PDHonline Course G218 (2 PDH)

Engineering Sketching for Design and Communication

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ENGINEERING SKETCHING FOR DESIGN AND COMUNICATION

John Andrew P.E.

1.0 Freehand Sketching

This 3 PDH (professional development hour) course emphasizes the importance of freehand sketches in the execution of typical engineering projects. Sketches are used to communicate engineering: ideas, solve problems, innovate, and plan activities. The reader is encouraged to practice the drawing examples presented in the course.

Graphics is a universal language. A picture is still worth a thousand words.

Engineering requires graphics in the form of: Flow Diagrams, Performance Graphs, Schedule Bar Charts, P&ID's, Electrical Schematics, HVAC drawings, Control Diagrams, Product Drawings, Production Equipment Drawings, Building Drawings, Topography, etc.

This course presents freehand sketching as a method for:

* creating initial concepts of production processes
* originating equipment designs
* analyzing equipment performance
* communicating ideas
* reducing the time to complete engineering projects.

Usually clients of engineering companies want their new product to get to the market place as quickly as possible. Many engineering and construction projects over-run their budgets in time and money. The time to produce a complete set of client approved drawings is often longer than anticipated. CAD designers and drafters create the engineering graphics for each stage of a typical project. They need a clear description of the scope of their work. Freehand sketching can be used to clarify what the CAD designer needs to do.

Mechanical, electrical, piping, structural, chemical, instrumentation, environmental, industrial, and process engineering disciplines use graphics in one or more forms. The freehand sketching techniques described in this lesson apply to all engineering disciplines.

Clients and engineers sketch modifications and revisions on plant layout drawings to improve system performance and correct mistakes.

1.1 Innovation

Freehand sketches are vital to the innovation process. Simple forms sketched on paper can represent the most complex products and manufacturing systems.

Almost all products and manufacturing methods are changing. And the trend is increasing complexity. Everything from cars to jogging shoes is changing. Think of the innovations in electronics and information technology. Many of the electronic innovations are appearing in: automobiles, our homes, and factories.

That means that all facilities that make things are changing. It is not enough to do engineering the way we have been doing it. Engineering is changing. Why are we studying continuing education for engineers? Because of the changing world we live in.

Unfortunately most universities do not offer engineering graphics. This subject is left to the private and public technical colleges. This short and to the point course attempts to partially fill the education gap by showing basic engineering sketching methods. Sketching is a simple way to speed up the communication of new engineering concepts.

2.0 Typical Project

The engineer designs a process, in a typical engineering project, with the capability, control, and cost specified by the client. An outline of an engineering project is given here:

2.1 Summary of the Client's Needs

Client **A** has invited the Smith Engineering Company to make a proposal to engineer and supervise construction of a new facility for manufacturing and assembling product **X** in quantities of **Y** per month at sell price **Z** for each unit.

2.2 Conceptual Design and Cost Estimate

The chief engineer of Smith Engineering appoints project engineer Jones to assemble a Scope of Work that will met and exceed Client A's request.

2.3 Submit Scope of Work to Client

Several copies of one or more three ring binders filled with: process flow diagrams, preliminary plant layout drawings, equipment specifications, control system charts, environmental considerations, OSHA, federal, state, and local compliance statements, specifications defining raw materials, outsourced parts, labor costs, break even, and return on investment analysis. In addition, work not included must be clearly defined.

The engineering time and cost estimate are the first things the client looks at. The cost is about the same for all engineering companies. The engineering company that offers the least time to complete will have the best chance of winning the contract.

2.4 Detailed Design and Specifications

The following activities are accomplished, if a manufacturing facility is to be engineered, when lawyers for the client and those for the engineer have agreed to terms and conditions of the finalized Scope of Work:

1. Manufacturing process flow diagram.
2. Power supply and control system and equipment list.
3. Product assembly and part drawings with bills of materials.
4. Layout of machining cells.
5. Paint and powder coat area is defined.
6. Manual and robot assembly cells are designed.
7. Factory and warehouse plans and elevations.
8. Office plan.
9. Site plan and topography.
10. Environmental and regulatory report.

2.5 Equipment and Instrument Procurement

1. Equipment and control system list.
2. Equipment and instrument specifications.
3. List of acceptable equipment vendors.
4. List of approved materials vendors.
5. Requests for quotations.

2.6 Bid Evaluations

Relative merits of each bid and vendor are compared.

2.7 Preliminary Drawings

Preliminary client approval of plant layout drawings.

Approval of equipment: performance, cost, and delivery schedule.
Approval of: civil, mechanical, electrical, instrumentation, and piping drawings.

2.8 Construction Drawings

Preliminary client approval of plant and office building drawings.
Approval of building cost and delivery schedule.

3.0 Process Plant Design

Consulting engineering companies design process piping systems. When designing process plant piping systems, engineers consider: the products to be produced, environmental requirements, and building codes.

a. Free hand sketches are sometimes used by lead engineers to communicate piping designs, flow diagrams, and process and instrumentation systems to CAD designers.

b. Symbols are linked together describing each stage of the processes in the Flow Diagram.

c. The top and side view drawings show the piping system installation.

d. Three-dimensional drawings called Isometrics are made of piping assemblies.

e. Spool or detail drawings show dimensions for manufacturing pipe assemblies.

f. Many piping drawings need to be changed from time to time. Lead engineers can use sketches to communicate each revision to the client for preliminary approval.

3.1 Flow Diagram Example

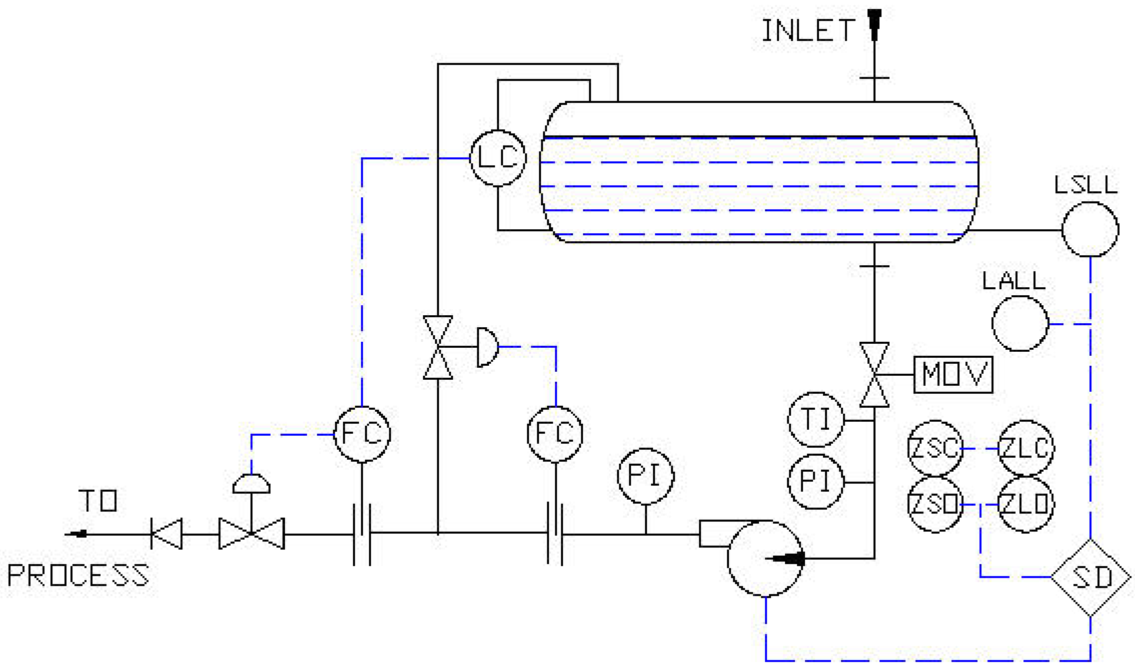
These are the instructions given to a CAD designer:

Make a process flow diagram of a pump station for a hazardous fluid that includes:

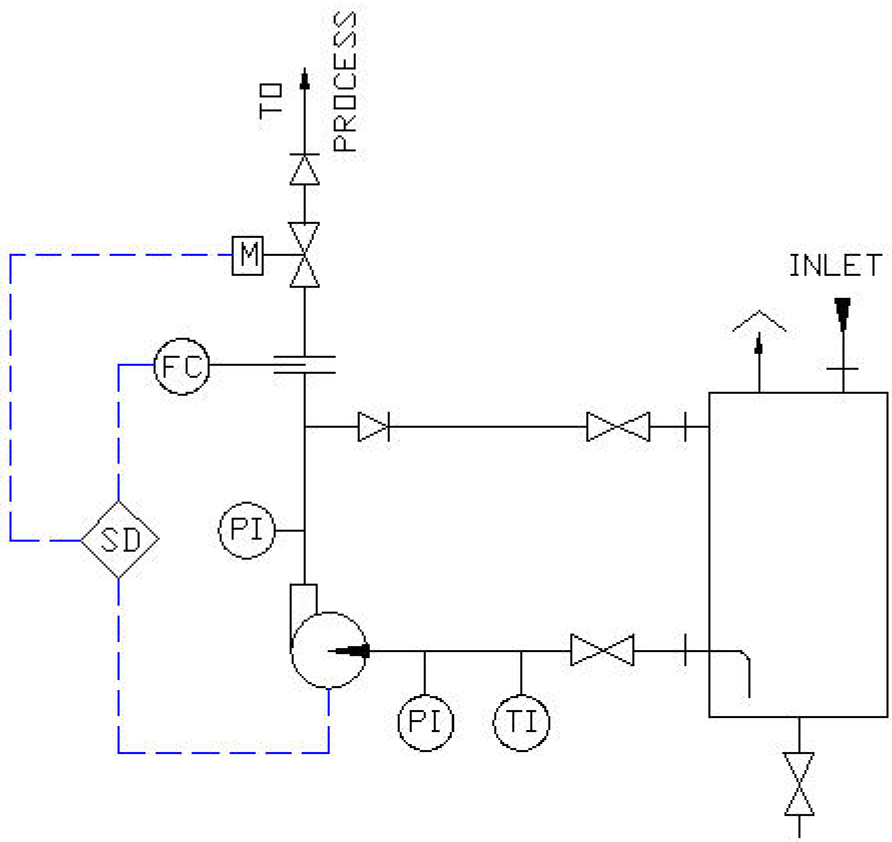
3.2 Specification List

* A level / flow cascade loop on the pump discharge to provide process control.
* A check valve on the discharge down stream of the control valve to prevent reverse flow when the pump is shut down.
* A fire safe motor operator valve (MOV) in case of seal leakage and fires.
* An interlock from the MOV to stop the pump if the valve is not fully open.
* A low level interlock from the vessel to stop the pump if the vessel loses its liquid seal.
* A pressure gage on the suction to indicate adequate NPSHA.
* A thermometer on the suction to indicate potential high vapor pressure.
* A minimum flow recycle loop back to the vessel.
* A pressure gage on the pump discharge to indicate that the pump is working.

The lead process engineer has asked a CAD operator to use the specification list above to make the flow diagram below.



The flow diagram below is the result obtained from the CAD designer based on the above list of instructions:



3.3 Time Consuming Mistakes

The CAD designer made several mistakes in his drawing above:

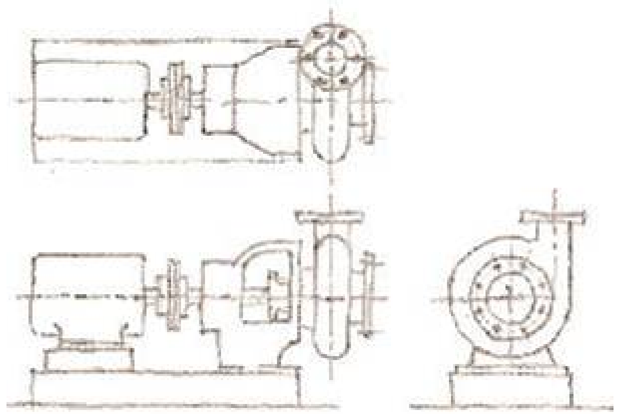
1. Manual instead of power valve in the pump suction line.
2. Vertical tank instead of horizontal.
3. An un-pressurized tank.
4. Manual instead of power valve in the pump recycle line.
5. Pump suction located above tank bottom.
6. Inadequate motor valve control.
7. Tank vent and drain were not specified.

3.4 Error Reduction

A freehand sketch from the lead engineer would have clarified the design and eliminated the mistakes. The lead engineer would have to visualize 20 equipment items working together when he wrote the description of the system. A flow diagram sketch would have taken less time than the written list because it would have clarified the diagram to the original system designer, the lead engineer.

4.0 Equipment Performance Graph

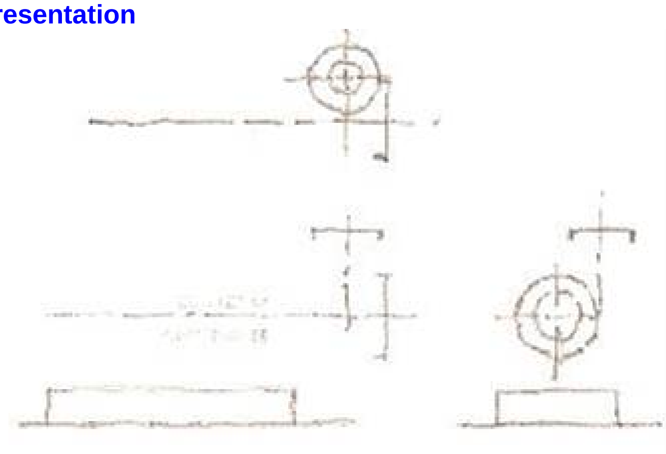
The centrifugal pump is widely used in process piping systems.



4.1 Detail Equipment Sketch

The sketch of a centrifugal pump above is fully representative of the equipment. However the simplified representation below could also be very useful.

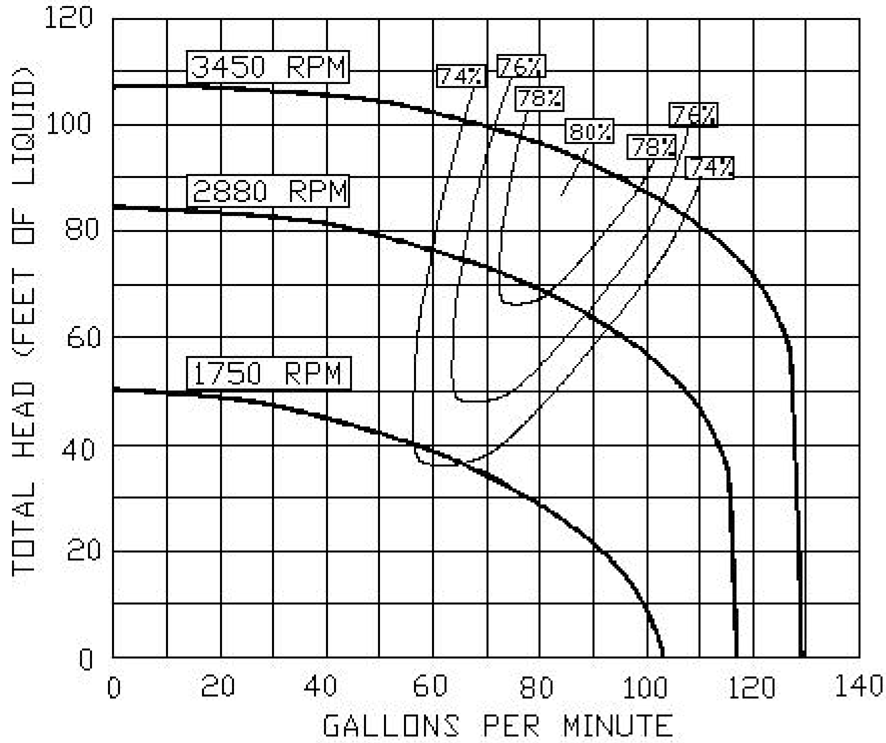
4.2 Simplified Representation



The, “Simplified Rep” of the centrifugal pump above or any other equipment item may be used to create a preliminary plant layout.

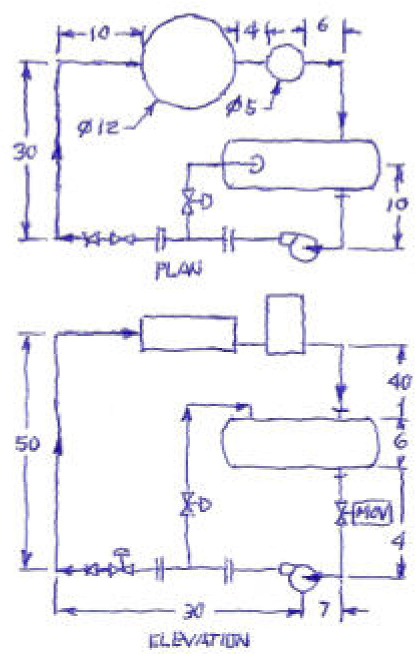
4.3 Pump Performance Graph

A characteristic curve supplied by the centrifugal pump vendor at various speeds is illustrated below.



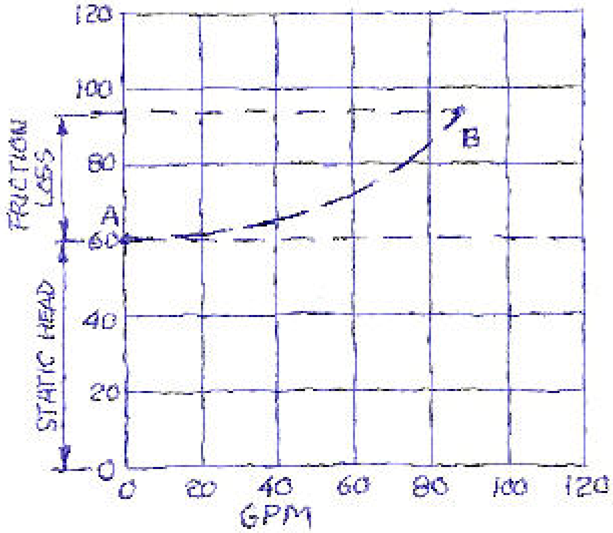
4.4 Ideal Layout

The lead engineer made a preliminary sketch of the plan and elevation views of the pump and pipe runs as shown below.



The preliminary system sketch above represents the ideal layout. As the project develops, more constraints will be imposed, causing deviations from the ideal. Never-the-less we should start with the highest efficiency system.

A preliminary system static and friction head curve can now be sketched.



4.5 System Head Graph

The system head curve above was sketched without the need for graph paper. It is based on the ideal process piping sketched above and the calculations below.

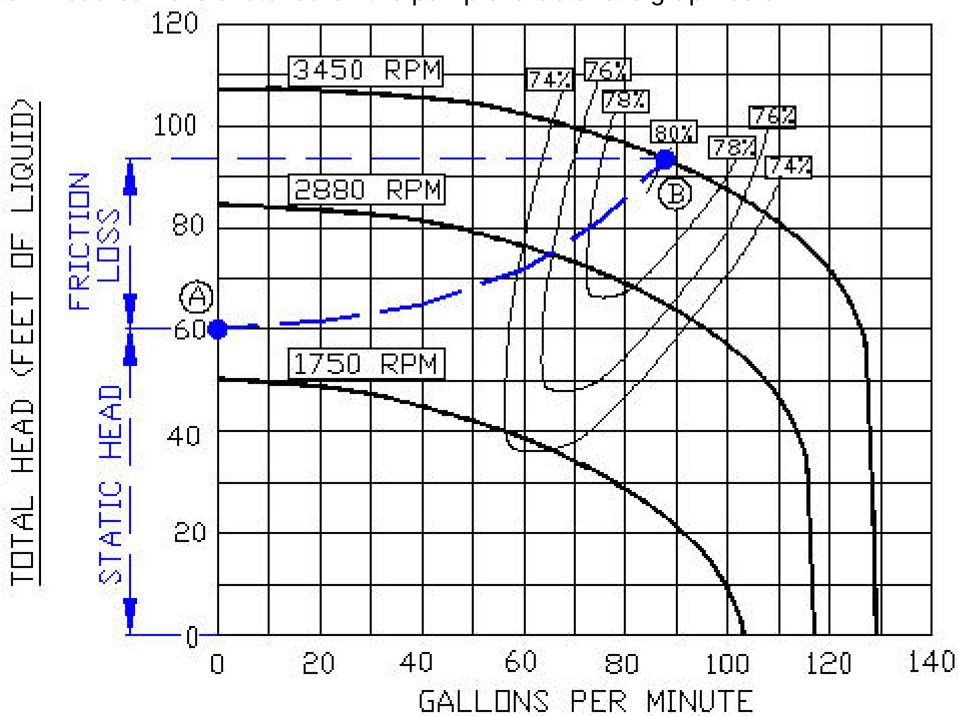
4.6 Static Head

The static head is equal to the vertical distance between the system origin and termination plus the gage pressure difference at the same points, measured in feet.

4.7 Friction Loss

Friction loss is the sum of the: line plus fitting losses and the changes in velocity head across the system. Velocity head difference between origin and termination is: V1^2 / 2*g – V2^2 / 2g.

The system head curve is sketched on the pump characteristic graph below.



4.8 System Performance Graph

The system will operate up and down the system head curve shown here. A preliminary pump size and motor can be selected quickly from the performance curve sketch.

5.0 Manufacturing and Process Plant Layout

Manufacturing processes can be divided into four categories:

Job Shop: Custom designed: Furniture, Advertising signs, Machine tools.
Batch: Robots, Earth moving machines, Conveyors.
Repetitive: Computers, Printers, Cell Phones, Automobiles, and Clothing.
Continuous: Paper, Oil, Plastics, and Chemicals.

Job Shop and batch production layouts usually group similar functions together. All machining for example would be done in a machine shop area.

Repetitive and continuous production arrangements group the workers and equipment as needed for the sequence of operations.

A preliminary determination of the layout and overall dimensions of each of these manufacturing facilities can be made quickly with a freehand sketch once the initial flow diagram has been determined.

5.1 Manufacturing Process Flow

A typical manufacturing process flow diagram for manufacturing will include:

Receiving > Materials Modification > Surface Finishing > Assembly > Packaging > Warehousing.

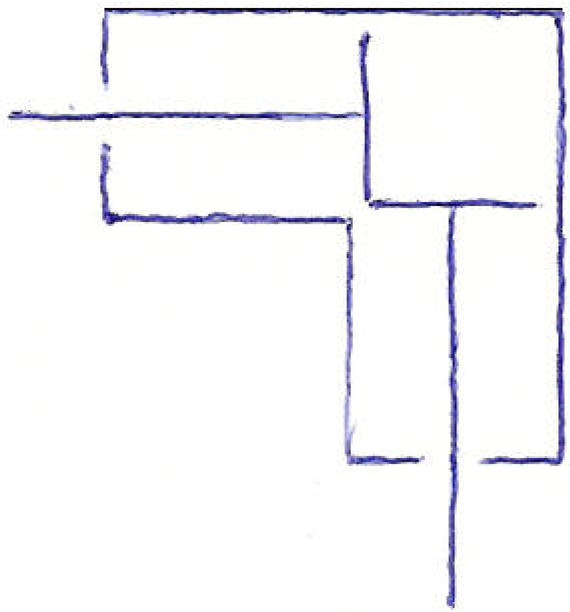
Sketches of the equipment used in each of these processes will facilitate the design of the factory layout.

5.2 Product Design

The drawings of the product to be manufactured must be available before the manufacturing process can be planned. The one-of-a-kind and small batch manufacturing model is extremely challenging. The special purpose gearbox shown below falls into this category.

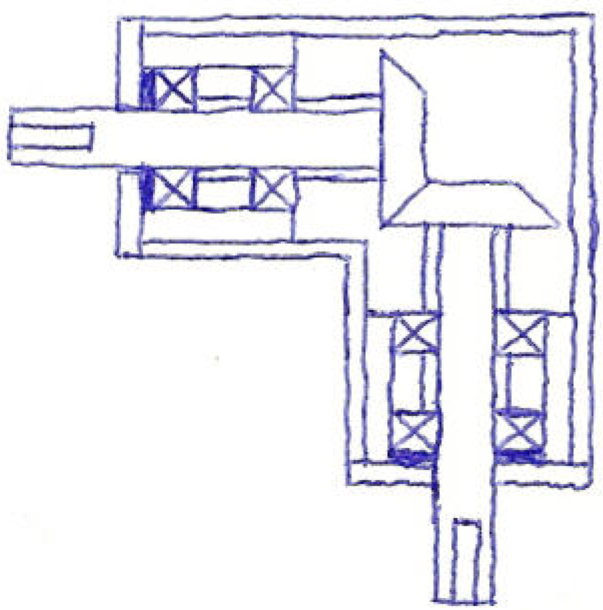
5.3 Concept Sketch to Assembly Drawing

The progression from: initial concept sketch, to functional diagram, to assembly drawing is illustrated below. The concept sketch and function diagrams are used to communicate the design to the CAD operator. The initial concept is constructed using simple single lines. The components of the new gearbox design are defined more clearly with blocks in the function diagram.



5.4 Function Diagram

The interaction between components can be seen in the function diagram.



a. The drive bevel gear connected to a motor will mesh with the driven bevel gear to change the axis of rotation.

b. Each bevel gear is mounted on a shaft.

c. Each shaft is free to rotate in bearings.

d. Bevel gears need to be prevented from rotating on shafts by key.

e. Each bevel gear will be prevented from sliding toward the bearings by collar.

f. The bearings rest against the sleeve on the shaft.

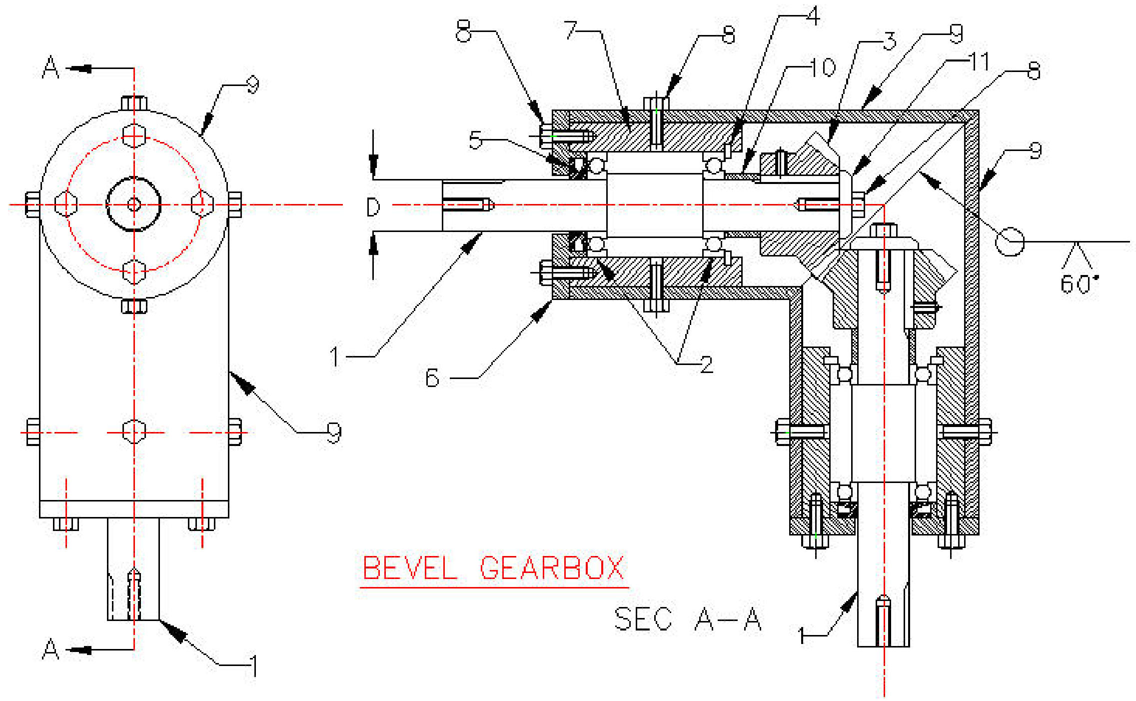
g. Shafts, bearings, and gears are contained in a chamber for lubricating oil or grease.

h. Bearings housings are attached to the chamber.

i. Each end cap needs to hold an oil seal.

5.5 Assembly Drawing

The assembly is drawn to scale using CAD software. Detail dimensioned drawings of each part are made after the assembly drawing is completed. AutoCAD, MicroStation, Solid Works, Katia, and Pro-Engineer are widely used software systems in use today.



5.6 Bill of Materials

The components in the assembly drawing are identified with numbers. The, "Bill of Materials" (B.O.M.) shown below, is a list giving: quantity, brief description, and material of each part of the assembly.

BILL OF MATERIALS

ITEM	QTY	DESCRIPTION	MATERIAL
1	2	SHAFT	1.000" DIA 304 STAINLESS STEEL
2	4	BALL BEARING	SKF 25.40
3	2	BEVEL GEAR	25 TEETH, 20 DEG. 10 PITCH
4	2	INTERNAL RETAINING RING	MC 25-A-563
5	2	OIL SEAL	OS-100-5
6	2	END CAP	#M0011865
7	2	BEARING HOUSING	2024 ALUMINUM
8	18	MACHINE SCREW	CH-25-150
9	2	GEARBOX	STAINLESS STEEL PIPE
10	2	COLLAR	C-1040
11	2	RETAINER	303 SS
12	2	SQUARE KEY	303 33

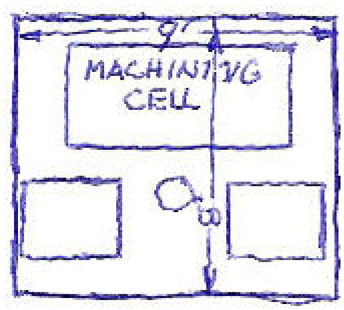
5.7 Make or Buy Decision

Some of the gearbox parts will be purchased. Bearings, gears, retaining rings, seals, keys, and machine screws are readily available and will be purchased.

There will be a range of gearbox sizes. Small, 0.5 to 1.5 hp, Medium, 2.0 to 5.0 hp, and large 7.5 to 10 hp. Cold rolled steel shafting (Item 1) of three standard diameters will be purchased in 20 foot lengths and machined in-house. Stainless steel pipe (Item 9) in three sizes will be cut to length and welded to form the gearbox housing.

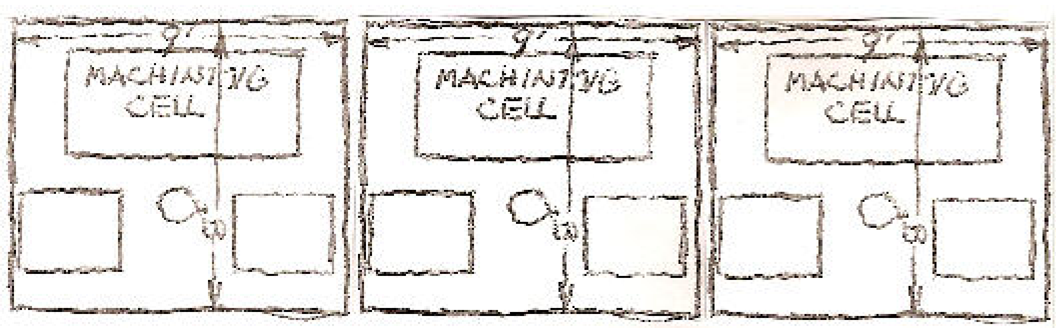
5.8 Machining Cells

A typical machining cell is sketched below. The approximate size of a machining cell can be estimated using vendor drawings and a sketch. Incoming material in one bin and finished parts in the other bin on each side of the machine operator. The operator is represented by a circle. The dimensions of parts must be inspected before assembly. Storage for gauges and tooling should be provided at each machining center.



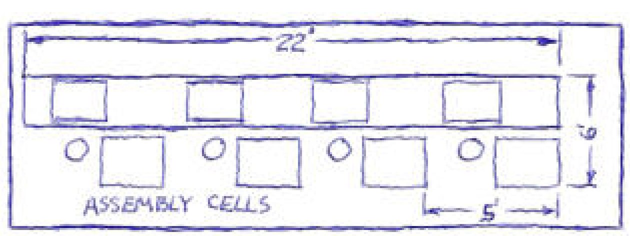
MACHINING CELL

Copies of the machining cell sketch may be duplicated on the copy machine. Each cell is cut out of the sheet of paper and arranged in various patterns. One possible arrangement is shown below. Three machining cells are grouped together.



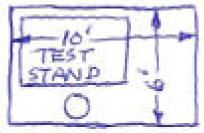
5.9 Assembly Cells

The approximate area needed for four proposed assembly cells adjacent to a pallet conveyor is sketched below. Each cell will be provided with trays of parts and an assembly fixture. The circles are operators.



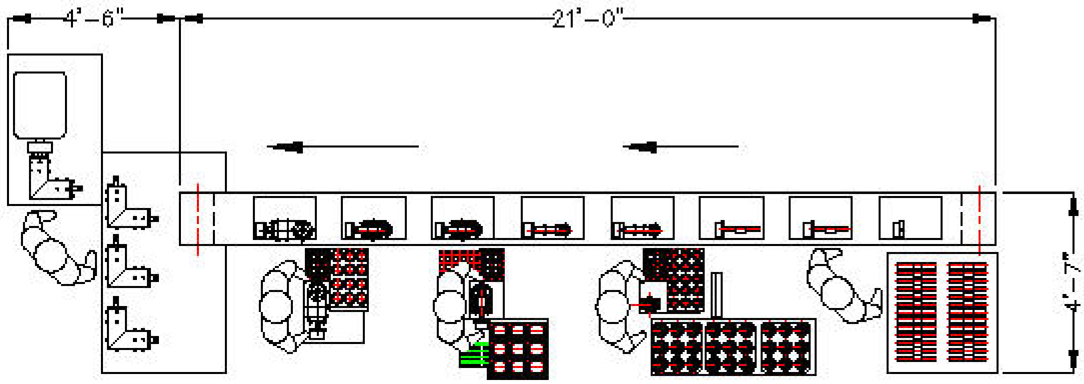
5.10 Product Test Stand

The function of each assembly should be tested before delivery to the buyer. The area required for a product test stand can also be represented by a sketch as shown below.

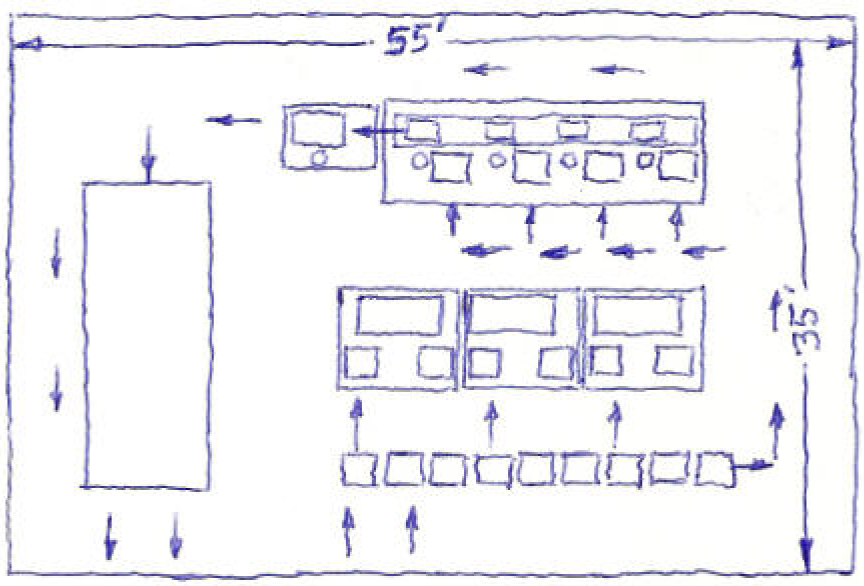


5.11 Assembly Line Drawing

The assembly line and test stand CAD drawing was created using the freehand sketches above. Note how close the final arrangement area is to initial concept sketch.



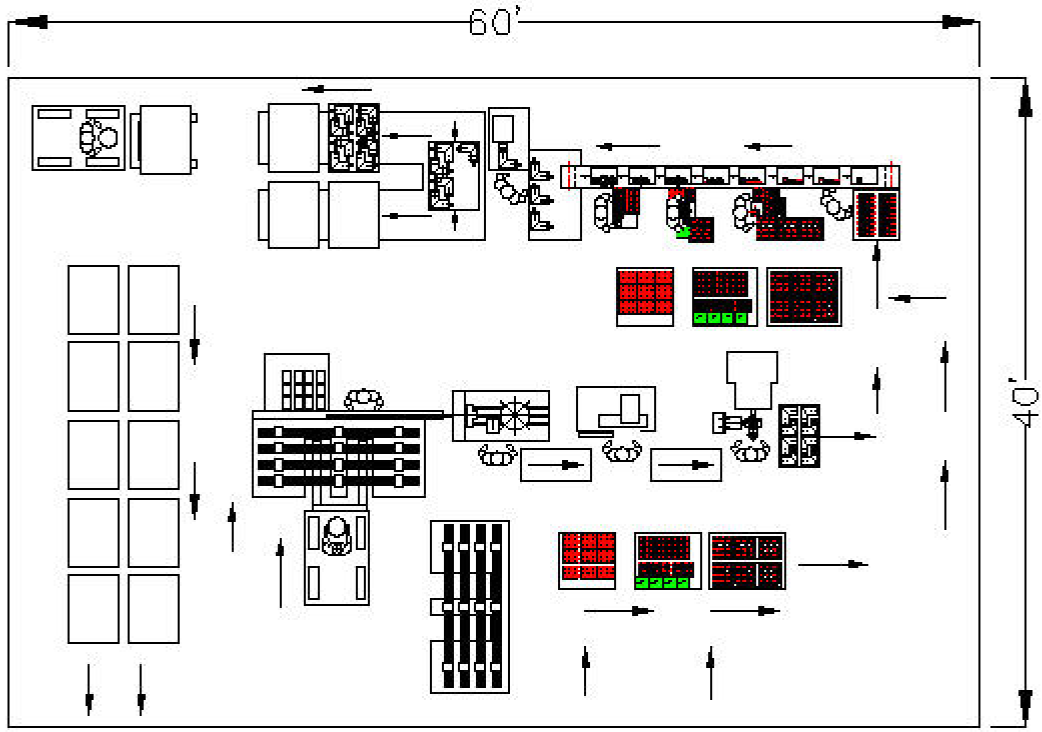
5.12 Factory Layout Sketch



FACTORY LAYOUT SKETCH

The factory layout above is composed of manufacturing and assembly cell sketches pasted on a blank sheet of paper in the form of a collage. The arrangement of production items was changed until an efficient layout was achieved. This very preliminary layout sketch is 55 ft by 35 ft. The final CAD layout below has almost the same dimensions. The sketch / collage method can be used to communicate a factory layout and overall dimensions to a CAD designer quickly.

5.13 Factory Layout Drawing



The CAD drawing of the proposed factory layout is shown here. The overall size of the manufacturing area drawn to scale is, 60 ft by 40 ft.

6.0 Sketching Techniques

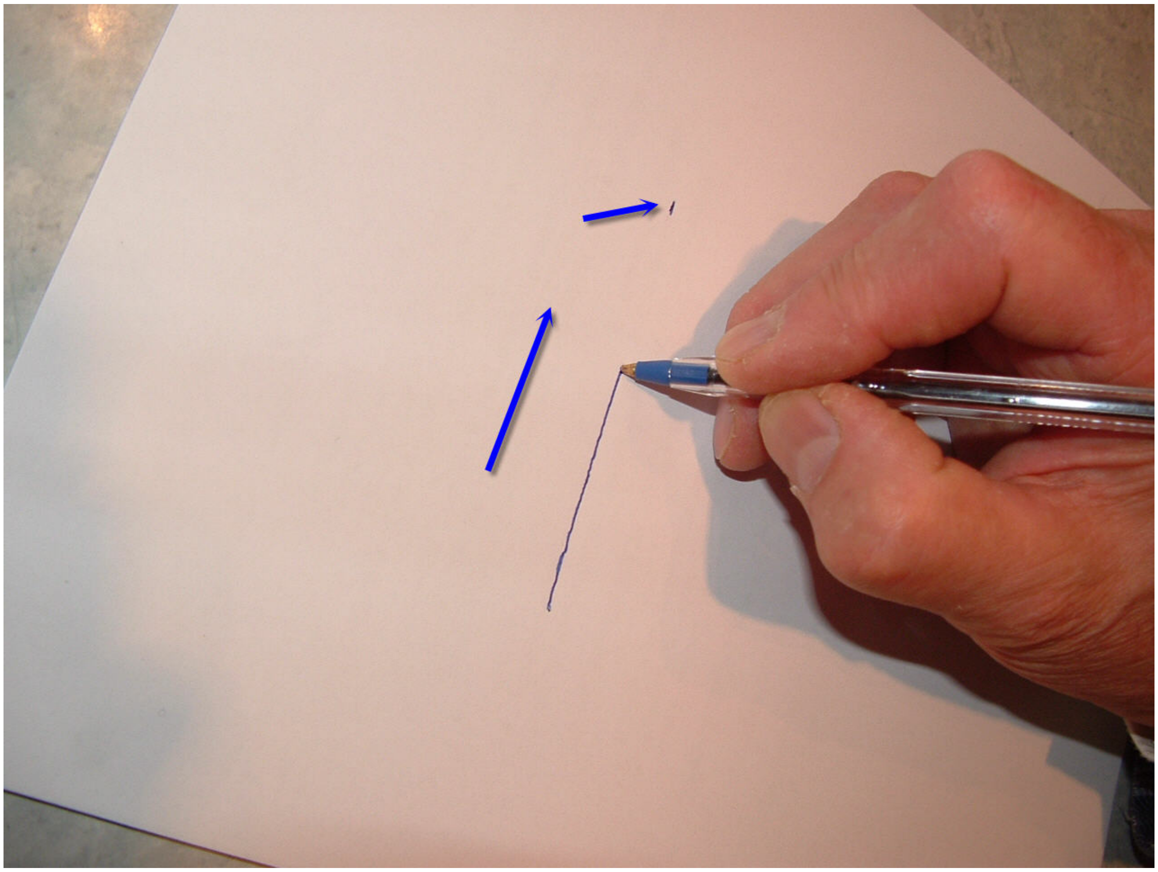
a. The most important rule in sketching is: Keep the sketch in proportion.

b. A new product design often begins with a free hand sketch.

c. Step-by-step illustrated examples below show some freehand sketching basics.

d. Sketching can be done with pen or pencil.

e. The sketching techniques described below need to be practiced repeatedly.



6.1 Straight Line

a. Hold the pen or pencil in a comfortable position.

b. Rest hand on paper and pivot wrist while drawing a short line.

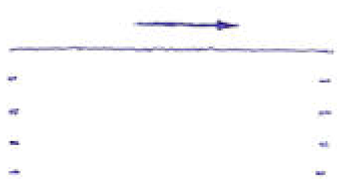
c. Extend fingers and pen to maintain the straight line.

d. Mark a dash beyond the line.

e. Move hand and pen to end of line, as shown above.

f. Look at the dash and continue the line to the dash.

g. Repeat the above steps until the line is complete.



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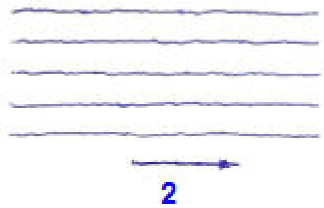
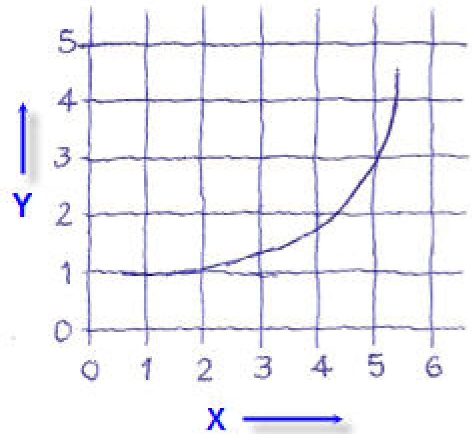


6.2 Parallel Lines

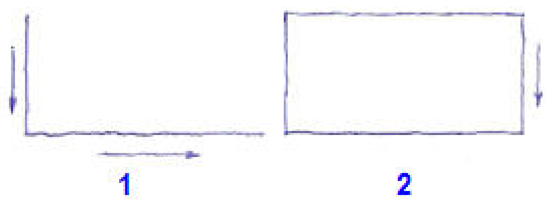
1. Make two columns of dash marks as illustrated above.

2. Draw straight lines between the marks.



6.3 Graph

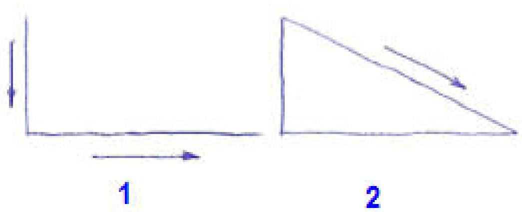
Sketch vertical and horizontal parallel lines using the parallel line method above.



6.4 Rectangle

1. Sketch a vertical and horizontal line.

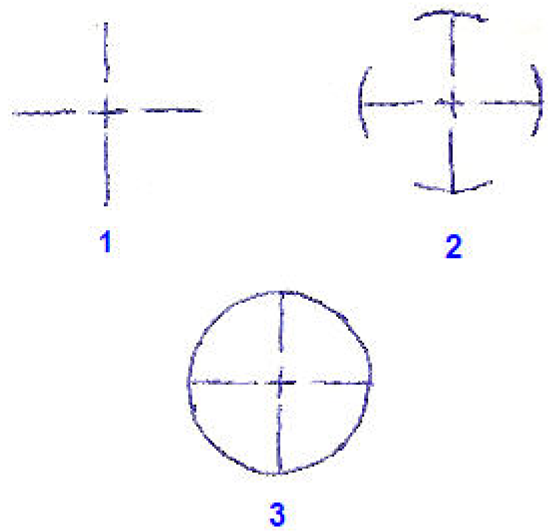
2. Complete the rectangle.



6.5 Triangle

1. Sketch a vertical and horizontal line.

2. Tilt the paper so that the sloping side is horizontal and complete the triangle.

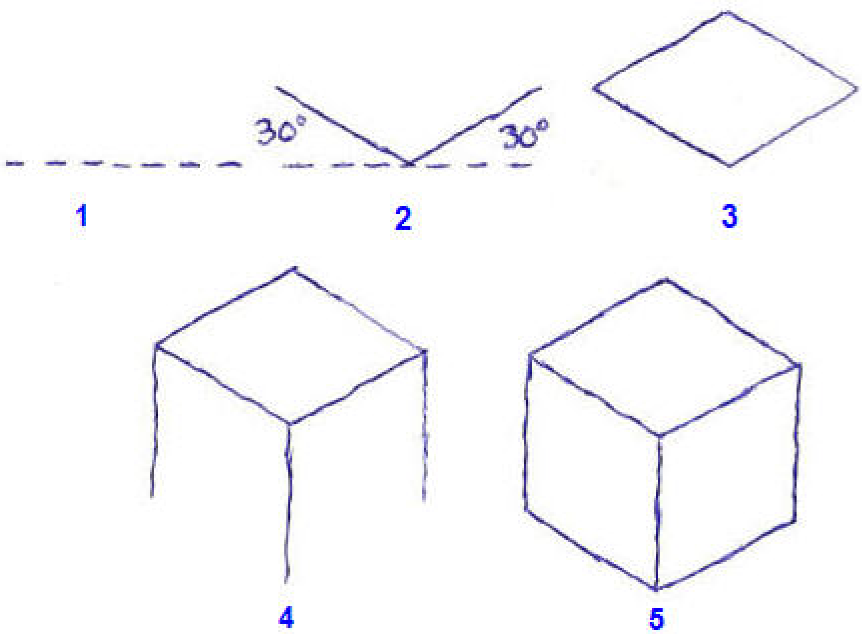


6.6 Circle

1. Draw a cross using centerlines as shown above.

2. Draw short arcs at the ends of the centerlines.

3. Complete the circle.



6.7 Isometric Box

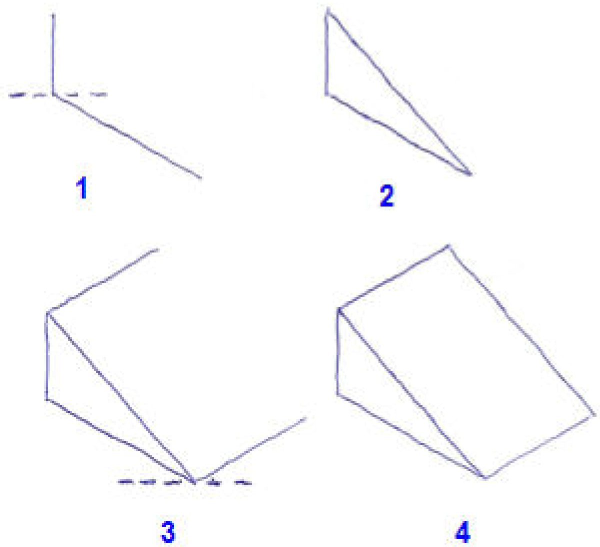
1. Sketch a short horizontal line of dashes.

2. Draw two receding lines at approximately 30 degrees above the dashed line.

3. Draw a line parallel to each of the receding lines to complete the box top.

4. Draw three vertical lines from the box top front corners.

5. Draw two lines to complete the box bottom.



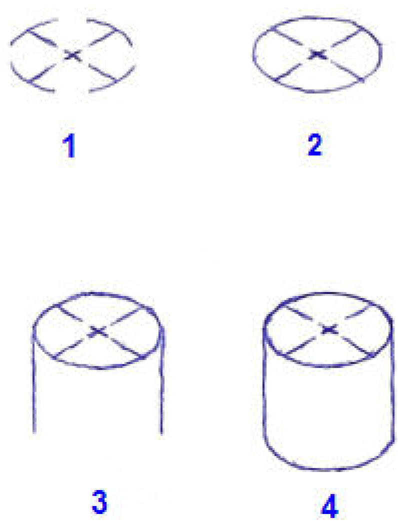
6.8 Isometric Wedge

1. Sketch a short horizontal line of dashes and one receding line at approximately 30 degrees below the dashed line.

2. Complete the triangle.

3. Draw top and bottom receding lines at approximately 30 degrees above the horizontal.

4. Complete the wedge as shown above.



6.9 Isometric Cylinder

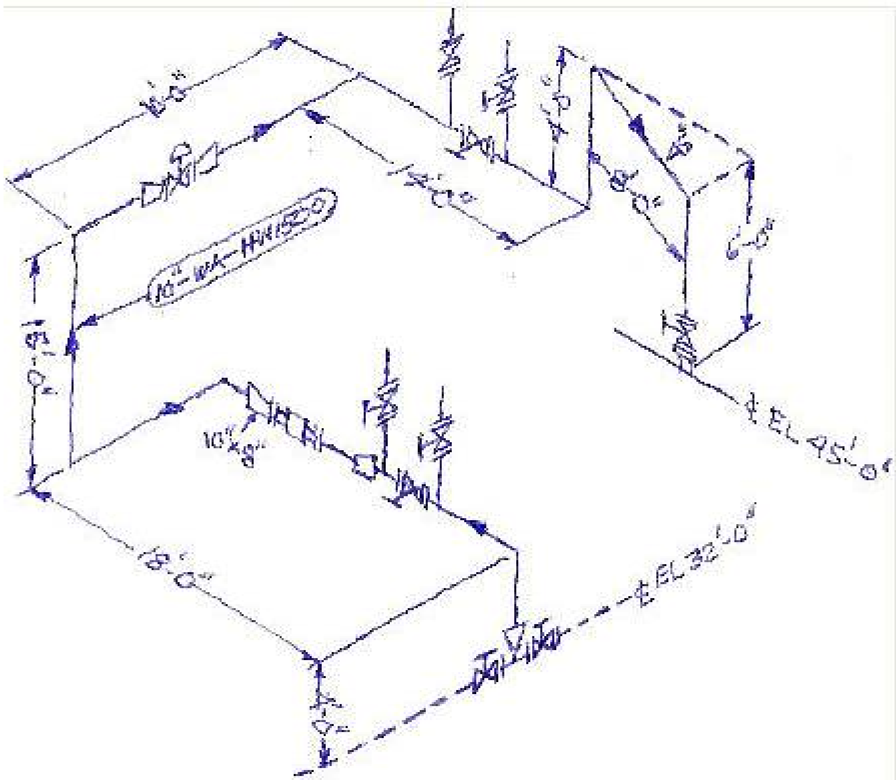
1. Draw two crossing centerlines at approximately 30 degrees to the horizontal.

2. Draw short arcs at the ends of the centerlines and complete the ellipse.

3. Draw one vertical line tangent to each side of the ellipse.

4. Draw the cylinder bottom half ellipse.

6.10 Pipe Run Isometric



a. Isometric sketches are used to develop new designs and document existing installations.
b. This sketch was used to record measurements made at the client's process plant.
c. The pipe isometric sketch communicates information the CAD designer needs, quickly and efficiently.
