1781.3	1781.3	**3.2**				4629	4629	4629	4629	10070	10070	#####	#####	3946	3946	1778	3946	3946	1778
CO	kg/h						2251.5	2251.5	**2251.5**																	
CO2	kg/h		###		1078	1078.0	1125.9	1125.9	**1125.9**				3	3	3	3										
H2O	kg/h						494.90	494.90	**494.90**	494.90		495														
N2	kg/h	1.28			1	1.28	1.28	1.28	**1.28**		17132	####	17132	17132	17132	17132										
O2	kg/h										5171	5171	1060	1060	1060	1060										
Waste	kg/h	Waste products for fuel.								26.30		26.30														
Check	kg/h	1457	###	3269	5803	5803	5803	5803	4025	521	22303	####	22824	22824	22824	22824	10070	10070	#####	#####	3946	3946	1778	3946	3946	1778
Flow	**kg/h**	**1457**	**###**	**3269**	**5803**	**5803**	**5803**	**5803**	**4025**	**521**	**22303**	**####**	**22824**	**22824**	**22824**	**22824**	**10070**	**10070**	**#####**	**#####**	**3946**	**3946**	**1778**	**3946**	**3946**	**1778**
Flow	Mols/h	90.76	###	181.44	#####	296.69	459.64	459.64	**360.93**	258.55	#####	1032	903	903	903	903	559	559	25108	25108	####	#####	98.70	219	219	99
Liquid	L/min																168		7553	7553	####		29.69	66		30
Vapor	SL/min	81	###	67738	#####	110764	171597	#####	**#####**	96524	#####	####	337213	337213	337213	#####		#####				81779			81779	
Vapor	L/min	2171	547	7076	10666	17013	49210	20975	**10831**	48660	#####	####	######	906640	918410	#####		21709				7834			7834	
Pressu	BarG	15.2	15.2	14.2	14.2	14.2	14.2	14.2	**14.2**	1	1	1	1	1	1	1	14	14	3	3	15	15	14	15	15	14
T	°C	15.7	15.7	198.0	174.4	364.0	899.0	232.3	**43.3**	16	16	16	1930	1195	1105	232	16	199	30	34	16	202	43	16	202	43
MolWt	kg/Mol	16.0	44.0	18.0	19.6	19.6	12.6	12.6	**11.2**	2	29	22	25	25	25	25	18	18	18	18	18	18	18	18	18	18
Density	kg/m^3	11.18	###	7.70	8.67	5.69	1.97	4.61	**6.19**	0.18	2.56	1.87	1.09	0.42	0.41	1.11	998.00	7.70	#####	#####	####	8.20	####	998.00	8.20	####
Viscosi	Cp	0.01	0.01	0.02	0.01	0.02	0.03	0.02	**0.01**	0.01	0.02	0.02	0.05	0.05	0.05	0.02	0.80	0.02	0.80	0.79	0.80	0.02	0.80	0.80	0.02	0.80
Cp	kcal/kg	0.55	0.23	0.67	0.64	0.55	0.69	0.64	**0.64**	3.40	0.24	0.31	0.39	0.36	0.36	0.30	0.99	0.67	0.99	0.99	0.99	0.68	0.99	0.99	0.68	0.99
k	kcal/h-(	0.03	0.02	0.04	0.04	0.04	0.19	0.09	**0.08**	0.14	0.02	0.04	0.15	0.10	0.10	0.04	0.25	0.04	0.25	0.25	0.25	0.04	0.25	0.25	0.04	0.25
Heat D	MM kcal/h				-0.73	-6.296						17				-3.56		-6.404				-2.53			-2.526	
																Lost								122	123	

Exercise 6.

Now you will use some of the equipment symbols created in Chapter 3 in a 'hypothetical' example. Your new project specifies a 1000 kg/hr feed stream of waste materials consisting of about 20% of solids including some valuable recoverable components in a slurry with about 40% of waste oil and 40% of an aqueous phase heavy on soluble salts. You need to recover the solids and as much of the combustible component and energy as possible. The preferred process sequence will start with a pressurized fluid bed reactor, in which part of the oil phase is burned, providing heat to vaporize the rest plus all the water. As an 'exercise', copy and paste the components you have designed above on a new Excel work sheet and connect with flow lines. This may take you a couple of hours. Below is a possible/suggested "Revision 0" result. This will use all of the skills you have learned so far. If this were a classroom course, this exercise might be your final exam.



This looks good, and relatively ready to incorporate into a worksheet with process parameters as soon as you receive some data. Knowing or assuming a calorific value (HHV) and heat of vaporization for the "oil" and a credible heat capacity for the solids, you can estimate the amount to be burned to vaporize the rest, the air consumption, and flow rates of all product streams as per normal process design. (It was your Client's specification that the combustion/gasification/pyrolysis step has to be pressurized, and that the primary heat recovery tubes ne incorporated into the reactor). You can now do a conventional HMB (Heat and Material Balance) to establish that the process is workable, to be updated as soon as firm data is provided.

But as a process engineer, you have experienced normal "mission creep" as you recognize more components that will be needed. It was immediately obvious to you that once the vapors are all condensed, you will need an oil-water separator. Since you do not have a symbol for one in your reference archives, you used your new skills to design one. Creating it required 3 different selections from the shapes drop-down, 2 different fills, and one item from your archive, with 2 different fills. As a process engineer, you also immediately saw the need for, and added, auxiliary systems (cooling water and boiler feed) and essential instrumentation and process control loops. You added the data boxes, but they are left blank, because you have not yet computed the flow rates nor received firm composition data from the Client. Since this is only a course on the use of Excel graphics, such process data is “beyond the scope of this work”.

Assume that you forgot to include a major essential piece of equipment: A cyclone to remove carried-over dust from the hot vapor stream, which would foul the tubes in the condenser carry through in the recovered oil product and waste water. But you designed a cyclone in Exercise 4, so you can add it to your product above with some rearranging of the piping. Also, you could have added a vent line and valve from the lock hopper, between valves, to the vent/flare line. (However, this is not a course on process design.)

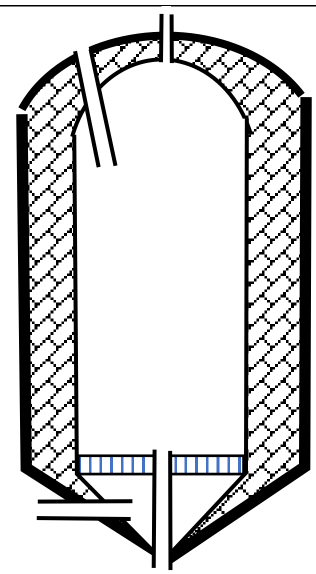
An actual process that could have been used for this example was one in which the feed slurry was a noxious pollutant that sometimes accumulates in puddles around oil fields. Such a composition was used in an encouraging pilot operation, which was as follows. Slurry feed rate: About 100 kg/h. Waste crude petroleum: 50%, HHV= 80,400 kcal/kg. Salty brine: 30%. Solids (sand, rock dust and used drilling mud): 20%. Reactor and vapor temperature: 1200ºC. Pressure: Ambient. All of the oil was burned resulting in high temperature, with intent to maximize available process heat with no liquid recovery. Dry cooled solids were disposed of to landfill with no value recovery. *If* this case had been used, Exercise 6 would have been too simple, not using enough of your experience from Chapters 2 and 3. The lock hopper, cooled valves, liquid separator, and solid product leaching vessel would not have been needed. For such a process, would you consider the symbol for the pressurized reactor vessel, which you just created, descriptive enough for a high temperature gasifier? If not, another exercise is in order.

Exercise 7.

To indicate a gasifier, with temperatures as high as possibly 1200ºC, you need to emphasize that the inner surface is a rather thick refractory brick wall, inside the steel shell. So-

1. Retrieve your insulated fluidized be reactor from your archive sheet, and take it apart (ungroup).
2. Separate the bottom/back layer, which shows the insulation pattern.
3. Stretch it horizontally by 10~20%.
4. Format the border lines, to 4- or 5-point width.
5. Now put it all back together and regroup.

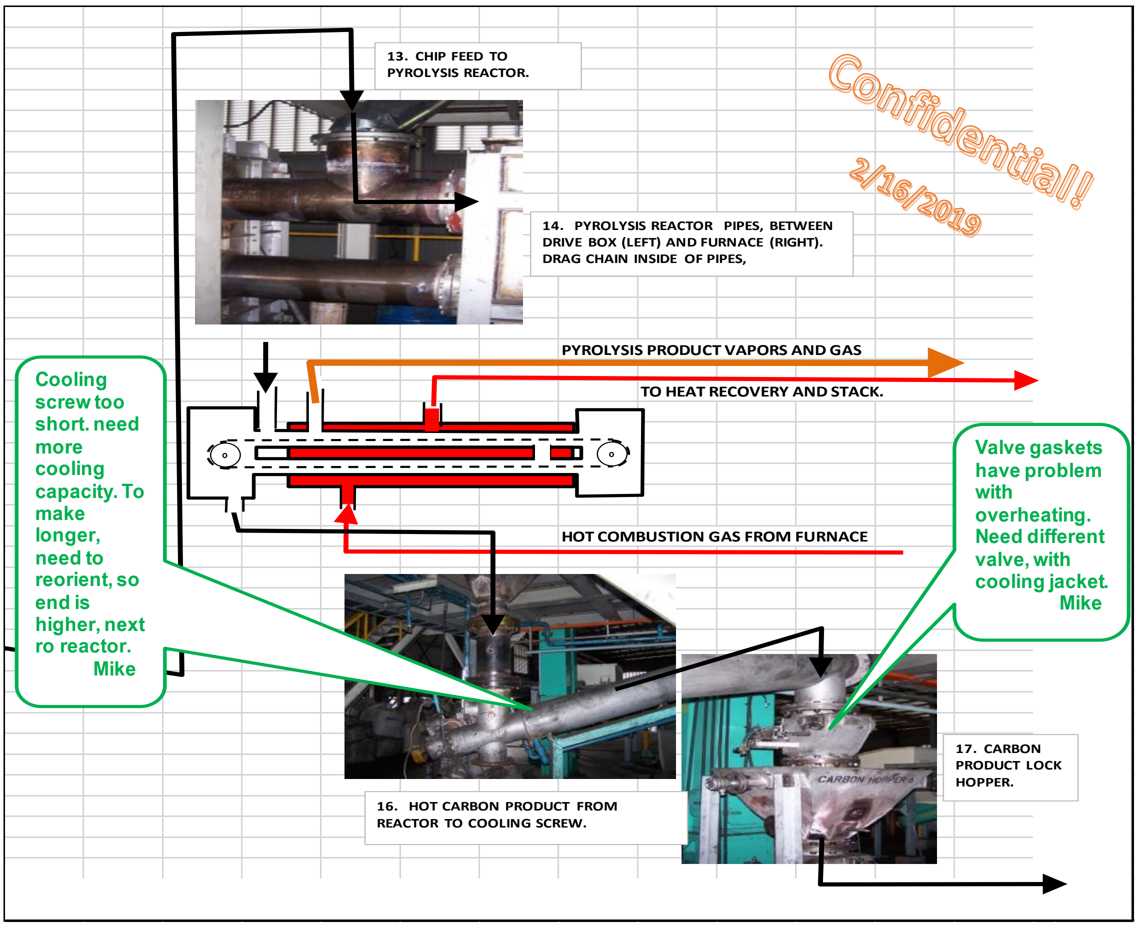
Now you have a composite object that looks like a gasifier, albeit perhaps not an optimum design, with a thick refractory lining inside a sturdy steel vessel. Save it. This exercise shows the time-saving value of redesigning items from your “junk yard” (Archive sheet) create new equipment.



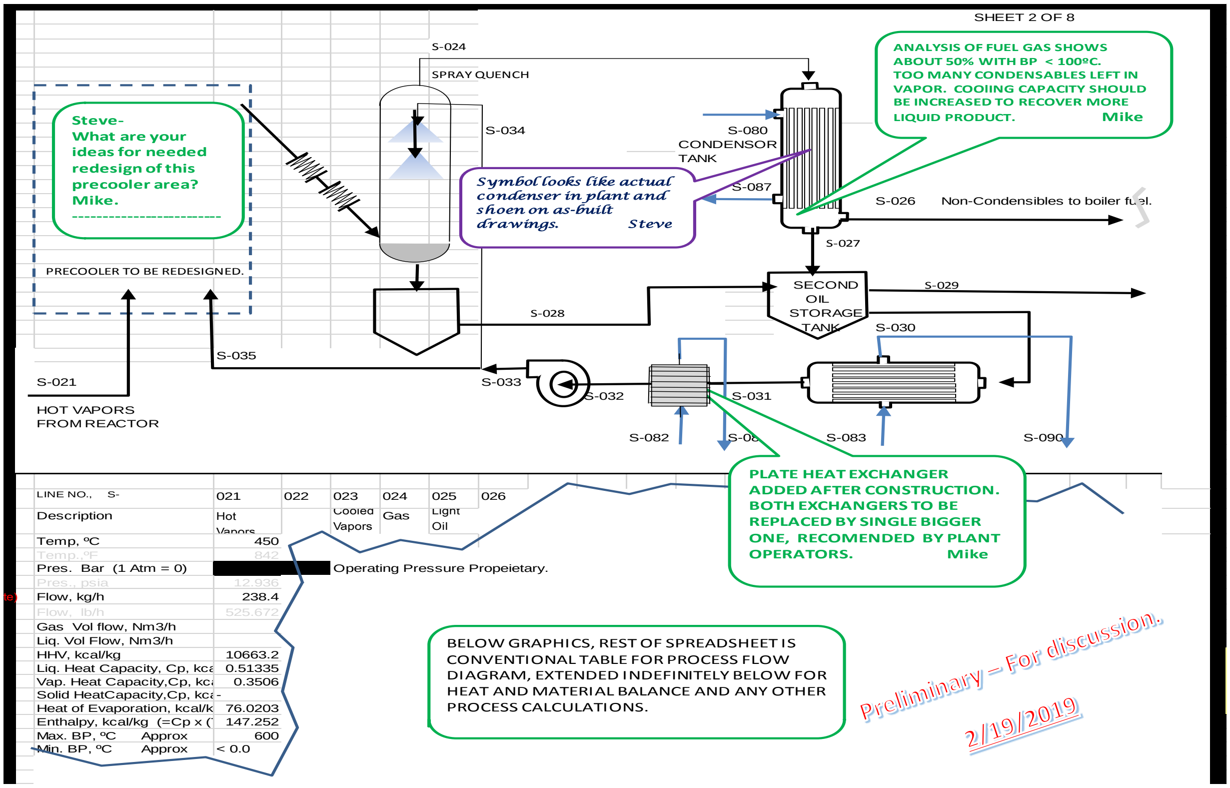
Example 2.

Finally, we shall once again consider the usefulness of Excel graphics for quick informal working documents. Consider the following scenario:

Engineer Mike is out in the field, far from Engineer Steve who is developing the PFD and defining numbers for equipment specs. Mike at least has a camera, as he pokes around the old plant, discussing its performance with operating staff and identifying possible problems. Shown below is a cut from a fairly long, quickly-constructed "walk-thru" Excel flowsheet, with imbedded photographs showing much of the existing equipment. On it, Mike has added notes citing his concerns. For these comments, the most useful tool here is the **Callout**, at the bottom of the **Shapes** drop-down. To use it, simply select from menu, click anywhere on the spread sheet, and drag the corner dot to define an area. At the end of the pointer, a yellow dot is the handle, to put the tip exactly on your point of interest. Then **Format Shape**, to select a white fill, with Lines and text in any color, and start typing the comment, which will at first be white/invisible. So highlight and edit the comment and select color and font style to identify the one making comments. Mike has added his current comments for his daily email back to the office.



Meanwhile back in the office, Engineer Steve is overhauling the current flow sheet, a different part of which is shown below.



Steve is working from a simple, earlier, client's flowsheet and as-built drawings and some old operating data (details are proprietary). Some of Mike's earlier comments are added in green callouts. Steve is selecting the best symbols – standard or custom – for the equipment components. For the condenser, he has used a custom creation from Chapter 2 because it simply looks like the real unit in the plant. However, he has concerns as to whether this is actually the best kind of heat exchanger for this application, which he expresses in his callout comment in purple. Apparently, the Client and plant operators agree that the old pre-cooler, before the spray quench, has room for some major improvements.

In response to Mike's last transmission of the draft, with his question about an apparently malfunctioned area of the process, Steve simply adds his comment to the expanded Callout with different script and color to avoid any confusion to others, such as Jack who will shortly have the design challenge dumped on him by e-mail. Though completely unfamiliar with the project, and possibly at a different office, Jack will have this complete picture of it, along with all the data he may need. While this flow sheet is still far from a final product, it is a complete, one-view description of the evolving process, for discussion/contribution by all participating members.