2.1 Overview

Almanara water treatment process is based on the raw water and treated water quality requirements. Main treatment process consists of following processes (coagulation, flocculation, clarification and filtration).

Removal of raw water suspended particles is to be achieved with the aid of coagulants.

In Almanara Poly aluminum chloride (PACL) is confirmed by experiment and laboratory test work as coagulant which works well with raw water.

PACL dosing pumps incorporate a variable speed drive facility that insures that the chemical dose is maintained proportional to the flow rate. The PACL dosing pumps is connected to A five cubic meter capacity buffer tank, which is provided with a PACL) from a (200 L) drums by using small AC pump ($0.04 m^3/min$). In order to accomplish this process a forklift vehicle is needed to take the PACL drums from the nearby store and line the drums in the PACL buffer tanks area and three labors and the forklift driver. Considering other method to loading the PACL into the buffer tank. Stephan drum discharging systems research - an empirical evidence of design- proved that performed perfectly as will have been explained in this chapter.

2.2 Stephan Drum Discharging Systems

Following the discharging of highly viscous food ingredients from a drum there should be as little product remaining as possible as shown in Figure (2.1).

Special systems are required if the product is not to be diluted during any recovery process. The Stephan Drum Discharging System minimizes residual quantities and is easy to handle and clean.

It is designed for discharging drums quickly and easily (e.g. tomato paste). Other forms are possible.

2.2.1 Advantages of the system

- Minimizes residual quantities in the drum
- Easy handling
- Compact design
- Easy to clean
- Individual adaption to the entire plant possible [1].

2.2.2 Function and use of the Stephan Drum Discharging System

A special drum discharging pump system enables the quick and easy discharging of drums into a product buffer tank. From there the product is pumped out via a frequency-controlled positive pump to the next recipe-controlled metering process.

Handling is easy. A 'grab' places the individual drums on a conveyor and pushes them towards the drum discharging system. The discharging pump is lowered onto the open drum. It consists of a double diaphragm pump with

base plate, assembled in a frame. This base plate with pump lies directly at liquid level and lowers along with the contents of the drum as they are discharged. To compensate for this movement a food hose on the pressure side of the discharging pump acts as a flexible connection and is attached to a connecting panel above the product buffer tank. The special design enables optimal discharging of drums whilst minimizing residual quantities.

Equipped with valves, instruments, a frequency controlled positive pump for product discharge and a cleaning pump, the Stephan Drum Discharging System is a completely optimized unit. Transfer from the buffer tank is integrated into a centralized automation system as part of the recipe management.

The Stephan Drum Discharging System and, if required, the buffer tank is pre-assembled on a stainless steel frame at the factory. Extensions to your operation can be shortened and simplified by preassembled units. Down times are minimized [1].

2.2.3 Performance of the Stephan Drum Discharging System

With a pump discharging system approximately 10 drums x 200 liter can be discharged per hour.

Discharge output from the buffer tank is adjusted to the subsequent process. Outputs between 5,000 and 20,000 kg/h are usual. Other outputs are possible. The Stephan Drum Discharging System can of course be expanded and customized to the requirements of the entire plant. In addition, equipping the piping from the product buffer tank to next module with a pigging station has been recommend.

This is how the Stephan Drum Discharging System optimizes your handling of highly viscous food ingredients [1].
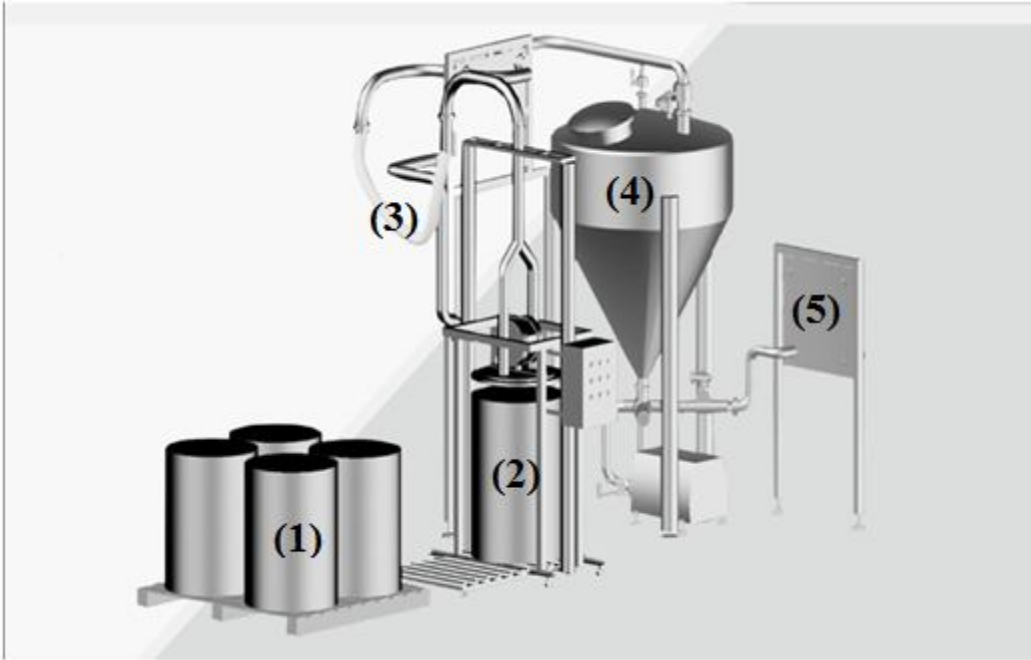

Figure (2.1): Stephan`s drums discharging system

Where:

(1): drums in ranking.

(2): drum under discharging.

(3): deliver tube.

(4): buffer tank.

(5): control panel.

2.3 Ball screw

The ball screws are a mechanical elements that convert a rotational motion into a linear motion, or vice versa. Needless to say, the ball screws can accomplish their objectives only when they are used in combination with various other mechanical elements as shows in figure (2.2). [2].

The screw is divided into two types as follow:

2.3.1 Sliding contact screws

This type can be divided into:

   i.   Triangular thread screws
- Used to fasten two objects.
- Move a nut linearly by rotating a screw.

  ii.   Acme thread lead screws
- Used to move things or to transfer forces.
- Screw portion of a jack, one of the tools furnished with a car, is a good example.

2.3.2 Rolling contact screws

This type contains:

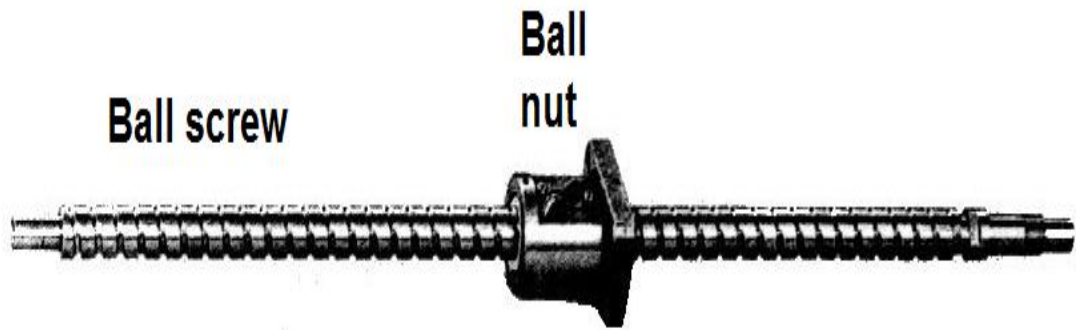   i.   Ball screws
  ii.   Roller screws

Figure (2.2): Ball screw

2.3.3 Construction of Ball Screw

By providing steel balls in between the screw shaft and the nut (grooves) as shown in figure (2.3), and the balls roll on the grooves to change the rolling contact from sliding contact to reduce friction. [2].

Figure (2.3): Contact between a ball & a ball nut

2.3.4 Friction force (Sliding and rolling friction)

When wanted to slide a box sitting on a floor, it does not move while pushing force is yet too small (static frictional force). But, it starts moving when the

pushing force has reached a certain level. In order to keep the box moving on, if needed to maintain pushing force at its dynamic frictional force, which is far less than the static friction force.

As described above, the friction force is the force that two objects exert upon each other through their contact surface and hinder each other's relative movement when they are in contact.

The intensity of frictional force varies with the state of contact. A friction force of rolling contact is usually smaller than that of sliding contact.

2.3.5 Ball screws advantages compared with sliding contact screws

The ball screw has several advantage when the comparison is done with sliding contact as follow:

  i. High mechanical efficiency

Most (90% or more) of the force used to rotate the screw shaft can be converted to the force to move the ball nut.

(Since friction loss is extremely low, the amount of force used to rotate the screw shaft is as low as one third of that needed for the acme thread lead screw).

Ball screws are used where motion direction must be changed (converted).
  - ✓ From rotations to linear motion.
  - ✓ From linear motion to rotations.

ii.   Low in wear

Because of rolling contact, wear is far less than that of sliding contact.

Thus, deterioration of accuracy is extremely low. This is used for application that calls for precise positioning.

Ball screws move smoothly enough under very slow speed.

They run smoothly even under a load.

- ✓ Used when a light, smooth motion is needed.
- ✓ Used when precise positioning is required.
- ✓ Used when heavy items must be moved lightly.

iii.   Estimation of life is possible.

Estimation of fatigue life of ball screw under given conditions is possible because the basics of life estimation are the same as those of rolling element bearings.

- ✓ It is possible to design a machine based on required life.
- ✓ Decision of ball screw specifications is easy.

iv.   Ball screw lead

In case of a ball bearing, its steel balls roll only in a circular groove, thus there is no way for steel balls to go out of it. However, since the groove in the ball screw is helical, its steel balls roll along the helical groove, and, then, they may go out of the ball nut unless they are arrested at a certain spot. Thus, it is necessary to change their path after they have reached a certain spot by guiding them, one after another, back to their "starting point" (formation of a recirculation path). The recirculation parts play that role.

When the screw shaft is rotating, as shows in figure (2.4), a steel ball at point (A) travels 2.5 turns of screw groove, rolling along the grooves of the screw

shaft and the ball nut, and eventually reaches point (B). Then, the ball is forced to change its pathway at the tip of the tube, passing back through the tube, until it finally returns to point (A). Whenever the nut strokes on the screw shaft, the balls repeat the same recirculation inside the return tube. The specifications of ball screws are standardized in ISO, JIS, etc.
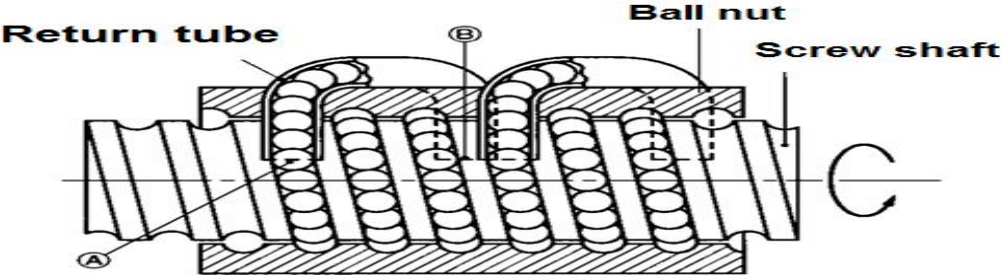

Figure (2.4): Ball screw recirculate

2.3.6 Parts of Ball Screws

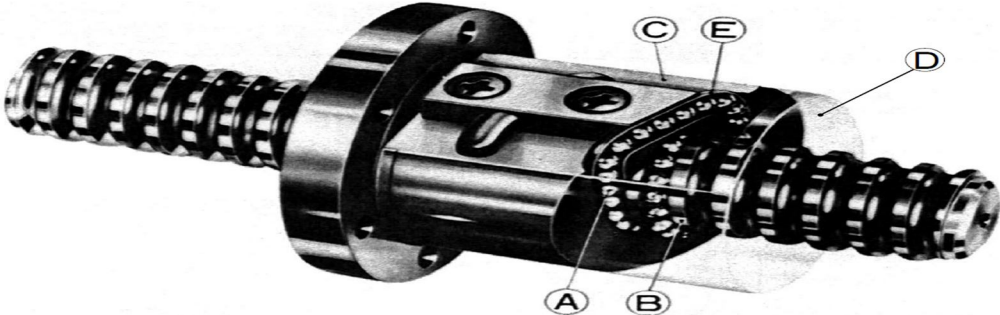Ball screw is made of parts which are shown in figure (2.5). [2]

Figure (2.5): Ball screw parts

A: Steel ball **B**: Screw shaft **C**: Ball nut **D**: Seal (both sides of ball nut)

E: Recirculation parts (return tube, etc.)

Ball screws utilize three different recirculation systems:

i. Profile of ball groove (Return tube) see figure 2.6

. Applicable to wide range of combinations of shaft diameter and lead.

. Good constant performance.

. Adaptability to mass production: Excellent

. Number of turns of balls/circuit: Generally 1.5 ~ 3.5 turns.
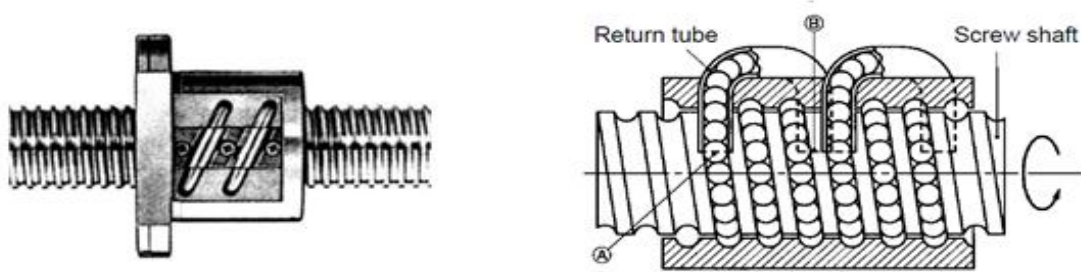

Figure (2.6): Recirculation return tube

ii. Ball pitch circle diameter (Deflector) as shown in figure (2.7)

. Suites for fine pitch lead. Compact in ball nut diameter.

. Adaptability to mass production: Poor

. Number of turns of balls/circuit: One turn only.
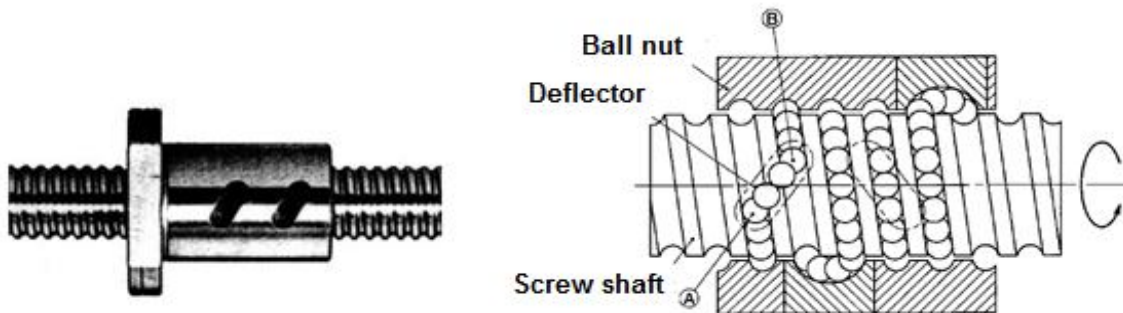
Figure (2.7): Recirculation deflector

iii.   End cap type (Ball recirculation hole is provided in the ball nut) as figure (2.8)

. For high helix leads for which the return tube and the deflector type are not applicable.

. Not versatile in production as a die mold is required for respective models.

. Adaptability to mass production: Moderate

. Number of turns of balls/circuit: 0.7 and 1.7 turns (Generally, it is applied to a multi start thread ball screw) [2].

Figure (2.8): End cap recirculation

2.3.7 Accuracy Grade of Lead Error

When choosing a lead screw accuracy grade should be selected depend on the purpose of usage (positioning or transportation) as shown in table (2.1).

Table (2.1): Accuracy grade of lead error

Item &category	Positioning series				Transportation series		
Accuracy grade	C0	C1	C2	C3	C5	Ct7	Ct10
V $_{300}$	3.5μm	5 μm	7 μm	8 μm	18 μm	52 μm	210 μm
Quality	High accuracy ←←←←←←←←←←←←←←←←						

Table (2.2): Shaft diameter verses lead

Nominal shaft diameter(mm)	Nominal lead Ph0 (mm)														
6	1	2	2.5												
8	1	2	2.5	3											
10	1	2	2.5	3	4	5	6								
12		2	2.5	3	4	5	6	8	10	12					
16		2	2.5	3	4	5	6	8	10	12	16				
20				3	4	5	6	8	10	12	16	20			
25					4	5	6	8	10	12	16	20	25		
32						5	6	8	10	12	16	20	25	32	
40						5	6	8	10	12	16	20	25	32	40
50						5	6	8	10	12	16	20	25	32	40
63						5	6	8	10	12	16	20	25	32	40
80							6	8	10	12	16	20	25	32	40
100									10	12	16	20	25	32	40
125									10	12	16	20	25	32	40
160										12	16	20	25	32	40
200										12	16	20	25	32	40

Occasionally, a customer may ask that a product have accuracy of "10 µm or less in v300," instead of specifying an accuracy grade as shown in table (2.1). *v300*: This is the largest variation (travel variation) in lead errors over any 300-mm interval within the effective travel length. [2].

2.3.8 Combination of Shaft Diameter and Lead

A combination of nominal screw shaft diameters and nominal leads according to JIS are shown below in table (2.2) (basic combinations).

2.4 Centrifugal Pump

A centrifugal pump is a device whose purpose is to produce pressure by accelerating fluid particles to a high velocity providing them with velocity energy as shown in figure (2.9).
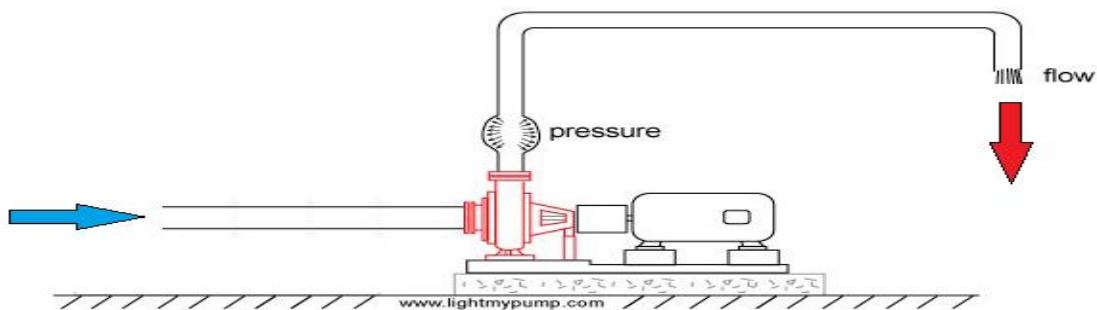

Figure (2.9): Centrifugal pump

A pump is a machinery or device for raising, compressing or transferring fluid.

A fluid can be gas or any liquid. Pumps are one of the most often sold and used mechanical devices and can be found in almost every industry.

Due to this there is a wide range of different pumps available, in general the family of pumps is separated into positive displacement and kinetic pumps.

A subcategory of kinetic pumps are centrifugal pumps which are again separated into radial pumps, mixed flow pumps and axial pumps.
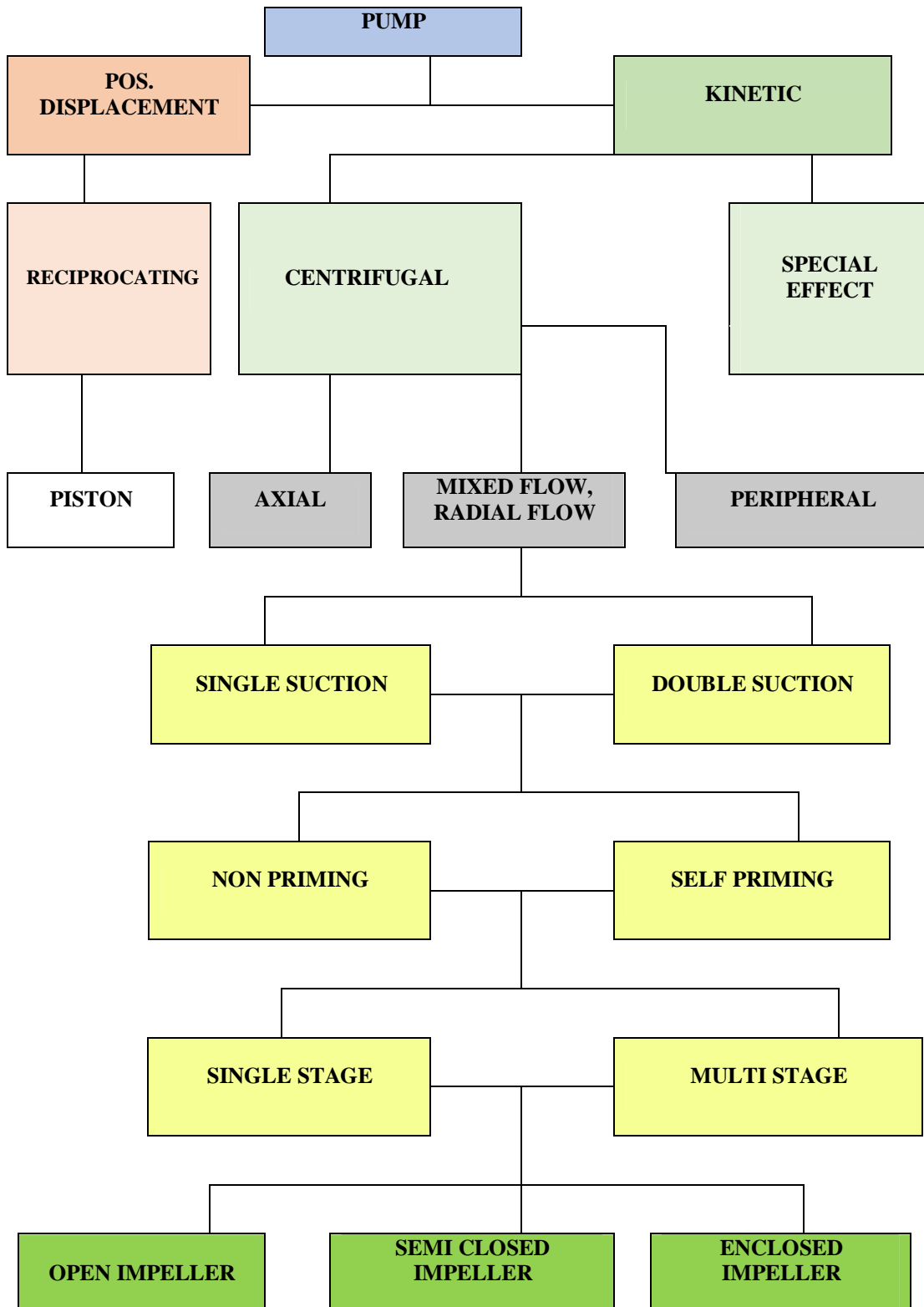
Figure (2.10): Types of pumps

But even at the axial end of the spectrum there is still a part of the energy coming from centrifugal force unless most of the energy is generated by vane action.

On the other hand in radial pumps almost all the energy comes from centrifugal force but there is still a part coming from vane action.There are also several pumps combining both principles placed somewhere in between the two extremes in the centrifugal pump spectrum known as mixed flow impellers. Characteristic for radial pumps are low specific speeds. Figure (2.10) illustrate the several types of pumps and classifies them.

2.4.1 Energy and head in pump systems

Pressure is produced at the bottom of the reservoir because the liquid fills up the container completely and its weight produces a force that is distributed over a surface which is pressure. This type of pressure is called static pressure.

Energy and head are two terms that are often used in pump systems. We use energy to describe the movement of liquids in pump systems because it is easier than any other method. There are four forms of energy in pump systems as follow:

i. Pressure energy

The energy that builds up when liquid or gas particles are moved slightly closer to each other.

ii. Elevation energy

The energy that is available to a liquid when it is at a certain height. If you let it discharge it can drive something useful like a turbine producing electricity.

iii. Friction energy

The energy that is lost to the environment due to the movement of the liquid through pipes and fittings in the system.

iv. Velocity energy

The energy that moving objects.

Pump energy = Friction energy + Elevation energy $\qquad$ (2.1)

2.4.2 Principal of centrifugal pumps

A centrifugal pump as shown in figure (2.11) is a rot dynamic pump that uses a rotating impeller to increase the pressure of a fluid. The fluid enters the pump near the rotating axis, streaming into the rotating impeller. The impeller consists of a rotating disc with several vanes attached. The vanes normally slope backwards, away from the direction of rotation. When the fluid enters the impeller at a certain velocity due to the suction system, it is captured by the rotating impeller vanes. The fluid is accelerated by pulse transmission while following the curvature of the impeller vanes from the impeller center (eye) outwards. It reaches its maximum velocity at the impeller's outer diameter and leaves the impeller into a diffuser or volute chamber. [3].
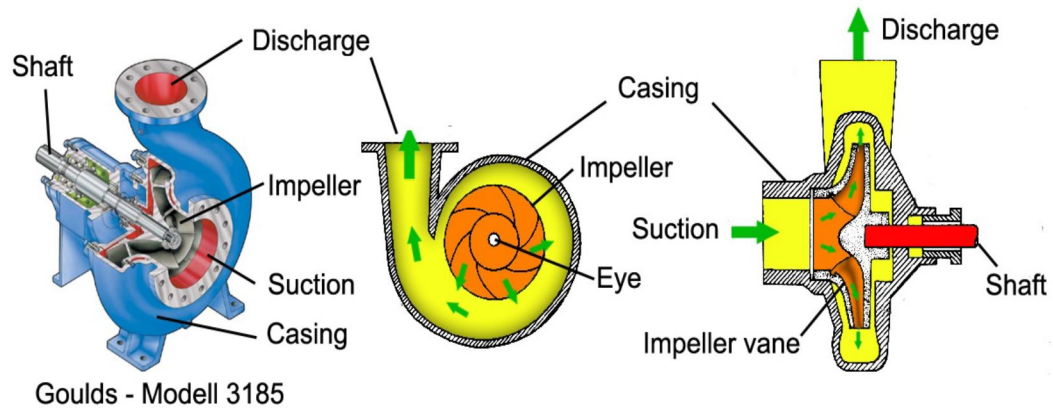
Figure (2.11): Centrifugal pump components

So the centrifugal force assists accelerating the fluid particles because the radius at which the particles enter is smaller than the radius at which the individual particles leave the impeller. Now the fluid's energy is converted into static pressure, assisted by the shape of the diffuser or volute chamber. The process of energy conversation in fluids mechanics follows the Bernoulli principle (equation 2.2) which states that the sum of all forms of energy along a streamline is the same on two points of the path. The total head energy in a pump system is the sum of potential head energy, static pressure head energy and velocity head energy.

$$Z_1 + \frac{V_1{}^2}{2 \cdot g} + \frac{P_1}{\rho \cdot g} = Z_2 + \frac{V_2{}^2}{2 \cdot g} + \frac{P_2}{\rho \cdot g} \qquad (2.2)$$

Where:

Z: elevation

P: pressure

V: velocity

g: gravity acceleration

ρ: density

As a centrifugal pump increases the velocity of the fluid, it is essentially a velocity machine. After the fluid has left the impeller, it flows at a higher velocity from a small area into a region of increasing area. So the velocity is decreasing and so the pressure increases as described by Bernoulli's principle. This results in an increased pressure at the discharge side of the pump. As fluid is displaced at the discharge side of the pump, more fluid is sucked in to replace it at the suction side, causing flow [4].

2.4.3 Centrifugal pump selection
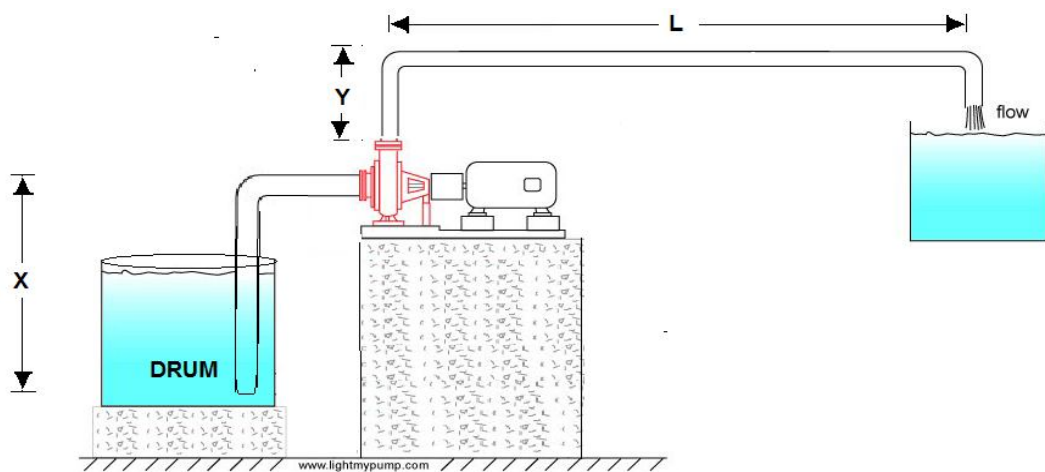
Figure (2.12): System high level

It is unlikely that can be bought a centrifugal pump off the shelf, install it in an existing system and expect it to deliver exactly the flow rate you require. The flow rate that will be obtained depends on the physical characteristics of the system such as friction which depends on the length and size of the pipes and elevation difference which depends on the building and location. The pump manufacturer has no means of knowing what these constraints will be.

This is why buying a centrifugal pump is more complicated than buying a positive displacement pump which will provide its rated flow no matter what system you install it in.

The main factors that affect the flow rate of a centrifugal pump are: [4]

- ✓ Friction, which depends on the length of pipe and the diameter
- ✓ Static head, which depends on the difference of the pipe end discharge height vs. the suction tank fluid surface height
- ✓ Fluid viscosity, if the fluid is different than water.

The steps to follow to select a centrifugal pump as the system that illustrate in figure (2.12) are:

1. Determine the flow rate

To size and select a centrifugal pump, first determine the flow rate by equation (2.3). In an industrial setting, the flow rate often depends on the production level of the plant. Selecting the right flow rate may be as simple as determining that it takes 100 gpm (6.3 L/s) to fill a tank in a reasonable amount of time or the flow rate may depend on the interaction between processes.

$$Q = A_1 \cdot V_1 = A_2 \cdot V_2 \qquad (2.3)$$

Where:

Q: flowrate (m^3/sec)

A: cross section area (m^2)

V: velocity (m/sec)

2. Determine the static head

This a matter of taking measurements of the height between the suction tank fluid surface and the discharge pipe end height or the discharge tank fluid surface elevation.

3. Determine the friction head

The friction head depends on the flow rate, the pipe size and the pipe length. For fluids different than water the viscosity will be an important factor. The equation (2.4) illustrates the friction head:

$$\text{friction head} = \frac{\text{force required to overcome friction } _x \text{ displacement}}{\text{weight of fluid displaced}} \qquad (2.4)$$

4. Calculate the total head

The total head is the sum of the static head and the friction head as illustrates in equations (2.5) & (2.6).

$$\text{TDH} = h_d \ - \ h_s \qquad (2.5)$$

Where:

TDH: total dynamic head

h_d: delivery head

h_s: suction head

$$\text{TDH} = (z_2 \ - \ z_1) + \frac{(p_2 \ _- \ p_1)}{\rho \ _x \ g} + \frac{(v_2{}^2 - v_1{}^2)}{2 \ _x \ g} \qquad (2.6)$$

Where:

Z: elevation

P: pressure

V: velocity

g: gravity acceleration

ρ: density

5. Select the pump

You can select the pump based on the pump manufacturer's catalogue information using the total head and flow required as well as suitability to the application. [4].

2.5 Bearings

The main function of a rotating shaft is to transmit power from one end of the line to the other end.

It needs a good support to ensure stability and frictionless rotation. The support for the shaft is known as "bearing".

The shaft has a "running fit" in a bearing. All bearings are provided some lubrication arrangement to reduce friction between shaft and bearing.

Bearings are classified under two main categories:

2.5.1 Plain or slider bearing

In which the rotating shaft has a sliding contact with the bearing which is held stationary as shown in figure (2.13). Due to large contact area friction between mating parts is high requiring greater lubrication.

Classification of the sliding contact bearing are:

a) Journal bearing.

b) Footstep or pivot bearing.

c) Bushed bearing.

Figure (2.13): Sliding bearing

2.5.2 Rolling or anti-friction bearing

Due to less contact area rolling friction is much lesser than the sliding friction, hence these bearings are also known as antifriction bearing as shown in figure (2.14).the rolling bearing can divided as follow:

- ✓ Single row deep-groove ball bearing

- ✓ Straight row roller bearing:

As well as the roller bearings have a several applications as follow:

- ● Tapered roller bearing (TRB):

- ● Thrust ball bearing:

- ● Needle roller bearing:

- ● Spherical Roller Bearings
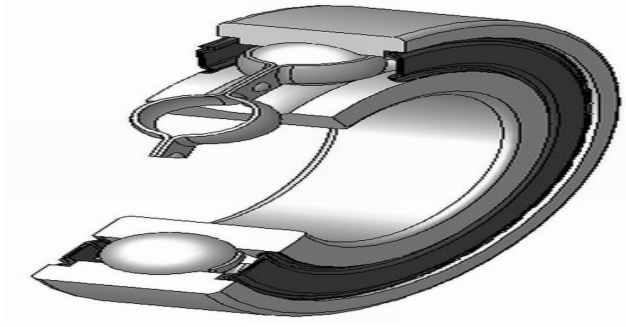
Figure (2.14): the rolling bearing

Due to low rolling friction, ball and roller bearings are aptly called "antifriction" bearing:

✓ Frictional resistance considerably less than in plain bearings

✓ Rotating – non-rotating pairs separated by balls or rollers

✓ Ball or rollers has rolling contact and sliding friction is eliminated and replaced by much lower rolling friction.

✓ In plain bearing the starting resistance is much larger than the running resistance due to absence of oil film.

✓ In ball and rolling bearings the initial resistance to motion is only slightly more than their resistance to continuous running.

✓ Hence ball and rolling bearing are more suitable to drives subject to frequent starting and stopping as they save power.

✓ Owing to the low starting torque, a low power motor can be used for a line shaft running in ball bearing. [5].

Table (2.3) lists some general types of ball bearings and their typical load capabilities.

Table (2.3) Different types of bearings

	Type	Capacity	
		Radial	Thrust
Ball Bearing	Conrad Type	Good	Fair
	Self-aligning	Fair	Fair
Straight/Cylindrical Roller Bearing	Separable inner ring non-locating	Excellent	0
	Self-contained two direction locating	Excellent	Poor
Tapered Roller Bearings	Self-aligning	Good	Fair
Spherical Roller Bearings	Self-aligning	Excellent	Good
Needle Bearings	Complete bearing	Good	0
Thrust Bearings	Single direction ball with grooved race	Poor	Excellent
	Single direction eye roller	0	Excellent

2.6 Pipes

Considered as the carrier line which transfers the PACL from the drums into buffer tanks. These lines made of polyvinyl chloride PVC which have the following characteristics:
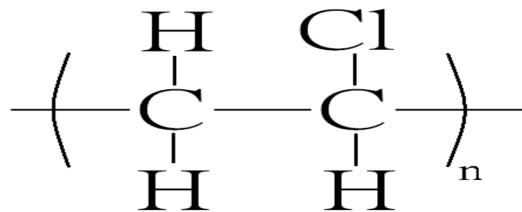
$$\left(\begin{array}{c} H \\ | \\ -C- \\ | \\ H \end{array} \begin{array}{c} Cl \\ | \\ -C- \\ | \\ H \end{array}\right)_n$$

Figure (2.15): PVC chemical construction

28

PVC is a thermoplastic polymer as shown in figure (2.15). Thermoplastic means it melts into a liquid and cools into a brittle, glassy solid. Polymer is a substance composed of repeating molecular units. Polys means many, and (menos) means many in the Greek language. In common use, polymer is used synonymously with plastic.

PVC is often used in building materials and often replaces more expensive wood, concrete and clay. The first vinyl chloride was accidentally discovered by a scientist as early as the 1830s (Henri Victor Renault), but it wasn't until 100 years later, in 1926 that Waldo Simon of B.F.

Goodrich learned to plasticize the compound with additives, making it much more flexible and suitable for widespread commercial use.

In consumer products, PVC is often used in plastic bottles such as those for detergent, clothing, and many soft baby toys. PVC poses some health risks, however, in that the additives used to plasticize the compound can leach out of the material and have been linked to carcinoma and other health problems. This is a concern when babies chew on the toys or when PVC is used in hospitals. The alternatives for plasticization are generally more expensive.

Another environmental concern in the use of PVC is that the chlorine in the compound produces poisonous dioxins that are released when PVC is incinerated in municipal waste facilities.

Dioxins can travel great distances in the atmosphere and have been lined to immune system impairment, carcinoma and reproductive problems. Municipal waste incinerators are equipped to collect a portion of hazardous byproducts. Private backyard waste burning releases the dioxins when PVC is burned, and should be avoided at all costs.

The code for recyclable PVC is shown in Figure (2.15), however, PVC is often not recycled because the cost of post-consumer PVC far outweighs the cost of manufacturing new material.

PVC has a density of 1380 kg/m³, making it slightly denser than water (1000 kg/m³).

The carrier line is divided into two sides (suction side and delivery side), the delivery side size is a degree bigger than the suction side size as a rule of thumb due to:

- ✓ Reduce the friction on the delivery side due to high pressure.
- ✓ Increase the transfer efficiency.

The carrier line has a set of elbows and tees a cording to carrier line requirements.

2.7 Electric motor

The electrical motor is a device converts the electrical energy into mechanical energy.

2.7.1 Calculation of operation cost and service factor

Operation cost is an important aspect that should be taken in consideration during the design. Calculating the operation cost depend on several equations as follow:

i.   West Virginia (relationship)

$$P = V * I * COS \Theta \qquad\qquad (2.7)$$

Where:

P: Power (Watts)

V: Voltage (Volts)

I: Current   (Amperes)

Ө: Phase angle (degree)

ii.   Power factor (PF)

The ratio of apparent power to actual power [7].

$$\text{Power factor} = \frac{\text{actual power}}{\text{apparant power}} \qquad\qquad (2.8)$$

At high PF the customer uses efficient motors in their processes [6].

$$\text{Watt consumed} = \text{volts} * \text{amps} * \text{PF} \qquad\qquad (2.9)$$

iii.   Service factor (S.F):

Amount of over load the motor can tolerate on a continuous basis at rated voltage and frequency.

1.0 S.F: no overload is tolerated for extended periods.

1.25 S.F: motor can be overload 25% for an extend period of time when operated at rated voltage and frequency.

Common service factors for AC (alternating current) motors: 1.15, 1.20, 1.25, 1.35 and 1.40.

2.7.2 Factors to be considered in selection of an electric motor

Motor must do three things:

i. Start the equipment load.
ii. Drive the load once it's start.
iii. Survive the abuse of the surroundings in which it operates.

   Before selecting an electric motor different criteria should be considered as follow:

- Type of power available:

230 volt motor should not be used if only 115 volt circuits are available as well as three phase motor cannot be operated on electrical system with only single phase service as illustrated in table (2.4).

Table (2.4): Typical operating voltage

Single-phase	115	208	230	240	460	480
Three-phase	208	230	460	480		

- Size of motor:

Rate of horse power refers to power that it will develop when the motor is turning at full speed. The rule of thumb for estimating size needed:

- ✓ If equipment can be operated by hand, a ¼ HP motor will usually be adequate.
- ✓ If gasoline engine is to be replaced by electric motor, an electric motor approximately 2/3 the HP rating of the engine will be adequate.

- Replace tractor (power take-off) PTO with an electric motor of approximately the same HP.

- Starting load:

Motor selected must produce adequate starting torque to start the load so the motor was departed as follow:

- ✓ Split phase.
- ✓ Capacitor start – induction run.
- ✓ Capacitor start - capacitor run.
- ✓ Repulsion start – induction run.
- ✓ Series or universal.
- ✓ Shaded pole.
- ✓ Three phase.

Capacitor start – induction run and three – phase are the most common and produce highest starting torque.

- Speed requirement:

The speed of shaft will turn in revolutions per minute (RPM) when motor is operating at full speed as well as the RPM of motor should be speed needed to operate equipment at proper speed.

- Bearing type:

The motor bearing has two types as follow:

- ✓ Sleeve bearings.
- ✓ Ball bearing.

It designed for axial loads and pressed into the motor housing.

- Base type:

The motor has different kinds of based determine by application of motor as follow:

- ✓ Rigid base.
- ✓ Sliding adjustable base.
- ✓ Cushion amount (reduce vibration and wear).
- Environment:

The motor was departed based on the environment to protect it from surrounding elements as follow:

- ✓ Open drip proof.
- ✓ Splash proof.
- ✓ Totally enclosed – fan cooled (TEFC)
- ✓ Explosion proof.
- ✓ -Totally enclosed – air over (TEAO).
- ✓ Totally enclosed – non ventilated (TENV).

The environment in which the motor is placed helps to dictate the type of the right motor.

2.7.3 Common electric motor types

1- Split phase motor:

It is primarily single voltage motors used for starting load as fans, bench grinders, laundry equipment, and machinery tools. It has high starting current requirement and will draw 5 – 7 times more than normal.

2- Capacitor - start motor:

This kind of motors use for difficult starting loads or starting torque due to starting winding capacitor. It has medium starting current requirement and will draw 3 to 6 times than normal running current when starting.

3- Permanent split - Capacitor (PSC) motor:

It used when load requires a higher starting torque than a shaded-pole motor can produce. It is a high efficient and it available with higher HP than shaded-pole motors.

4- Repulsion start – induction run.

5- Series or universal motor:

Use for special purpose motor and usually it a part of portable appliances or tools so it can operated on AC or DC.it has high starting torque and high starting current.

6- Shaded pole motor:

It is light duty motor (single phase) operates on AC as well as it is low starting torque and low efficiency. Addition to that it isn't reversible except by reversing field coils.

7- Three phase motor:

This kind of motors operated on three-phase AC for medium to high starting torque as well as low, medium or high starting current requirement: [6].

It is common used in industry due to:

- Less expensive to purchase and operate than single phase motors.

- Longer life time, fewer parts and fewer reliability problems.

Motors can be connected with different ways (as shown in figure (2.16)) depends on nature of the work as follow:

✓ Flexible shaft drive:

This drive operate when machine has a same speed ,used on equipment operating at various angles as well as manufactured to operate in only one direction.

✓ Flexible hose coupling drive:

It is a piece of plastic or rubber hose is used as a drive it connects the end of hose with machine and motor shaft and fitted with clamps.

✓ Cushion-flange coupling drive:

It is two flanges attached to the shaft and a flexible center part fastened to the flanges, the center is made of rubber or similar material.

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┌─────────────────────────────────────────────────────────────────────┐
│              Classification of electric motor drives                  │
└─────────────────────────────────────────────────────────────────────┘
          │                                              │
┌─────────────────────────┐              ┌─────────────────────────┐
│    Direct (same speed)   │              │    Speed conversion      │
│                          │              │    (different speed)     │
└─────────────────────────┘              └─────────────────────────┘
          │                                              │
┌─────────────────────────┐              ┌─────────────────────────┐
│    Flexible shaft drive  │              │        Gear drive        │
└─────────────────────────┘              └─────────────────────────┘
          │                                              │
┌─────────────────────────┐              ┌─────────────────────────┐
│  Flexible hose coupling  │              │  chain and sprocket drive│
│          drive           │              │                          │
└─────────────────────────┘              └─────────────────────────┘
          │                                              │
┌─────────────────────────┐              ┌─────────────────────────┐
│  Cushion-flange coupling │              │       Pulley –belt       │
│          drive           │              │                          │
└─────────────────────────┘              └─────────────────────────┘
          │
┌─────────────────────────┐
│  Flange coupling drive   │
└─────────────────────────┘
```

Figure (2.16): Classification of electric motor drives

✓ Flange coupling drive:

It is consists of two metal discs and a flexible middle disc.

✓ Gear, chain and sprocket drive:

It is relatively complex however generally included as a part of the machine.

✓ Pulley- and belt drives:

Very common and easy to install however use large pulleys to prevent slippage, the common types of belt drive is:

2.8 Switches

Switches commonly used to control the "on/off function" of a component and/or circuit, it is used to "direct the current" in an electrical circuit or can be used as "momentary contact" switches.

The term "pole(s)" refers to the number of input circuits of the switch and "throw(s)" refers to the number of output circuits of the switch.

Switches may be "normally open" (NO), or "normally closed" (NC) depending upon the application and also can be used on either power or ground side of circuit. [7].

2.9 Programmable Logic Controller (PLC)

Programmable logic controllers (PLCs) have been an integral part of factory automation and industrial process control for decades. PLCs control a wide array of applications from simple lighting functions to environmental systems to chemical processing plants. These systems perform many functions, providing a variety of analog and digital input and output interfaces; signal processing; data conversion; and various communication protocols as shown in figure (2.17). All of the PLC's components and functions are centered on the controller, which is programmed for a specific task.

The basic PLC module must be sufficiently flexible and configurable to meet the diverse needs of different factories and applications. Input stimuli (either analog or digital) are received from machines, sensors, or process events in the form of voltage or current. The PLC must accurately interpret and convert the stimulus for the CPU which, in turn, defines a set of instructions to the output systems that control actuators on the factory floor or in another industrial environment. [7].

Modern PLCs were introduced in the 1960s, and for decades the general function and signal-path flow changed little. However, twenty-first-century process control is placing new and tougher demands on a PLC: higher performance, smaller form factor, and greater functional flexibility. There must be built-in protection against the potentially damaging electrostatic discharge (ESD), electromagnetic interference and radio frequency interference (RFI/EMI), and high-amplitude transient pulses found in the harsh industrial setting.

2.9.1 Robust Design

PLCs are expected to work flawlessly for years in industrial environments that are hazardous to the very microelectronic components that give modern PLCs their excellent flexibility and precision. No mixed-signal IC Company understands this better than Maxim. Since our inception, we have led the industry with exceptional product reliability and innovative approaches to protect high-performance electronics from real environmental dangers, including high levels of ESD, large transient voltage swings, and EMI/RFI. Designers have long endorsed Maxim's products because they solve difficult analog and mixed-signal design problems and continue solving those problems year after year.

2.9.2 Higher Integration

PLCs have from four to hundreds of input/output (I/O) channels in a wide variety of form factors, so size and power can be as important as system accuracy and reliability. Maxim leads the industry in integrating the right features into ICs, thereby reducing the overall system footprint and power demands and making designs more compact. Maxim has hundreds of low-power, high-precision IC's in the smallest available footprints, so the system designer can create precision products that meet strict space and power requirements.
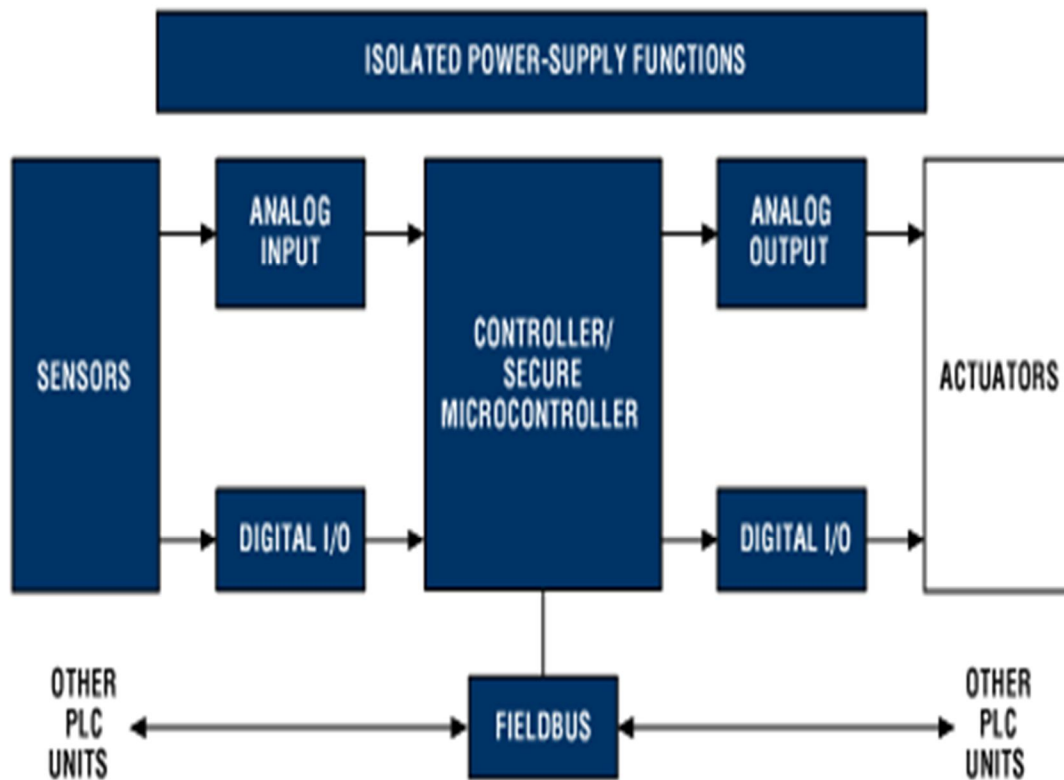

Figure (2.17): overview of PLC structure