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Exam Seat No. _____

MECHANICAL GROUP | SEMISTER VI | DIPLOMA IN ENGINEERING AND TECHNOLOGY

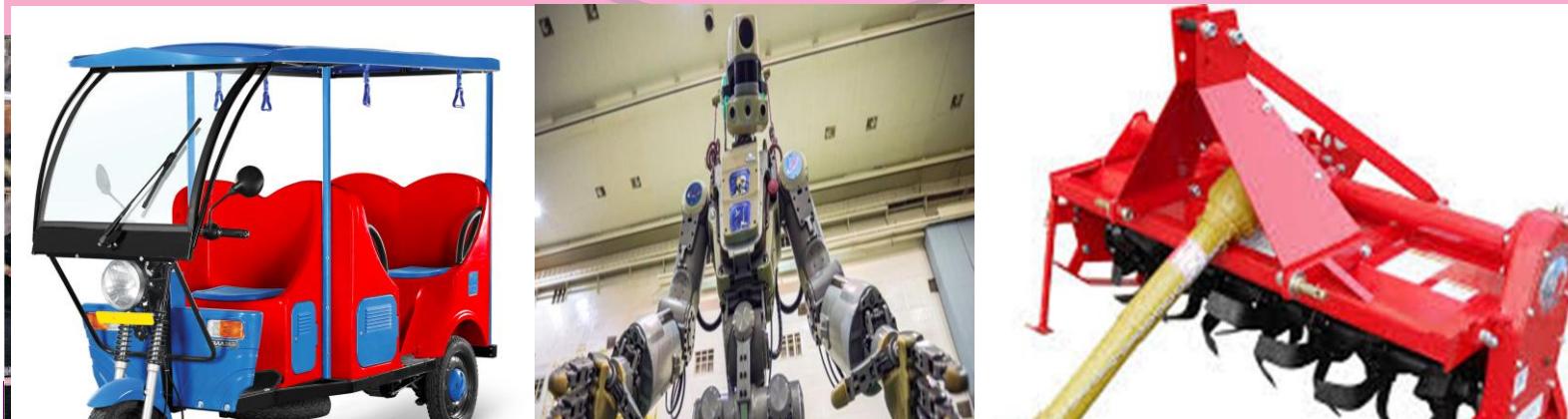
A LEARNING MANUAL

FOR

Emerging Trends in Mechanical Engineering

(22652)

(ME)



MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
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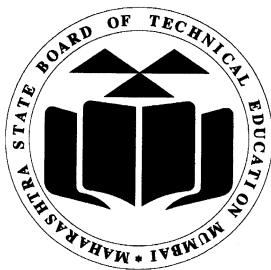
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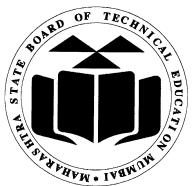
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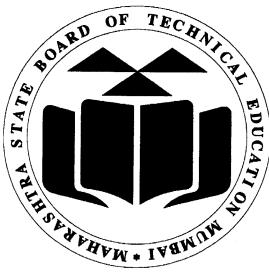
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This is to certify that Mr. / Ms.

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in.....of Institute
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has attained pre-defined practical outcomes(POs) satisfactorily
in course **Emerging Trends in Mechanical Engineering**
(22652) for the academic year 20.....to 20..... as prescribed in
the curriculum.

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Date:..... Exam Seat No.

Course Teacher

Head of the Department

Principal



Preface

The primary focus of any engineering work in the technical education system is to develop the much needed industry relevant competency & skills. With this in view, MSBTE embarked on innovative “I” scheme curricula for engineering diploma programmes with outcome based education through continuous inputs from socio economic sectors. The industry experts during the consultation while preparing the Perspective Plan for diploma level technical education categorically mentioned that the curriculum, which is revised and implemented normally further revised after 4-5 years. The technological advancements being envisaged and faced by the industry in the present era are rapid and curriculum needs to be revised by taking care of such advancements and therefore should have a provision of accommodating continual changes. These views of industry experts were well taken & further discussed in the academic committee of MSBTE, wherein it was decided to have a dynamism in curriculum for imparting the latest technological advancements in the respective field of engineering. In order to provide an opportunity to students to learn the technological advancements, a course with a nomenclature of “Emerging Trends in Mechanical Engineering” is introduced in the 6th semester of Mechanical Engineering Group.

The technological advancements to be depicted in the course called emerging trends was a challenging task and therefore it was decided to prepare a learning material with the involvement of industrial and academic experts for its uniformity in the aspect of delivery, implementation and evaluation.

Over the coming years, technological developments such as Robotics, IOT, Artificial intelligence, smart controls are likely to have a significant impact on the world of work and employment. Looking towards the era in Technological advancement, Mechanical / Automobile / Production Engineering offers addition of new Dynamic subjects and new versions of core subjects. Diploma Mechanical/Automobile/Production Engineers should be familiar with new technologies from the fields of Automobile Engineering, HVAC, Energy Management, Advanced Manufacturing Processes, Agriculture and Farm Machines and many more. This Dynamic course will give insight to the recent practices adopted by the Mechanical Industries and awareness of these techniques will enhance career opportunities of Diploma Mechanical / Automobile / Production Engineers.

This learning manual is designed to help all stakeholders, especially the students and teachers and to develop in the student the pre-determined outcomes. It is expected to explore further by both students and teachers, on the various topics mentioned in learning manual to keep updated themselves about the advancements in related technology.

MSBTE wishes to thank the Learning Manual development team, specifically Mr. R A Panchal, Chairman of the Course Committee, Industry Experts, Mr. Anant Zanpure, Coordinator & Mr. Sanjay Harip, Co-coordinator of the Programmes and academic experts for their intensive efforts to formulate the learning material on “Emerging Trends in Mechanical Engineering”. Being emerging trend and with the provision of dynamism in the curricula, any suggestions towards enrichment of the topic and thereby course will be highly appreciated.

(Dr. Vinod M.Mohitkar)
Director
MSBTE, Mumbai

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Unit 1: Recent Trends in Automobile Industry

1.1 HYBRID CARS

Definition: A hybrid electric vehicle (HEV) is a type of hybrid vehicle that combines a conventional internal combustion engine (ICE) system with an electric propulsion system (hybrid vehicle drivetrain).

There are three main reasons for which the automotive manufacturers are developing and selling HEVs:

- Reduction of the CO₂ emissions (by reduction of the fuel consumption)
- Reduction Of The Exhaust Gas Toxic Emissions
- Improvement of the powertrain dynamics (by increasing total power and torque)

There is a variety of HEV types, and the degree to which each functions as an electric vehicle (EV) also varies. The most common form of HEV is the hybrid electric car, although hybrid electric trucks (pickups and tractors) and buses also exist.

The powertrain of a HEV is quite complex because it contains all the components of an ICE vehicle plus most of the components of a pure electric vehicle (EV). Also, depending on the level of hybridization, it needs two energy sources, the fuel tank for the engine and a battery for the electric machine.

Main components of a Hybrid vehicle:

1. An internal combustion engine (i.e. Petrol engine / Diesel engine): In most of the hybrid vehicles, IC engine acts as the main source of power.
2. Electric motor: It transforms the electric energy stored in a battery into mechanical energy i.e. it drives wheels with the help of electricity stored in a battery.
3. Electric battery: Its function is to store electric energy and supply it whenever necessary.
4. Inverter: Electricity stored in an electric battery is in the form of Direct Current (DC) while the majority of the motors used in the present day hybrid vehicles require Alternating Current (AC) to run. So, an Inverter performs the function of converting the DC from the battery to AC for the motor.
5. Electric Generator (Exclusive for series & series-parallel hybrids): The function of a generator is to produce electricity when driven by an external power source. Series hybrids use this component where an IC engine drives a generator to produce electricity which then charges the battery.
6. Control Module: It is the most important component of the hybrid vehicle. It controls the entire operation of the vehicle by synchronizing all the power sources employed.

Types of Hybrid Cars:

Classification of Hybrids:

Hybrids are mainly classified based on the following criteria:

1. The structure of drive-train
2. The degree of hybridization

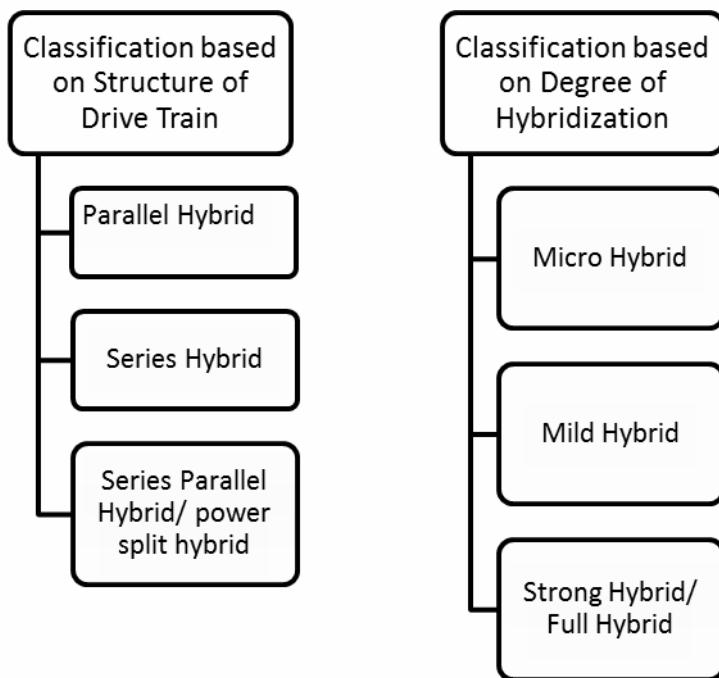


Figure 1.1: Classification of Hybrid Vehicles

1. Depending upon the structure of drivetrain, hybrid vehicles are further classified as:

Series Hybrid:

In this type of hybrid vehicle, wheels are powered only by an Electric motor which ultimately derives its power from the electric battery. The IC engine installed in the vehicle does not supply power to wheels directly. So, these vehicles need large capacity batteries.

The series hybrid vehicle is more efficient in low-speed driving involving frequent start-stop.

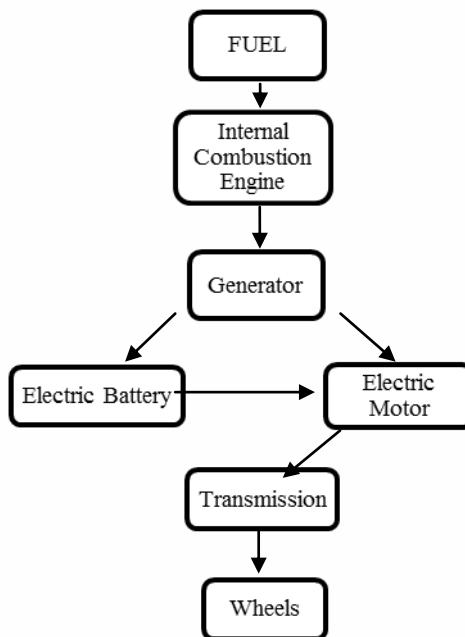


Figure 1.2: Block diagram of Series Hybrid Vehicle

Parallel Hybrid:

In this type of a hybrid vehicle, wheels get power from both the IC engine and an Electric Motor. The drivetrain of these vehicles is so designed that it can receive power from both the IC engine and Battery simultaneously. However, the IC engine serves as the main source of power in the Parallel hybrid vehicle.

As electric battery's role is only to support the engine, these vehicles need a smaller capacity battery. A parallel hybrid is more effective in high-speed driving.

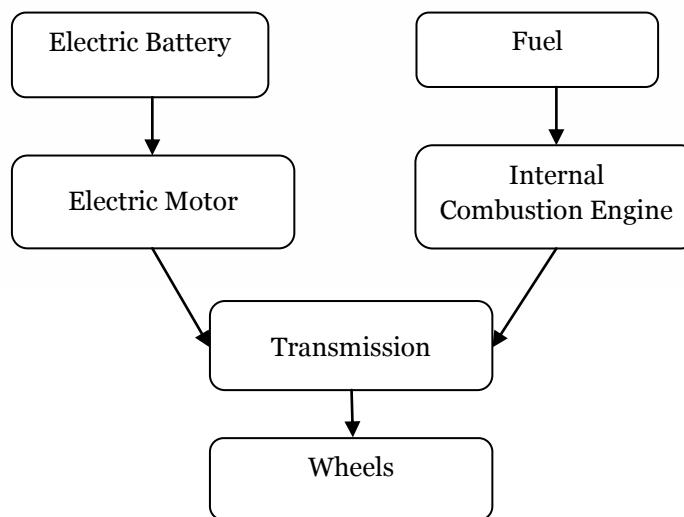


Figure 1.3: Block diagram of Parallel Hybrid Vehicle

Series-Parallel Hybrid/ Power split Hybrid:

This recently developed system is a combination of a series hybrid system and parallel hybrid system. Thus, it takes the best from both the worlds. Depending upon

the load on the vehicle, it can act like a parallel hybrid vehicle or a series hybrid vehicle. The control module governs the selection of the most suitable mode.

Almost all the modern hybrid vehicles belong to this category. E.g. Toyota Prius, Toyota Camry, Honda Civic etc.

2. The degree of hybridization

Based on the degree of hybridization, hybrids are classified as follows:

a. Micro hybrid:

Micro hybrid technology is the lowest level of vehicle hybridization. It contains mainly start stop technology. Here, energy stored in an auxiliary battery is used to quickly start a vehicle at the traffic signal. In India, a common example of micro hybrid is the Mahindra Scorpio.

b. Mild Hybrids:

These hybrids cannot run on electric battery alone. They always need the support of an IC engine to run as the battery used in these vehicles is of a small capacity.

c. Strong Hybrids/ Full Hybrid:

This vehicle can run on either the IC engine or the electric battery alone as the battery used in them is of a higher capacity.

The next level of hybridization is the mild hybrid where electrical energy is used for start stop and also for driving vehicle for short distance at low speed or to aid in acceleration. Above this there are full hybrid and plug in hybrid vehicles where the vehicle can move considerable distance using batteries

• **Plug-in hybrids (PHEVs)**

A plug-in hybrid electric vehicle (PHEV), also known as a plug-in hybrid, is a hybrid electric vehicle with rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle, having an electric motor and an internal combustion engine; and of an all-electric vehicle, also having a plug to connect to the electrical grid. PHEVs have a much larger all-electric range as compared to conventional gasoline-electric hybrids, and also eliminate the "range anxiety" associated with all-electric vehicles, because the combustion engine works as a backup when the batteries are depleted.

Hybrid Vehicle Manufacturers:

1. Mahindra e-Verito

Mahindra is now integrating electric technology in almost every future car. The Verito sedan is the perfect combination of electric and conventional cars.

2. BMW i8

The BMW i8 is not just an electric-hybrid car. It is a sports car that has an all-electric range of 37 km, with 0-100 kmph ability in less than 4.5 seconds.

3. Volvo XC90 T8

It is the first hybrid SUV across Indian soils when launched. The most distinguished features of the car include individual electronically-adjustable reclining rear seats with massage & ventilation functions. Furthermore, the car

also offers increase legroom with footrests. Additionally, the car also has ambient lighting and illuminated storage in addition to a regal design.

4. Lexus LS500h

Lexus is ever-present in luxury segments. It recently launched a range of hybrid cars in various segments. The cars were under ES (mid-size sedan), LS (full-size sedan), RX (mid-size crossover), and NX (compact SUV) categories.

5. Toyota Camry

Toyota is hailed as the pioneer for hybrid technology in cars. The Camry sedan by Toyota has enjoyed spectacular success elsewhere in the world. It is now poised to enter the Indian market.

Table -1.1Technical Specifications of Mahindra E Verito

TECHNICAL SPECIFICATIONS						
Variants		C2	C4	C6	D2	D4
Driving Range*		110			140	
With Revive® (Km)				8		
*Charging Time @ 25 Degree Celsius		Normal Charging (0-100%)		8 hours 30 min (+/- 15 min)	11 hours 30 min (+/- 15 min)	
Fast Charging (upto 80%)		1 hour 20 min		1 hour 30 min		
Motor	Construction	3 Phase AC Induction Motor				
	Power (kW)	31kW @ 4000 rpm				
	Torque (Nm)	91 Nm @ 3000 rpm				
	Controller	550 A				
Battery	Usable Capacity (Ah)	199.5			266	
	Technology	Lithium Ion				
	Total On-board power (kilowatt-hour)	13.91			18.55	
Gear Box	Type	Direct Drive				
	No of Forward Ratios	1				
	Gear Ratios	10.83:1				
Brakes	Front	Disc				
	Rear	Drum				
	Parking Brake	Manual				
Steering	Power Assisted	Electric				
Suspension	Front	Macpherson Type with Wishbone Link				
	Rear	H-Section Torsion Beam with Programmed Deflection Coil Spring				
Tyre	Wheel Rim Size (inch)	14				
	Tyre Dimensions	185/70 R14				
	Spare Tyre Dimensions	185/70 R14				
Performance	Gradability (Degrees)	9.7				
	Top Speed (Km Per Hour/KMPH)- Fleet	80				
	Top Speed (Km Per Hour/KMPH)- Personal	86				
	Time from 0-60 KMPH (sec)	10.7			11.2	
Dimensions	Overall Length (mm)	4247				
	Overall Width (mm)	1740				
	Overall Height (mm)	1540				
	Unladen Ground Clearance (mm)	172				
Weight	Wheel Base (mm)	2630				
	Boot Space (Litres)	510				
	Unladen Kerb Weight (Kg)	1225			1265	
Warranty	Gross Weight (Kg)	1704			1704	
	Car	2 years or 40,000 Km (whichever is earlier)				
	Battery	3 years or 36,000 Km (whichever is earlier)				

3 YEARS/36,000 KMS
BATTERY WARRANTY

2 YEARS/40,000 KMS
VEHICLE WARRANTY

DESAT SILVER

DIAMOND WHITE

*at 25 +/- 2 degrees ambient and battery temperature.

The Main Limitations of a HEV are:

- It adds more weight to the vehicle due to additional electric components,
- It is more difficult to build and
- The total price of purchasing and ownership increases (compared to a ICE vehicle). In most of the HEVs the electric propulsion is done using permanent-magnet electric machines.

The main Benefits of an electric machine, compared to an ICE, are:

- Constant high torque at low speeds
- Very high efficiency

- Instant torque delivery
- Energy recovery capability

Compared with a conventional powertrain, by putting together an electric machine with an ICE we get the following advantages:

- By providing torque assistance with the electric motor, the ICE can work in the most fuel efficient point (speed and torque)
- The ICE can be downsized, retaining in the same time a constant overall torque and power of the powertrain, thanks to the electric motor assistance
- The kinetic energy of the vehicle during braking can be recovered and stored in the high voltage battery, with the help of the electric machine operating as a generator
- The torque response of the powertrain can be improved, because of the instant torque delivery of the electric motor
- The gear ratios of the transmission can be lowered, to keep the engine at lower speed operating points (better fuel efficiency), because the electric motor can deliver instant torque request from the driver

Having two sources of power, the hybrid control system needs to decide the torque split between the Internal Combustion Engine and electric machine, depending on the driver input and vehicle operating state.

A hybrid electric vehicle performs at least one or more of the following functions:

- Engine idle stop/start
- Electric torque assistance (fill and boost)
- Energy recuperation (regenerative braking)
- Electric driving
- Battery charging (during driving)
- Battery charging (from the grid)

1.2 Electric Vehicles

Definition: An electric vehicle (EV) is one that operates on an electric motor for vehicle propulsion, instead of an internal-combustion engine that generates power by burning a mix of fuel and gases.

Battery based Electric vehicle includes electric 2-wheeler, 3-wheeler, cars and electric buses. Electric vehicle is seen as a possible replacement for current-generation automobile, in order to address the issue of rising pollution, global warming and depleting natural resources.

Battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) offer the potential to reduce the CO₂ emissions of the traffic sector and the dependence on mineral oil. The reasons for this are the higher efficiency of electric power trains and the possibility of using renewably generated electricity for transportation. As BEVs and PHEVs in electric mode are operated locally emission-free, they also reduce the pollution in densely populated areas. Besides ecological reasons, economic reasons will facilitate

the introduction of electric vehicles. Increasing prices for mineral oil and decreasing batteries prices are the drivers for this.

An advantage of battery electric vehicles is that batteries can be charged at off-peak times -enhances options to make grid electricity less costly and more efficient.

Though the concept of electric vehicles has been around for a long time, it has drawn a considerable amount of interest in the past decade amid a rising carbon footprint and other environmental impacts of fuel-based vehicles.

Indian Government Policies/ Programmes:

In India, the first concrete decision to incentivize electric vehicles was taken in 2010. According to a Rs 95-crore scheme approved by the Ministry of New and Renewable Energy (MNRE), the government announced a financial incentive for manufacturers for electric vehicles sold in India. The scheme, effective from November 2010, envisaged incentives of up to 20 per cent on ex-factory prices of vehicles, subject to a maximum limit. However, the subsidy scheme was later withdrawn by the MNRE in March 2012.

In 2013, Indian Government unveiled the 'National Electric Mobility Mission Plan (NEMMP) 2020' to make a major shift to electric vehicles and to address the issues of national energy security, vehicular pollution and growth of domestic manufacturing capabilities. Though the scheme was to offer subsidies and create supporting infrastructure for e-vehicles, the plan mostly remained on papers. While presenting the Union Budget for 2015-16 in Parliament, then finance minister announced Faster Adoption and Manufacturing of Electric Vehicles (FAME), with an initial outlay of Rs 75 crore. The scheme was announced with an aim to offer incentives for clean-fuel technology cars to boost their sales to up to 7 million vehicles by 2020.

In 2017, Transport Minister made a statement showing India's intent to move to 100 per cent electric cars by 2030. However, the automobile industry raised concerns over the execution of such a plan. The government subsequently diluted the plan from 100 per cent to 30 per cent.

In February 2019, the Union Cabinet cleared Rs 10,000-crore programme under the **FAME-II** scheme. This scheme came into force from April 1, 2019. The main objective of the scheme is to encourage a faster adoption of electric and hybrid vehicles by offering upfront incentives on purchase of electric vehicles and also by establishing necessary charging infrastructure for EVs.

EV manufacturers and their product offering:

1. Okinawa

Okinawa is one of the fastest growing Electric Vehicle two-wheeler manufacturers in India. Okinawa is the first Indian company that launched electric scooters in the market with the highest speed.

Table 1.2 Okinawa Praise (Scooter) Specifications

Motor Warranty	3 Years or 20000 km (Whichever is earlier)**
Battery Warranty	3 Years or 20000 km (Whichever is earlier)**
Rated Power	1000watt, BLDC Motor(Waterproof)
Max. Power	2500watt

Speed	Economy:30-35kmph, Speed:50-60kmph, Turbo:60-70kmph
Range/Charge	160 km/per charge*
Climbing	15 Degrees
Brake System	FR-Big/Small Disc RR-Disc Brake
Seat Height	800mm
Dimensions	1970X745X1165mm
Loading Capacity	150Kg
Tyre	90/90-12 Tubeless (Front/Rear)
Speedometer	Digital
Voltage	72V
Battery	3.3kwh Lithium-ion (Detachable Battery)
Controller	E-ABS (Electronic- Assisted Braking System) with Regenerative Energy
Ageing Protection	Battery with automatic sleep mode
Charger Specification	Micro Charger with Auto Cut
Charging Time	3-4hrs*
Ground Clearance	175mm
Boot Space	7ltr
Suspension	Front- Hydraulic Telescopic, Rear- Double Shocker with dual tube technology
Key Feature	Central Locking with Anti-theft Alarm, Keyless Entry, Find My Scooter Function, Mobile Charging USB Port, Motor Walking Assistance (Front/Reverse Motion), Geo-Fencing, Immobilization, Trips, Secure Parking, Tracking & Monitoring, Maintenance/Insurance Reminder, Battery information, Speed Alerts and Driver Score
Side Stand Sensor	Sensor Enabled - Vehicle Will Not Start
Headlight	LED with DRL (Day Running Light) Function
Back light	Unique Design with LED Rear Winkers
Wheel	Stylish Aluminium Alloy Wheel
Mobile App Connectivity	Yes
Floor Mat	Stylish Body Coloured
Brake Lever	CNC Machined with Lever Adjustment
Roadside Assistance (RSA)	Yes

2. Mahindra Electric

The Indian Automobile manufacturer Mahindra Electric made its green move towards eco-friendly transportation. Mahindra Electric has released 4 electric vehicles in the Indian market, which indirectly supporting the Govt. of India Mission 2030 Electric.

3. Tata Motors

Tata Motors is building an EV ecosystem for greener future. In 2017, company won the tender to supply 10,000 Tigor EVs to Energy Efficiency Services Ltd (EESL). In March 2018 company provided a fleet of Tata Starbus' to MMRDA in Mumbai. Later, company signed a MoU with the Government of Maharashtra to deploy 1000 EVs across PVs and CVs. In February 2019, company flagged off the first 9/9m AC Electric bus in Lucknow as part of a larger order for 40 electric buses for Lucknow City Transport Services Ltd.

4. Hyundai Electric

Hyundai Kona Electric is the electric SUV to zoom under the Indian skies. The Kona has a torque of 325 km. It takes anywhere between 6-9 hours to be completely charged.

5. Ather Energy-

Ather Energy is currently building India's first smart and electric scooter, the S340. Along the way, we plan to setup charging infrastructure for EVs and redefine the consumer experience in the automobile industry.

Types of Batteries

Table 1.3: Relation between Electric vehicle performance parameters and Battery

Vehicle Performance parameter	Battery specifications
Range	Energy density in Wh/ kg, Volumetric energy density in Wh/ L, Self- discharge in percentage / day.
Refuelling	Recharge time, rapid recharge capability
Acceleration	Specific power in W/ kg
Service life of battery	Number of recharges and discharges, number of cycles according to test specifications
Reliability	Battery behaviour when subjected to shock and vibration, effect of temperature, protection against overcharging and excessive discharge

1. Li-Ion batteries:

In the lithium-ion system, a lithium-carbon electrode acts as the negative electrode material. The lithium is not present in the form of metal, but either as an ion in the electrolyte or chemically bound to the positive or negative electrode. The carbon electrode is characterized by its high life-cycle stability. Small cells using lithium-ion systems have so far displayed energy density of 120 Wh/kg. The lithium-ion system used at the moment for portable batteries already satisfies two key conditions for an electric vehicle i.e. high specific energy and a long service life. Cobalt, the main element in the positive electrode, is a relatively expensive metal. The cobalt is replaced by manganese oxide. Cells using these new materials achieve comparable specific energy and specific power. The next generation of lithium-ion is expected to contain a solid polymer electrolyte. Estimation of material costs show that there is a possibility of producing batteries for electric vehicle at costs considerably more favourable than those of Ni-MH.

Specifications:

Specific energy : 100 to 120 Wh/kg

Energy density	: 200 to 250 Wh/L
Maximum power	: 200 W/kg
Charge time	: 4 hours

2. Sodium Nickel Chloride Batteries:

Sodium–nickel-chloride batteries are under development but not yet widespread, because the high operating temperature currently still results in too high self-discharge losses. These batteries show energy density over 80 Wh/ kg and specific power over 110 W/kg at full charge. The battery has the potential to meet a life goal of 5 years.

3. Sodium Sulphur Batteries:

Research is underway to improve battery technology to have a higher energy density for electric vehicles. A potential contender however is the sodium sulphur (NaS) battery, which has reached the production state in near past. The NaS battery offers high specific energy 100 Wh/kg with relatively low-cost battery materials. Specific power value is 130 W/kg. The sodium sulphur (NaS) battery uses a cathode of liquid sodium into which a current collector, a solid electrode of B-alumina is placed. The complete assembly is surrounded by a metal can, which is in contact with the anode, a sulphur electrode. A running temperature of 300°C is necessary with NaS system, which is the major problem. A heater in the capacity of a few hundred watts forms part of the charging circuit, which maintains the battery temperature when the vehicle is not running. The battery temperature is maintained when it is in use due to losses in the battery.

Each cell of this battery is very small, using only about 15 gm of sodium. This is a safety feature because if the cell is damaged the sulphur on the outside causes the potentially dangerous sodium to be converted into poly-sulphides, which are comparatively harmless. The additional advantage is that the cells can be located around the car. The capacity of each cell is about 10 Ah with an output voltage of about 2 V. These cells fail in an open circuit condition and hence this must be taken into account. A problem yet to be solved with this system is its casing material, which is prone to fail due to the very corrosive nature of the sodium. Presently an expensive chromised coating is used.

This type of battery combined with an electric motor, seems to be a very good competitor to the internal combustion engine. The servicing and charging infrastructure needs to be developed but looks promising. It is estimated that the cost of running an electric vehicle may be little around 15% of the petrol version, which may absorb the extra cost of production.

Specifications	Lead Acid	Li-ion		
		Cobalt	Manganese	Phosphate
Specific energy (Wh/kg)	30–50	150–250	100–150	90–120
Internal resistance	Very Low	Moderate	Low	Very low
Cycle life (80% DoD)	200–300	500–1,000	500–1,000	1,000–2,000
Charge time	8–16h	2–4h	1–2h	1–2h
Overcharge tolerance	High	Low. No trickle charge		
Self-discharge/month (roomtemp)	5%	<5% Protection circuit consumes 3%/month		
Cell voltage (nominal)	2V	3.6V ¹	3.7V ¹	3.2–3.3V
Charge cutoff voltage (V/cell)	2.40 Float 2.25	4.20 typical Some go to higher V		3.60
Discharge cutoff voltage (V/cell, 1C)	1.75V	2.50–3.00V		2.50V
Peak load current Best result	5C 0.2C	2C <1C	>30C <10C	>30C <10C
Charge temperature	–20 to 50°C (–4 to 122°F)	0 to 45°C ³ (32 to 113°F)		
Discharge temperature	–20 to 50°C (–4 to 122°F)	–20 to 60°C (–4 to 140°F)		
Maintenance requirement	3–6 months (topping chg.)	Maintenance-free		
Safety requirements	Thermally stable	Protection circuit mandatory		
In use since	Late 1800s	1991	1996	1999
Toxicity	Very high	Low		
Coulombic efficiency	~90%	99%		
Cost	Low	High ¹		

Table 1.4: Characteristics of commonly used rechargeable batteries. The figures are based on average ratings of commercial batteries.

4. Fuel Cell:

The energy of oxidation of conventional fuels, which it usually manifested as heat, may be converted directly into electricity, in a fuel cell. The process of oxidation involves a transfer of electrons between the fuel and oxidant and in a fuel cell works on this principle where the energy is directly converted into electricity. All battery cells involve an oxide reduction at the positive pole and an oxidation at the negative pole during some part of their chemical process. For the separation of these reactions in a fuel cell an anode, cathode and electrolyte are required. The electrolyte is fed directly with the fuel. When hydrogen fuel is combined with oxygen it is found to be a most efficient design. Fuel cells are very reliable and silent in operation, but at present are very expensive to construct. Figure shows a simplified representation of a fuel cell.

In one type of fuel cell hydrogen is passed over an electrode (the anode) of porous nickel, which is coated with a catalyst, and the hydrogen diffuses into the electrolyte. This causes electrons to be stripped off the hydrogen atoms. These electrons then pass through the external circuit. Negatively charged hydrogen anions (OH^-) are formed at the electrode over which oxygen is passed, such that they also diffuse into the solution. These move through the electrolyte to the anode. The electrolyte used is a solution of potassium hydroxide (KOH). Water is formed as the by-product of a reaction involving the hydrogen ions, electrons and oxygen atoms. If

the heat generated by the fuel cell is used, then an efficiency of over 80% is possible together with a very good energy density. The working temperatures of these cells varies but about 300–400°C. High pressure 2.4–40 MPa is also used. The pressures and storage of hydrogen are the main problems to overcome with fuel cells before they can be realistic alternatives to other forms of storage for the mass market.

It is believed that hydrogen fuel cell cars will hardly become commercially viable / economically competitive with other technologies because they have inefficiency of producing, transporting and storing hydrogen and the flammability of the gas.

Charging:

Electric Vehicle Supply Unit (EVSE):

EVSE stands for electric vehicle supply equipment and its function is to supply electric energy to recharge electric vehicles. EVSEs are also known as EV charging stations, electric recharging points or just charging points. EVSEs can provide a charge for the operation of electric vehicles or plug-in hybrid electric-gasoline vehicles. The Public charger makes communication that need to occur between the EVSE and an electric vehicle.

Charging Methods And Modes: Following are the charging modes for EV batteries.

- AC Slow Charging Mode
- AC Fast Charging Mode
- DC Fast Charging Mode
- Home / Private charger

The home private chargers are generally used with 230V/15A single phase plug which can deliver a maximum of up to about 2.5KW of power. Thus, the vehicles can be charged only up to this rate. The billing for the power is part of home-metering.

- Public charger

For charging outside the home premises: the electric power needs to be billed and payment needs to be collected. Further, the charges may depend on state of grid (whether it is power-surplus or is in power-deficit state). The power utilities may also want to manage power drawn by these chargers from time to time.

Under AC Charging there are 2 categories of charging.

- Normal AC charging

Electric 2-wheelers, 3-wheelers and 4-wheeler vehicles in India has on-board charger that charge at rate of around 2.5kW. These AC 2.5KW Chargers could fast charge a 2-wheeler (for a battery with an energy density of 2KWh) in an hour's time; 4-wheeler or larger vehicles with batteries of 12 KWh or more will be charged in about six hours.

- Fast AC charging.

Worldwide, electric cars like the Nissan Leaf or the Tesla have on board chargers with higher power ratings. This enables AC charging at a faster rate, from 7.7 kw to 22 kw.

- DC Fast Charging:

In this method of charging, DC current is sent to the electric car's battery directly

via the DC charge port. Fast charge rate (usually 50 KW or more outside India) can supply 100 or more km's of range per hour of charging.

DC Charging Specifications: Power rating of fast chargers are

- 10kW/15kW/30kW/50kW or even higher capacity.
Voltage rating at which fast charging has to be carried out.
- 48V/72V for Indian electric cars like the Mahindra e2o Plus P8, Mahindra e-Verito and upcoming Tata electric cars.
- Up to 750V or even higher used by global electric cars like Nissan Leaf and others.

Level 1 DC Chargers

Public DC Chargers at output voltage of 48V / 72V, with power outputs of 10 kW / 15 kW with maximum current of up to 200A.

Level 2 DC Chargers

Public DC Chargers at output voltage up to 1000V, with power outputs of 30 kW / 150 kW.

Issues with e-vehicles

1. **Cost of Electric Vehicle /Battery Pack:** The reduction in GST rate for electric vehicles (EVs) has helped Indian automobile industry to reduce cost to certain extent, but still they are expensive. The cost of a battery amounts to 40 percent of the total vehicle cost. The cost of the battery is expected to fall from Rs 20,000 per kilowatt hour (kWh) to Rs 5,500 per kilowatt/hour. The cost of electric vehicles is expected to be at par with combustion (engine) cars in the next 3-4 years.

The concept of *battery swapping* essentially enables reduced wait time for charging and significantly lower up-front cost for two and three-wheelers (since they would be sold without the battery).

2. **Charging Station Infrastructure:** Without an accessible infrastructure that can recharge an EV in a reasonable period of time, most motorists will be unwilling to purchase one, even if it is cheaper and its performance is better.

Owners of a conventional vehicle are unlikely to switch to an electric car, if the fueling process is more difficult, time consuming, and uncertain.

If charging facilities are to be deployed at scale, they will need to be accessible to all electric car models, and will require viable business plans—plans that will provide an opportunity for investors to make a positive return on their investments. All of this is possible, but the uncertainties around technologies, regulations, and costs will have to be substantially reduced.

3. **Range satisfaction:** Expectation of EV range depends on user. For personalized transport needs, with adequate charging infrastructure, present day electric vehicles provide adequate range. For intercity transport, there is a requirement of fast charging facility at every 50 km. Using artificial intelligence and navigation systems, driver can be well informed about the charging facility.

4. **Prediction of Electric Vehicle Range:** EV research related to the possibility of providing a more accurate prediction of range is required. Range prediction is a complex problem because it depends on a number of factors (internal, external, constant, variables- Vehicle design, the driver and the environment.)

1.3 Safety in Automobiles:

1. Air bags:

It is a safety restraint system of an automobile. It consists of air bags, sensors, inflation system / air bag module unit. The purpose of using an air bag is to cushion occupants during a crash, reduce their speed in collision without getting injured and provide protection to their bodies when they strike interior objects such as the steering wheel or window in passenger compartment. Air bag is made of thin nylon fabric, folded into a steering wheel or dashboard or the door or seat. Sensors are used to trigger the inflation of air bag.

Working of Air bags: During collision a mechanical switch is flipped and an electrical contact takes place. Sensors send an electric current to the air bag module. The impact sensor senses impacts. The sensors are set to a sensitivity level where they will only deploy in an accident that is equal to or greater than a 20 kmph crash into a concrete wall. The sensor functions by detecting automobile deceleration.

When the automobile decelerates at a rapid rate, the sensors are tripped. This deceleration detecting is the job of two or more deceleration sensors, placed at the front of the car. When the sensors go off, they send an electrical current to the inflation system, causing it to deploy the airbag. The air bag module unit consists of an inflator assembly, a nylon bag and a breakaway cover. Inflation system contains sodium azide and potassium nitrate. The electrical current from the sensors travels to the inflator assembly, where it causes a tiny initiator to be fired. This initiator creates a spark which ignites a propellant, which is generally sodium oxide. The reaction creates nitrogen gas. The gas expands quickly and inflation of air bags takes place, which literally bursts from its storage site like the steering wheel.

Side air bags are also offered in certain vehicles. It provides protection during side collisions. This prevents the air bag on the undamaged side of the car from inflating. Curtain airbags inflate in front of windows to provide passengers better head and neck protection. It is more efficient at tipping and side impacts. Door air bag has more space, allowing for a bigger bag that provides more coverage. Door mounted side air bags deploy in just 5 to 6 milliseconds. Cinders are removed and the gas is cooled through a filtration screen also inside the assembly. The nitrogen gas is what causes the air bag to inflate. This inflation occurs in a average of only 30 milliseconds. When an occupant plunges into the air bag, the gas is forced backwards through vents, a process which takes another 45 milliseconds. The whole sequence from initial detection of a crash, until the air bag is fully deployed, happens very quickly. This is to protect those inside of the vehicle. Once an air bag is used, it needs replacement.

2. Automatic Emergency Braking (AEB)

Auto Emergency Braking (AEB) is a feature that alerts a driver to an imminent crash and helps them use the maximum braking capacity of the car. AEB will independently apply brake if the situation becomes critical and no human response is made. AEB comes in three categories:

- Low speed AEB system – works on city streets to detect other vehicles in front of your car to prevent crashes and non-life threatening injuries.

- Higher speed AEB system – scans up to 200 metres ahead using long range radar at higher speeds
- Pedestrian detection system – detects pedestrian, object or animal movement in relation to the path of the vehicle to determine the risk of collision.

Front collision warning systems vary between manufacturers – and even models. Some vehicles feature two or more AEB systems. Automatic Emergency Braking is present in many high-end cars. Example: Volvo V40.

Working of AEB: AEB uses forward-looking radar, cameras or optical sensors to help driver avoid collisions with other vehicles. AEB continuously monitors the road and automatically applies the brakes if the driver fails to do in a possible crash situation.

At speeds between 5–50 kmph, the AEB feature would bring the car to a halt in case a collision is imminent. It won't work if you provide feed with the steering or manually apply the brakes to give full control to the driver. It has been designed to prevent an accident if the driver has lost concentration and is not aware of what lies ahead. This system can be combined with the Pedestrian Detection system also.

The Pedestrian Detection system is an optional extra which can identify individuals along the road and will stop an accident from occurring. However, if the accident does occur, Volvo has a solution for that also. When the car detects that a collision has occurred with a pedestrian, it would lift the hood up just a little and an airbag would be deployed for the pedestrian.

3. Adaptive Cruise Control (ACC)

Adaptive cruise control monitors the speed and distance of the vehicles ahead and automatically adjusts the speed of the car using ACC system to maintain appropriate/safe following distance without driver intervention. ACC system decelerates to speed of vehicle ahead. ACC requires the driver to set the desired travelling speed and will accelerate or decelerate up to that speed depending on the speed of the vehicles in front. It is an extension of the standard cruise control system.

Working of ACC: An ACC equipped vehicle has radar sensor with main controller, brake actuator, accelerator pedal actuator, audible buzzer, actuator controller and indicator. Radar sensor measures the distance to other preceding vehicles (downstream vehicles) on the highway. In the absence of preceding vehicles, the ACC vehicle travels at a user-set speed, much like a standard cruise control system. However, if a preceding vehicle is detected on the highway by vehicle's radar, the ACC system determines whether or not the vehicle can continue to travel safely at the desired speed. If the preceding vehicle is too close or traveling too slowly, then the ACC system switches from speed control to spacing control. In spacing control, the ACC vehicle controls the throttle and/ or brakes so as to maintain a desired spacing from the preceding vehicle.

When the danger of a collision is detected, it provides a red warning light that flashes on the windshield. The system provides an audible alert when it senses a reduction in traffic speed in vehicles ahead. Actuators control throttle valve and brake.

The ACC system maintains consistent vehicle performance even in poor visibility conditions, during turns and reduces accidents.

4. Electronic Stability Programme (ESP)

Electronic Stability Programme (**ESP**) is a computerized technology that improves a vehicle's stability by detecting and reducing loss of traction (known as skidding). Some **ESP** systems also reduce engine power until control is regained. **ESP** system is designed to stabilize the vehicle during cornering maneuvers.

Electronic stability control works in conjunction with a vehicle's anti-lock braking system (ABS), traction control and electronic power steering system. Components of ESP include steering wheel angle sensor, yaw rate sensor, lateral acceleration sensor, wheel speed sensor, roll rate sensor and longitudinal acceleration sensor. ESP checks where you are steering and where the vehicle is actually going. If there is difference in the direction of steering and vehicle direction of movement, the ESP will intervene in a number of ways. Typically, the vehicle ESP will communicate with Traction control system (TCS) and engine control unit (ECU) to reduce power, if the driver is applying throttle. This helps keep the vehicle from worsening its situation.

ESP decides what wheel to brake applies the brake at individual wheels with varying degrees of pressure and duration. ESP also decides whether to reduce engine torque to stabilize the vehicle. By doing so, the system can help the vehicle correct its path and prevent it from leaving the roadway, straying across a divided highway, or even rolling over. It allows for higher speeds at cornering with reduced skidding or better traction.

Working of ESP: ESP is always active. A microcomputer monitors the signals from the ESP sensors and checks 25 times a second, whether the driver's steering input corresponds to the actual direction in which the vehicle is moving. If the vehicle moves in a different direction ESP detects the critical situation and reacts immediately – independently of the driver. It uses the vehicle's braking system to "steer" the vehicle back on track. With these selective braking interventions ESP generates the desired counteracting force, so that the car reacts as the driver intends. ESP not only initiates braking intervention, but can also intervene on the engine side to accelerate the driven wheels. So, within the limits of physics, the car is kept safely on the desired track.

5. Anti-collision System

Today's vehicles have high speed and high performance. Due to reasons like human error, misjudging, driving dynamics, weather, distraction, inexperience, tiredness and alcohol - road accidents are increasing. As a result various anti-collision systems are designed for safety. These systems reduce severity of an accident that may result in loss of lives and/ or severe property damages.

Traffic collisions can be classified as follows.

- Head-on
- Road departure
- Rear end
- Side collision
- Rollovers

So, anti-collision systems are designed to avoid all relevant collisions. An anti-collision system generally has camera sensors and radars or laser to detect and warn the driver of any danger lying ahead on the road. The danger could be a car, a pedestrian, an animal, a stationary object such as a pole or tree. Several advanced features like audio warning the

driver, pre-charging of brakes, automatic partial or full braking are available to avoid any fatalities.

Following are major emerging anti-collision systems and their purpose.

- Forward collision warning system: uses an electronic system with sensors- cameras, radar or Light detection and ranging (LIDAR) to detect a vehicle or object in the front and warn the driver of possible collision.
- Lane departure warning system: has a camera that tracks the vehicle's position on the land and alerts the driver via warning signal such as steering wheel or seat vibration, when the vehicle steers off its lane.
- Adaptive cruise control: that allows the driver to drive vehicle at the desired speed, in which the system will control vehicle speed as per traffic and maintain safe distance with the leading vehicle.
 - Automatic braking system: avoids collision by automatically applying a brake on sensing an immediate collision with a nearby vehicle.
- Electronic Stability Program: featuring sensors and a microcomputer, it detects and reduces the loss of traction (skidding) of a vehicle, while also applying brake automatically to stabilize the vehicle and help steer the vehicle on the desired path.
- Blind spot monitor system: integrates sensors that monitor vehicle sides for approaching blind spots and warns the driver of any dangers during lane changes or turning.
- Automotive night vision system: uses infrared imaging for enhanced vision in dim lighting or poor weather conditions when headlights fail to reach drivers' viewing distance.

6. Active Passive Integration System

Active System: In active systems, pre-emptive measures are taken to reduce the possibility of crashes. Active safety is a design that avoids a risk.

Passive System: In passive system, reactive measures are taken to reduce severity of injuries. Passive safety is a design that minimizes losses when a risk occurs.

The Indian automotive active/passive safety market has been segmented on the basis of safety type, offerings, vehicle category, and end-user. Based on the safety type, the market is segmented into active safety and passive safety.

The active safety segment is further classified into blind spot detection, collision avoidance/warning system, early warning of severe braking ahead, Head Up Displays, Antilock Braking System, electronic stability control, traction control, brake assist, adaptive/autonomous cruise control system, and manual override for central locking system.

The passive safety segment is classified into seat belts, airbags, crumple zones, and whiplash protection.

On the basis of offerings, the active/passive safety market is segmented into hardware, technologies, and software/solutions. The hardware segment is further classified into devices and sensors & modules. The devices segment is further classified into camera, vision systems, RADAR systems, and ultrasonic systems.

The sensors & modules segment is further classified into image sensors, thermal sensors, acoustic sensors, ambience sensors, position sensors, gas sensors, inertial sensors, proximity sensors, and others. Based on vehicle category, the active/passive safety market is segmented into passenger cars, LCV, trucks, and buses. Passenger cars are further classified into

hatchback, premium hatchback, sedan, and SUVs. On the basis of end-user, the Indian automotive active/passive safety market is segmented into personal usage, commercial, and public usage. The commercial segment is further classified into cargo carriers, passenger carriers, and automotive rental providers.

7. Active Passive Integration:

1. Active Seatbelt Systems: For example, sensors may detect when a vehicle is following too closely and slow down the vehicle, straighten seat backs, and tighten seat belts, to avoid or prepare for a crash. Active Seatbelt Systems utilize a motor that retracts seat belt webbing in critical situations before a crash occurs. The active seat belt can be activated using data from active safety systems, such as the Electronic Stability Control or Brake Assist systems. It can also be triggered by data from environmental sensors, such as radar that provides the relative speed and distance to the vehicles ahead. Once activated, it puts front seat occupants in a better position by keeping them closer to the seat and lessening the forward movement of the body and is a great example of the integration of active and passive safety systems.

2. Early adopter Continental, contends its Active Passive Integration Approach (APIA), which links existing active safety devices such as ABS, Adaptive Cruise Control (ACC) and ESC with passive safety systems such as seatbelts and airbags, can prevent crashes before they occur. APIA enables up to 22 safety components and systems on a car to rapidly exchange data about the activities of the driver, the behavior of the vehicle and the status of the driving environment. For instance, a “closing velocity” sensor detects nearby events or objects that could cause an accident, such as a vehicle ahead suddenly braking.

A “danger control module” computes the hazard potential and, if an accident appears imminent, initiates a staged response to minimize its severity. The driver gets a visual or “haptic” warning (accelerator pedal vibration), seatbelts are pulled taut, windows and sunroof close automatically, the brake system is pre-pressureized and front seats are brought to the ideal position for airbag deployment.

3. Over time Mercedes-Benz has extended the range of features to include additional functionality, such as the PRE-SAFE impulse side function. Unlike in a frontal collision, there is only a limited crumple zone available in the event of a side impact, so to increase the size of the zone, the occupants in the danger area are moved away from the door and towards the centre of the vehicle just before the impact.

To do this, the system inflates air chambers in the side bolsters of the backrest within a fraction of a second of an imminent side impact being detected. The inflated chamber moves the occupant to the side, away from the danger area and towards the vehicle centre, thus increasing the distance between the passenger and the door.

To further reduce the side-effects of a collision Mercedes-Benz makes use of the body's natural reflex to prepare the occupants' ears for the loud noise experienced during an accident: A muscle in the ear, known as the stapedius, reacts to loud noises reflexively by contracting, briefly changing the link between the eardrum and the inner ear, thereby providing greater protection against high sound pressures. Mercedes-Benz uses this natural reflex as a biomechanical ear protection for the PRE-SAFE Sound innovation. By emitting a short interference signal through the vehicle's sound system the stapedius' reflex is triggered, which prepares the ears for the noise and thus lessens the risk of hearing discomfort or damage.

So while in the past, road users were expected to take complete responsibility for safety, concepts such Vision Zero are gradually shifting the emphasis of safety to underlying ethical principles that propose “it can never be ethically acceptable that people are killed or seriously injured when moving within the road transport system.”

Responding to this concept where responsibility is shared by transportation system designers, vehicle manufacturers and road users, OEMs are stepping up to the plate by making sure integrated passive and active systems offer passengers the best protection at all times; whether actively avoiding an accident or using ‘smart’ integrated systems to limit injury to occupants in the event of an accident.

Unit 2: Process Engineering

2.1 Process Boilers

Overview

A process boiler is a type of boiler with a capacity (rated maximum input) of 90KW or more, that serves a process. A process is an activity or treatment that is not related to the space conditioning, service water heating, or ventilating of a building as it relates to human occupancy.

Process Boilers used in various Industries

Process boilers are used in various industries such as dairy, sugarcane, pulp & paper, chemical, beverages and textile industries also in thermal power station etc. Process boilers are having application in following areas

Agriculture	Electrical industry	Refineries
Animal food industry	Food packaging industry	Spinning mills
Automotive industry	Fruit processing	Tobacco industry
Bakeries	Glass fiber production	Tyre manufacturing
Ceramic industry	Metal-working industry	Weaving mills
Cheese and dairies	Pharmaceutical industry	Wood processing
Distilleries	Dyeing factories	Plastics manufacturing

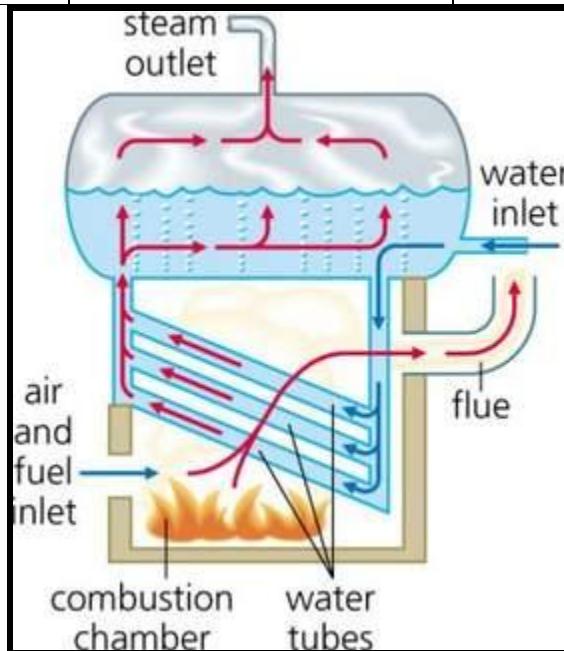


Figure 1: Process Boiler

Working of Process Boiler

Figure 1 shows Basic features of process boiler. A process boiler system is a hot water or steam boiler operated with a certain kind of fuel. The boiler heats up or evaporates the water inside it, which is then transported to the consumers via pipe systems. In case of hot water the transport energy is generated by pumps, in case of steam the transport is based on inherent pressure. The cooled water or the condensed steam returns to the boiler where it can be heated

again. Loss of water is compensated by makeup water pump. Flue gases created by combustion are discharged into the atmosphere through a chimney. In process boilers steam generation capacity ranges from 175 kg/h to 55 000 kg/h are available for industrial applications. High-quality equipment with intelligent control systems, modern burner technology and efficient heat recovery devices ensure environmentally friendly, economic and fully automatic boiler operation. These boilers are welded from thick steel plates that are up to 35 mm thick, making pressures of 30 bar and more possible. A thermal output of up to 38 MW is possible from a single boiler.

The use of process boiler systems in practice

Food industry

Food must often be heated or boiled during processing. Thus this industrial sector obviously needs plenty of thermal energy. However, some steam applications are still stunning; a good example is potato processing.

Cold potatoes are filled in a big pressure vessel and hot steam is abruptly injected. The abrupt heat supply causes the potato peels to fall off so they do not have to be peeled by hand any more

Breweries

In complex production process of breweries, malt has to be ground coarsely and mixed with water. The brewer calls this mashing. The mash must be heated to various temperatures in two to four hours for which the steam previously generated with the steam boiler is used. Subsequently, hops are added and the mixture has to cool down. Then yeast is added and triggers the fermentation so that the breweries get the desired effect. Depending on the type the breweries still has to mature for up to three months until it can be filled in bottles or barrels.

Dairy

Process Boilers are mostly used in dairy industry for milk pasteurization and UHT.

Milk Boiler ensures good shelf life and destroys disease-causing microorganisms. This emphasizes the requirement for flexible and reliable heat sources, which may keep the dairy milk systems running without any hurdle. Dairy Industry use steam for various purposes, Such as Heat Treatment of dairy products & Dairy Processing

Industrial milk boiler used to generate steam for following processes in dairy Industry

- (1) Milk powder
- (2) Cheese
- (3) Liquid milk pasteurization
- (4) Ultra-heat treatment (UHT) Milk



Figure 2:- Process Boiler used in dairy industry

Sugar Industry

Electricity and steam are almost required in every step of raw sugar process, especially in juice extraction, clarification, evaporation and sugar drying, good quality steam takes a crucial role. Thus selection of steam boilers becomes very important for sugar plant.

Bagasse, nearly 30% fiber contained in sugar cane, is produced during the processing of sugarcane, is burned as fuel for the generation of steam and power required for the operation of sugar mill. In fact, most cane sugar factories have been designed to be energy self-sufficient, with sugar as the primary product and bagasse as the primary fuel.

A bagasse-fired cogeneration system, made of steam boilers and steam driven turbo-alternators, provides all the steam and electricity needed to run the cane mills and factory, leaving little surplus bagasse. The bagasse is fired in the boiler for producing steam at high pressure, which is extracted through various single high capacity turbines and used in the process.

The installation of high pressure boilers and high pressure turbo-generators has provision for the operation of co-generation plant during the off-season also that enhances the power generation from 9 MW to 23 MW.



Figure 3:- Process boilers used in sugar industry

Paper & Pulp Industry

Boilers in the paper industry are used to generate steam for power and process systems. High pressure steam is generated for steam turbine generator sets to produce electric power. Medium and low pressure steam is used for various process heating applications such as heating and softening pulp wood chips for further reduction by chemicals to make wood pulp. Steam is also used to heat chemicals and other processes. In the paper making process, steam is used to evaporate moisture from pulp and to heat rotating dryer drums to dry the paper stock. Depending on the location and type of pulp wood used, bark chips can be burned as fuel for boilers.

Steam condensate

Condensate is the liquid formed when steam passes from the vapor to the liquid state. In a heating process, condensate is the result of steam transferring a portion of its heat energy, known as latent heat, to the product, line, or equipment being heated.

Difference between steam and condensate?

Flash steam is released from hot condensate when its pressure is reduced. Because both types of steam are produced in the boiler, it is impossible to differentiate between them. Only when flashing takes place at relatively low pressure, such as at the discharge side of steam traps, is the term flash steam widely used.

Steam Loop

An arrangement of pipes by which water of condensation can be returned to the boiler without a pump or injector as a result of condensation of boiler steam in a loop of two vertical pipes connected by a horizontal one.

Steam Trap

A steam trap is a valve designed to sense the difference between steam and condensate, and drain the condensate from the line. Steam traps allow only condensate and gases to drain and “traps” the steam in to provide heat and power.

Working of Steam Trap

In industrial and commercial facilities and plants, as well as the marine industry, steam is still used commonly as a source of energy—for heating, processing, and power. Steam traps are used anywhere there is a steam-powered system to discharge condensate, that is, the liquid that builds up in the pipelines, along with other non-condensable gases, to relieve the pressure in the lines and regulate the flow of steam within it. To do this effectively, steam traps are placed at intervals along the pipelines. Figure shows photographic view location of steam trap in process boiler.

**Figure 4 Steam Trap**

A steam trap is a valve designed to sense the difference between steam and condensate, and drain the condensate from the line. Steam traps allow only condensate and gases to drain and “traps” the steam in to provide heat and power. Too much condensate will lead to a buildup in pressure, causing hammering inside the pipeline, blown seals, work stoppages, etc. A proper functioning steam trap removes condensate and non-condensable gases without losing any live steam. Figure shows cross sectional view of steam trap.

Types of STEAM TRAPS

Depending on the methods the steam trap uses to differentiate between steam and the condensate, steam traps can be divided into 4 different types:

1. Mechanical
2. Temperature
3. Thermodynamic
4. Venturi nozzle

2.2 Introduction to Ultra Super Critical Boilers

A supercritical steam generator is a type of boiler that operates at supercritical pressure, frequently used in the production of electric power. In contrast to a subcritical boiler in which bubbles can form, a supercritical steam generator operates at pressures above the critical pressure 22 MPa.

Boilers are closed vessels in which a fluid is heated, most of the times, it is water. The key difference between a Subcritical and Supercritical boiler is that Subcritical boilers work at a subcritical pressure of the fluid whereas Supercritical boilers work at Supercritical pressure of the fluid. The Rankine Cycle can be greatly improved by operating in the supercritical region of the coolant. Most modern fossile plants employ the supercritical Rankine Steam cycle which pushes the thermal efficiency of plant as per equation shown below into the low to mid 40% range.

Efficiency of supercritical $\eta = (h_2-h_1) - (h_3-h_4) / (h_2-h_1)$



Figure 5 : T-S Diagram of Supercritical Rankine Cycle

For water, this cycle corresponds to pressure above 221.2 bar and temperature above 374.15°C (647.3 K). With the use of reheat and regeneration technique point 3 in the figure which corresponds to T-S vapour state of the coolant after it has expanded through the turbine, can be pushed to the right such that coolant remains in the gas phase. This simplifies the system by eliminating the need for steam separators, dryers and turbine specially designed for low quality steam.

Difference between supercritical and ultra supercritical

Virtually all coal plants in current operation employ pulverized coal combustion technology, which involves grinding coal into talcum-powder fineness and then burning it to heat water into high-pressure steam to drive an electrical generator. The difference between subcritical, supercritical, and ultra-supercritical versions of pulverized coal combustion technology has to do with the steam pressure within the boiler. In a subcritical plant, steam pressure is below 200 bar and temperature is below 550 degrees Celsius. Subcritical units have efficiencies of between 33% and 37%; i.e. between 33% and 37% of the energy in the coal is converted into electricity. In the late 1960s, supercritical combustion technology was commercialized, after advances in materials technology made it possible to build boilers that could operate at higher pressures. In supercritical units, the pressure of the boiler is about 240 bar and temperatures are 565 degrees Celsius. At this higher pressure and temperature, water can be maintained as a fluid despite being above the atmospheric boiling point, allowing greater efficiency. Efficiency ratings for supercritical coal plants range from 37% to 40%. In ultra-supercritical units, pressures are at 315 bar and temperatures of 600-610 degrees Celsius, and current research and development is targeting pressures of 380 bar and temperatures of 700-720 degrees Celsius, with the possibility of raising generating efficiency to the 44-46% range.

Based on the differences in temperature and pressure, the technology is categorized into three tiers: subcritical, supercritical (SC) and ultra supercritical (USC) (Table 1).

Table 1. Approximate pressure and temperature ranges

	Main Steam Pressure bar	Main Steam Temperature deg. C
Sub critical	Less than 220	Up to 565
Super critical	Between 220 to 250	Between 540- 580
Ultra super critical	Above 250	Above 580

SC and USC technologies achieve high efficiency and consequently use less coal and result in reduced CO₂ emissions.

Table 2: Estimated costs and thermal efficiencies

	Average Efficiency %	Co2 emission Gm/kWh	Power generation cost Rs/kW
Sub critical	Up to 36	766-789	300-350
Super critical	Up to 45	722	260-280
Ultra super critical	Less than 45	More than 722	350-400

Although SC/USC is a mature technology, the majority of existing coal-fired power plants worldwide are still using subcritical technology. The barriers to the diffusion of SC/USC technologies are not technical but largely economic and regulatory.

2.3 Hyperbolic Cooling Towers

A cooling tower is a heat rejection device that rejects waste heat to the atmosphere through the cooling of a water stream to a lower temperature. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature. In power plants the hot water from condenser is cooled in cooling tower, so that the water can be reused in condenser for condensation of steam. In a cooling tower as shown in the figure 6, water is made to trickle down drop by drop so that it comes in contact with the air moving in the opposite direction, so that some water is evaporated and is taken away with air. In evaporation the heat required for the evaporation is taken away from the bulk of water which is thus cooled.

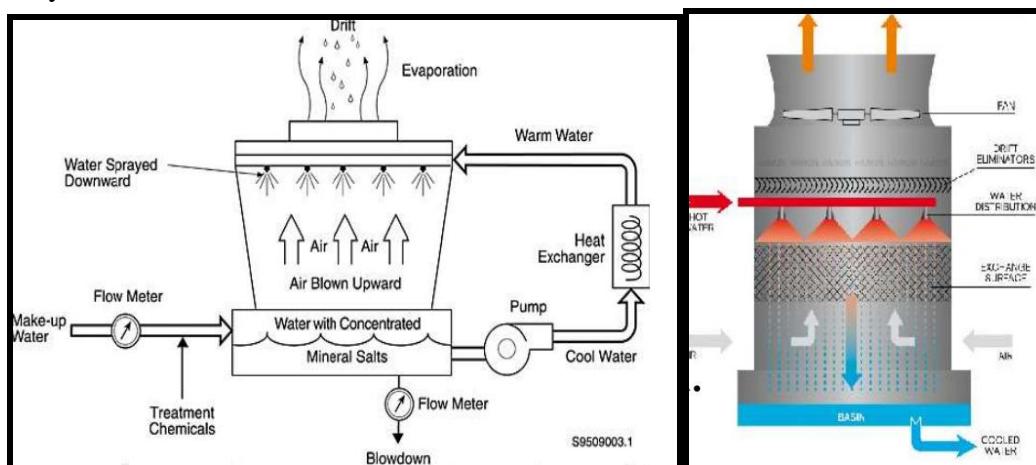


Figure 6 Working of Cooling Tower

Factors affecting cooling of water in a cooling tower are:

- Temperature of air
- Humidity of air
- Temperature of hot air
- Size and height of tower
- Velocity of air entering the air
- Accessibility of air to all parts of tower
- Arrangement of plates in tower
- Cooling towers are classified as

Hyperbolic Cooling Tower

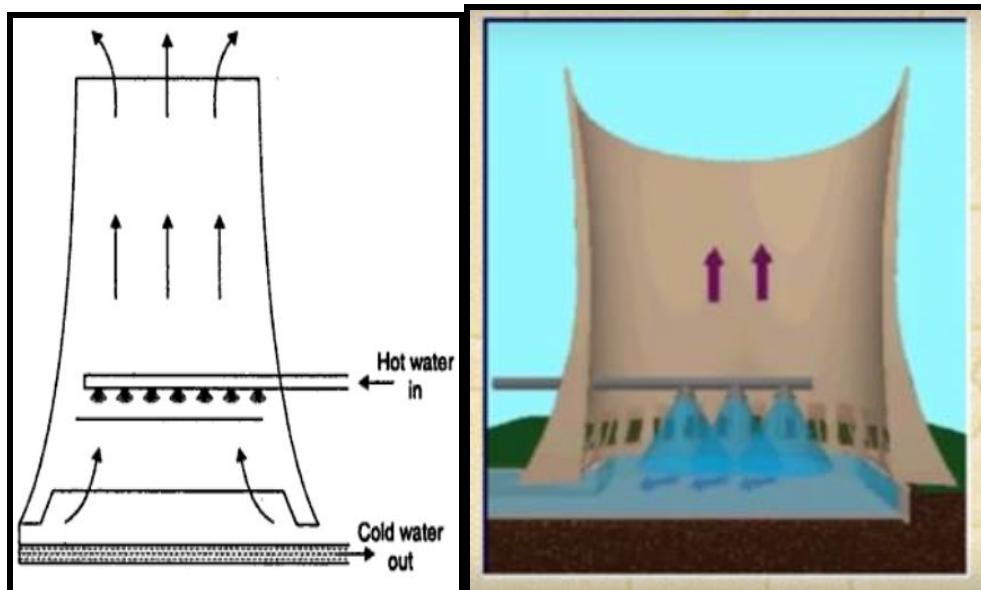


Figure 7 Hyperbolic Cooling tower

Figure 7 shows schematic & photographic view of Hyperbolic cooling Tower in which air flows into the tower through opening in the bottom and cools the entering hot water. Cooled water flows out the bottom and warm moist air exits out the top. The density difference between the cold entering air and warm exiting air results in a natural draft that causes the air flow through the column. No fans or other devices are needed.

Construction of Hyperbolic Cooling Tower

The cooling tower is constructed of a thin concrete shell with strong air resistance. The hyperbolic shape of the tower enhances the aerodynamic lift due to the wind passing over it, which increases the air flow rate.

The tower cools 480,000 gallons of water per minutes. Since the water vapour is discharged at a higher elevation, there is rarely a problem of fogging or recirculation. In addition to enhancing the air flow rate, the hyperbolic shape of this cooling tower provides superior strength, so that fewer materials are needed in its construction relative to other models. The opening at the bottom of the tower allows air to enter.

Advantages:-

- Superior strength provides a close match to a natural flow of air through the tower shell.

- Minimal operating and maintenance cost.
- It gives more or less trouble free operation
- Less ground area required
- Cooling tower structures are self-supported and withstands high speed of winds
- The enlarged top of the tower allows water to fall out of suspension.

Disadvantages:-

- Only effective for large quantities of utility water.
- Sensitive to climatic changes.
- Physical appearance may be negative in the public eye.
- High initial cost

2.4 Waste Heat Recovery System (WHR)

“Waste heat recovery” is the process of “heat integration”, that is, reusing heat energy that would otherwise be disposed of or simply released into the atmosphere. By recovering waste heat, plants can reduce energy costs and CO₂ emissions, while simultaneously increasing energy efficiency.

Typical Examples of Waste Heat Recovery

Several common consumer items recover waste heat. For example, consider turbocharged cars, which are provided by multiple car manufacturers.

In regular, non-turbocharged cars, the internal combustion gasoline engine expels hot gas through the car’s exhaust after its fuel is burned. That gas contains both heat and kinetic energy—a portion of which can be recovered. Turbocharged engines divert the hot gas to a turbine, which is used to spin an air compressor. The compressed air is routed to the engine’s combustion chamber with the vaporized gasoline, resulting in a more efficient ignition and greater power made with lower fuel consumption.

Necessity of waste Recovery System

Waste heat recovery (WHR) is essential for increasing energy efficiency in the chemical process industries (CPI). Presently, there are many WHR methods and technologies at various stages of implementation in petroleum refineries, petrochemical, chemical and other industry sectors. Increasing energy costs and environmental concerns provide strong motivation for implementing more and newer methods and technologies for WHR.

Waste heat is energy that is rejected to the environment. It arises from equipment and operating inefficiencies, as well as from thermodynamic limitations on equipment and processes. Often, part of waste heat could potentially be used for some useful purpose. At present, about 20 to 50% of energy used in industry is rejected as waste heat. A significant part of this wasted energy is low-temperature heat that is sent to the atmosphere mainly from cooling water, fin-fan coolers and flue gases. WHR can be defined as the process of capturing some portion of the heat that normally would be wasted, and delivering it to a device or process where it can be used as an effective, economical and environmentally friendly way to save energy.

Large investments are presently incurred to exhaust waste heat to the atmosphere in the form of cooling towers, fin-fan coolers and very tall stacks for the disposal of flue gases. WHR has the potential to minimize these costs, and to reduce environmental impact along with several other benefits.

WASTE SOURCE AND QUALITY

S.No.	Source	Quality
1.	Heat in flue gases.	The higher the temperature, the greater the potential value for heat recovery
2.	Heat in vapour streams	As above but when condensed, latent heat also recoverable
3.	Convective and radiant heat equipment	Low grade – if collected may be used for space heating or air lost from exterior of preheats.
4.	Heat losses in cooling water.	Low grade – useful gains if heat is exchanged with incoming fresh water.
5.	Heat losses in providing chilled water or in disposal of chilled water	(a) High grade if it can be utilized to reduce demand for refrigeration. chilled water or in the (b) Low grade if refrigeration unit used as a form of heat pump. disposal of chilled water
6.	Heat stored in products leaving the process	Quality depends upon temperature leaving the process
7.	Heat in gaseous and liquid effluents leaving process.	Poor if heavily contaminated and thus requiring alloy heat exchanger
8.	Heat in gaseous and liquid effluents leaving process.	Poor if heavily contaminated and thus requiring alloy heat exchanger

Benefits of Waste Heat Recovery

Benefits of 'waste heat recovery' can be broadly classified in two categories:

Direct Benefits:

Recovery of waste heat has a direct effect on the efficiency of the process. This is reflected by reduction in the utility consumption & costs, and process cost.

Indirect Benefits:

- a) **Reduction in pollution:** A number of toxic combustible wastes such as carbon monoxide gas, sour gas, carbon black off gases, oil sludge, Acrylonitrile and other plastic chemicals etc, releasing to atmosphere if/when burnt in the incinerators serves dual purpose i.e. recovers heat and reduces the environmental pollution levels.

b) **Reduction in equipment sizes:** Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes of all flue gas handling equipments such as fans, stacks, ducts, burners, etc.

c) **Reduction in auxiliary energy consumption:** Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption like electricity for fans, pumps etc.

Development of an optimum WHR system depends on the following factors

Quantity and temperature of waste heat: The quantity of waste heat should be large enough to make WHR economical. Costs of WHR systems are lower with increased availability of waste heat. Usually, waste heat at high temperatures can be utilized with a higher efficiency and with better economics. Also, more technology options are available for converting waste heat at high temperatures into other useful energy forms than waste heat at low temperatures

- **Uses of recovered waste heat:** The end use of recovered heat has a large influence on the implementation of WHR. For example, if the WHR project generates low-pressure steam that is already available in excess supply, then there will be little or no payout

- **Cost of energy:** This will be greatly influenced by the presence or absence of a cogeneration facility in the company

- **Availability of space:** In operating plants, space availability can be the biggest constraint. It is beneficial to place WHR equipment close to the heat sink to minimize piping and operating costs

- **Minimum allowable temperature of waste heat fluid:** For the case of flue gases heat recovery using carbon-steel equipment and ducting, the flue gases temperature should not be lower than the flue gases acid dew point

- **Minimum and maximum temperature of the process fluid:** If WHR generates steam and exports it to a steam header in a petroleum refinery, then WHR and steam temperature are dictated by the steam header pressure, since petroleum refineries generally operate steam headers at fixed pressures. Low-temperature steam generation will result in more WHR compared to high-temperature steam generation

- **Chemical compositions of waste heat process fluids:** These will dictate the materials of construction for the WHR system, and consequently affect the costs.

- **Facility's heat-to-power ratio:** If the heat-to-power ratio in the facility is higher than that for the cogeneration plant, the excess steam demand is usually met by utility boilers. Any saving in steam demand (by better heat recovery) saves fuel in the utility boilers and leaves the operation of the cogeneration plant unchanged. However, if the cogeneration plant meets the entire site's heat load, the value of savings from better heat recovery can be considerably reduced. Saving a ton of steam not only saves the fuel required to raise it, but also eliminates the associated power output that is produced at 80–90% marginal efficiency

Features of Condensate Recovery Pump:

- Uses inexpensive steam, air or gas to pump the condensate
- Negligible steam consumption
- Zero Maintenance, no cavitation, no leaking seals, impeller wear or motor problems
- Only one moving part (SS float) increases reliability
- Superior build quality and rugged construction
- Pre-wired, pre-piped packaged Skid Mounted for easy installation

- Widest range of steam-operated pumps
- Skid Mounted Unit which is easy to install



Figure8 Condensate Recovery Pump

Advantages of Condensate Recovery Pump

1. Reduction in Fuel Bill:
2. Reduction in Water charges:
3. Reduction in Exhaust Treat plant (ETP) load:
4. Maximizing boiler output:
5. Reduction in Blow down Loss:

Condensate is pure water, which contains almost no total dissolved solids (TDS). Returning more condensate to the feed-tank reduces the need for blow-down & thus reduces the energy lost from the boiler.

Flash Steam Separator as WHR unit

The steam is used in the process plants at various pressures depending upon the temperature requirements. The Condensate Recovery Pump from the high pressure steam when comes to low pressure, some part of the condensate get evaporated which is called as flash steam. Recovering the maximum possible flash steam back to the feed water tank reduces the fuel consumption of steam boiler. Flash steam has substantial amount of heat which is ignored & vented to atmosphere in most of the process plants.

Heat recovery steam generators (HRSG)

A heat recovery steam generator (HRSG) is a solution, when it is necessary recover heat from a hot gas stream. One can produce steam that can be used in a process (cogeneration) or used to drive a steam turbine (combined cycle). The HRSG boilers are manufactured either in horizontal or vertical types. The vertical boiler is more compact in structure and can be fit in smaller plants and even indoor facilities. The horizontal boiler is used mainly in larger plants. Supplementary firing can be added to both boiler types so that the required energy volume can be produced with gas turbine running on partial loads.

Saving Calculation

1000 kg/hr condensate recovered can save Rs. 45, 00,000/- per year as fuel considering 20 hrs a day & 300 days a year operational. 1000 kg/hr condensate recovered can save Rs. 700,000/- per year on Coal as fuel considering 20 hrs a day & 300 days a year operational. The payback for the complete system comes out to be less than 6 months.

Engine waste heat recovery Technology

Rising fuel prices and the increasing demand for high fuel economy make the improvement of the working efficiency of engines become necessary, thus resulting in the application of waste heat recovery (WHR) technologies. For light duty passenger vehicles, tight packaging constraints and the relatively low duty cycle of combustion engines make waste energy recovery difficult. Thus, the most promising WHR technology application lies in engines that operate steadily at high load for sustained periods, such as that found in heavy-duty diesel trucks.

The efficiency of a heavy truck diesel engine is generally less than 42%. Approximately 15% of fuel energy is wasted in the coolant heat transfer, whereas 8% is consumed through the air charging cooler. Friction and radiation account for 3% of fuel energy consumption. Exhaust gas accounts for the largest amount of waste energy: approximately 19% of the total fuel energy. Finally, approximately 13% of fuel energy is consumed during the exhaust gas recirculation period.

Among the various types of waste heat, the heat contained in exhaust gas and coolant is generally the most promising for recovery. WHR technologies can be classified into

- Electric turbo-compounding (ETC) systems
- Thermodynamic organic Rankine cycle (ORC)
- Thermoelectric generators (TEG)
- Hydrogen generation (HG) by using exhaust gas heat energy
- Hybrid pneumatic power systems (HPPS),

Advanced WHR Technology

Various methods have recently been adopted in internal combustion engines (ICE) to meet increasingly stringent emission regulations, such as diesel particulate filters, three-way catalytic converters, and selective catalytic reduction. The different advanced methods are listed & discussed below

1. Hydrogen generation by using exhaust gas waste heat
2. Thermoelectric generators
3. Thermodynamic cycle of organic Rankine cycle
4. Hybrid pneumatic power systems (HPPS)
5. Electric turbo compounding (ETC) systems.

1. Hydrogen generation by using exhaust gas waste heat

Engine exhaust heat energy has been used to heat and decompose methanol and other auxiliary fuels into hydrogen to improve the original heat value of fuels, increase combustion rate, and reduce emissions. For example, hydrogen can be used for homogeneous charge compression ignition (HCCI) combustion. Because ignition timing control is crucial in the application of HCCI combustion in engines, ignition timing control can be addressed by adjusting the proportion of dimethyl ether and hydrogen gas. Engine exhaust gas waste energy

can be used for hydrogen production without any changes in operating conditions. An HG system is shown in Figure 8.

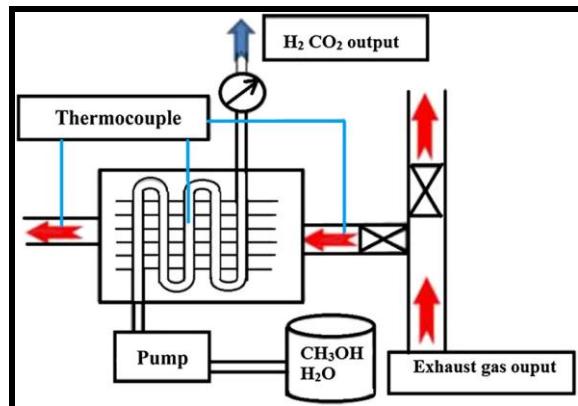


Figure 8 Hydrogen Generation WHR System

2. Thermoelectric generators

Thermoelectric materials are semiconductor materials that enable the conversion between heat energy and electric energy based on the thermoelectric effect. The thermoelectric effect refers to a phenomenon whereby a temperature difference creates an electric potential or an electric potential creates a temperature difference, including the Seebeck effect, the Peltier effect, and the Thomson effect. A schematic setup of a thermoelectric generator is shown in Figure 9.

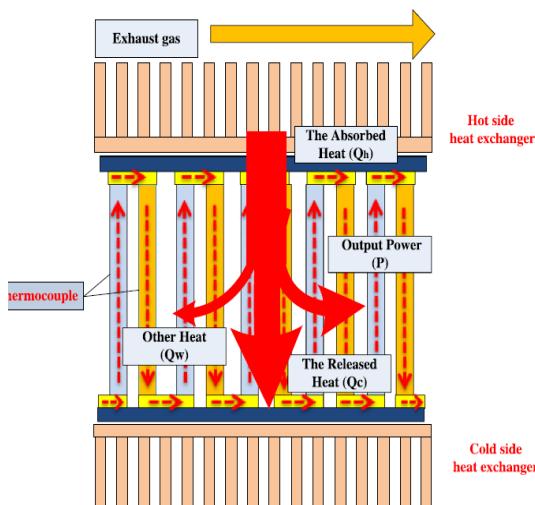


Figure 9 Thermoelectric generators

3. Thermodynamic cycle of organic Rankine cycle

Because of the low temperature of engine exhaust gas, the traditional Rankine cycle using the water as the working fluid cannot obtain ideal working performance. So, Organic Rankine Cycle (as shown in Figure 10) has become very popular method to improve the performance WHR because it works well with low-grade energy at a low flow rate.

4. Hybrid pneumatic power systems (HPPS)

HPPS generally consists of an ICE, an air compressor, a pressure tank, and a high-efficiency turbine. A concept schematic setup of HPPS is shown in Figure 10.

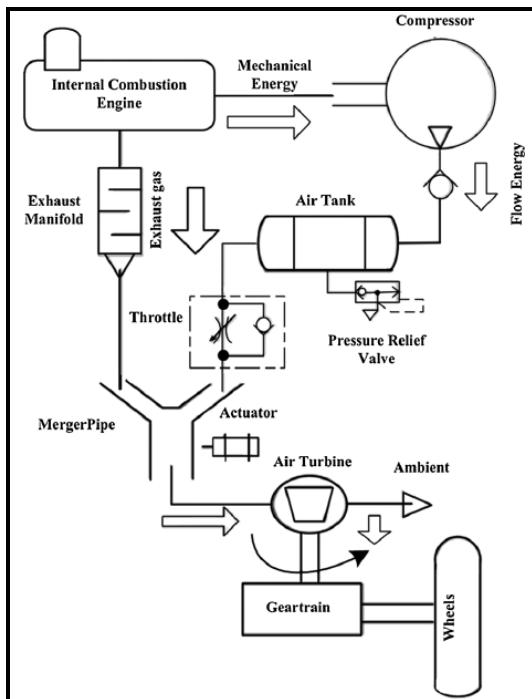


Figure 10 A concept setup of hybrid pneumatic power systems

The main working principle of pneumatic hybridization engines is to recover energy from a braking phase or from a combustion phase by pumping the exhaust gas or the pressurized air into the air tank, then the air tank can then be restored to start the engine or charge the engine during the strong transient accelerations or short-term high-power output period. An advantage of the pneumatic hybridization engine is that the pressurized air can be pumped into the combustion chamber to overcome the turbo-lag problem during the speedup period of the turbocharger, which can maximize the performance of the turbocharger. Pneumatic hybridization engines also offer improved fuel economy and reduced emissions.

5. Electric turbo compounding (ETC) systems

Considering the high temperature, relatively high pressure, and kinetic energy of exhaust gas, we classify waste energy of exhaust gas as thermal energy, pressure energy, and kinetic energy, with pressure energy accounting for the main part of the waste energy. ETC systems, which are mainly based on the Brayton cycle, are a very useful way to recover waste pressure energy. Figure 11 presents the setup of ETC system. The compound turbine mechanical-driven energy recovery prototype was originally proposed by the Volvo Corporation.

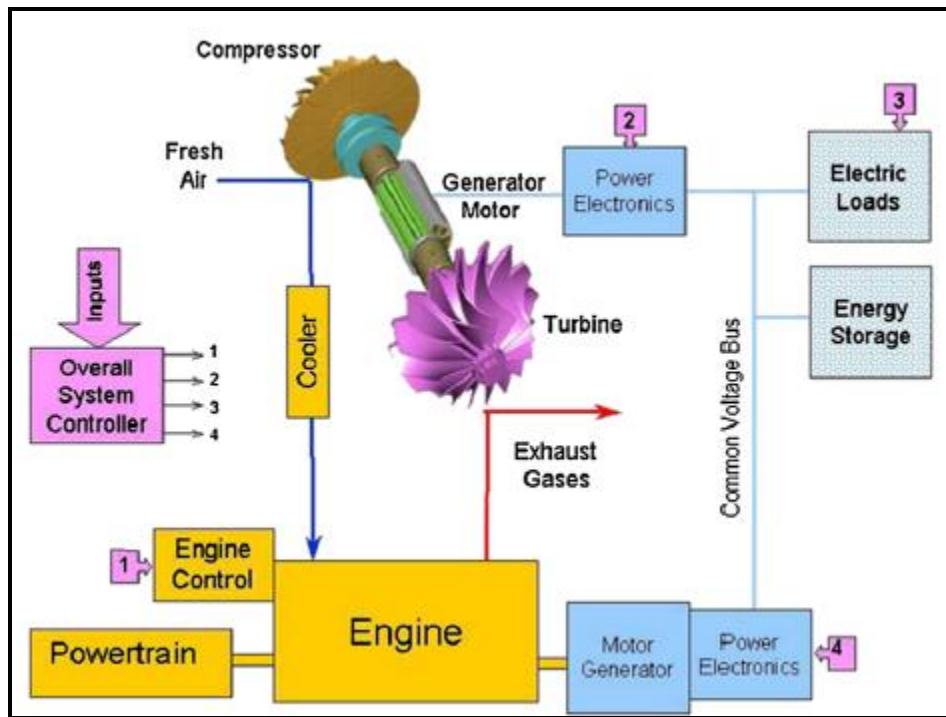


Figure 11 Electro turbo Compounding

The exhaust gas energy is transformed into shaft work through the turbine. Exhaust gas energy recovery of up to 20% is possible; this value is equal to a 5% decrease in fuel costs. However, efficient fuel consumption is possible only when the process is applied to high-load applications. More research attention was thus given to compound turbine power generation systems. Fuel economy can be improved by up to 10%, whereas power density can be increased by 20%.

Waste Heat Boiler (WHB)

Using a principle similar to economizers, waste heat boilers recover heat generated in furnaces or exothermic chemical reactions at industrial plants. These locations may contain significant energy that should not be wasted up a stack. Instead, this energy can be captured to generate low-to-medium pressure steam in a waste heat boiler (WHB). A WHB can also be used to remove the heat from a process fluid that needs to be cooled for either transport or storage, and generate steam from that heat. The steam generated in WHB may be used for heating applications, or to drive turbines that generate electricity, compress vapors, or pump liquids. WHB steam may contain significant wetness, so it is recommended that a high efficiency separator and steam trap combination is installed to ensure that the WHB delivers optimal quality steam to the recipient process.

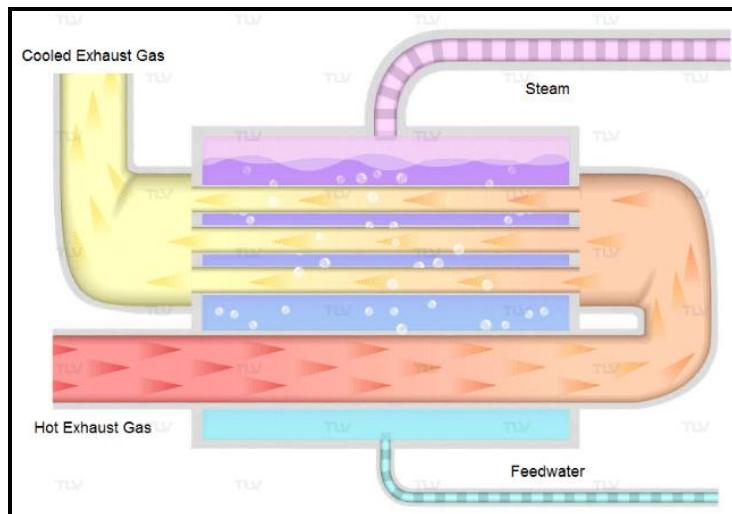


Figure 12 – Waste Heat Boiler

Absorption Chiller

Some energy efficient CHP systems may add refrigeration by incorporating absorption chillers that use steam created from waste heat.

The mechanism of absorption chillers can be broken down into the following stages:

1. Diluted absorbent liquid (60% lithium bromide salt, 40% water) is preheated with condensate as it moves from the absorber to the generator.
2. In the generator, the absorbent liquid is heated by steam, which causes some of the water contained within it to vaporize, making the liquid more concentrated.
3. The concentrated absorbent liquid flows downward back to the absorber to capture more water in its continuous loop. At the same time, the water vapor moves to the condenser.
4. In the condenser, cooling water causes the vapor to liquify and flow downward toward the evaporator, which has near vacuum pressure.
5. Just prior to entering the evaporator, the condensed water flows through an orifice or expansion valve. This restriction limits flow, and the water again vaporizes to a cold mist at 4.5°C [40°F]. This is where refrigeration occurs. The low temperature vapor pulls heat out of the chilled water loop, lowering its temperature by about 5°C [9°F].
6. The mist is heated when it absorbs heat from the chilled water loop, but the strong attraction of the concentrated salt solution pulls the water into the concentrated absorbent into the absorber, creating near vacuum pressure in the evaporator in the process.

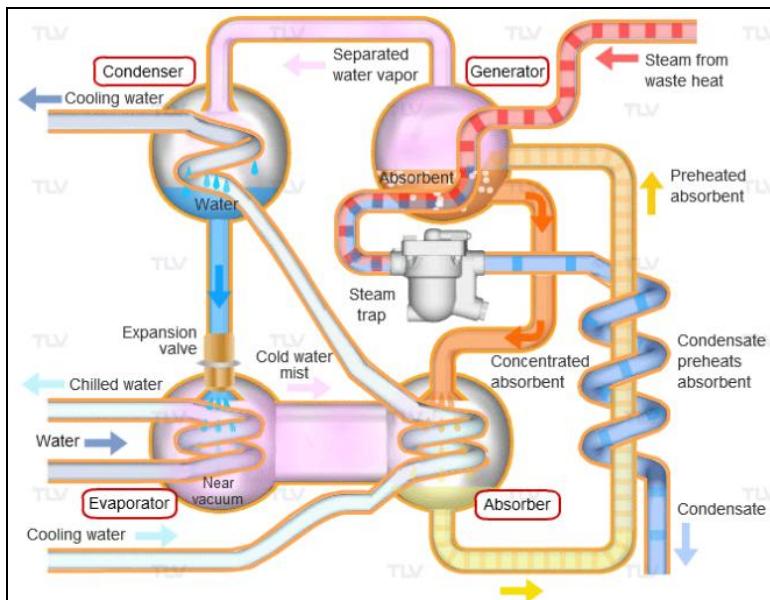


Figure 13 Absorption Chiller

- **Evaporator:** Actual refrigeration occurs here. Water passes through a valve, creating a low temperature mist. Sprayed over the chilled water loop, it absorbs heat and cools the refrigerant.
- **Absorber:** Concentrated absorbent attracts water mist from the evaporator, creating near vacuum pressure while diluting the absorbent.
- **Generator:** The 60/40% mixture absorbent is heated, evaporating the water, with the concentrated (regenerated) absorbent returning to the absorber.
- **Condenser:** The water vapor supplied from the generator is condensed by transference of heat to cooling water.
- **Heat Wheel**
- A heat wheel is finding increasing applications in low to medium temperature waste heat recovery systems. Figure 14 is a sketch illustrating the application of a heat wheel.

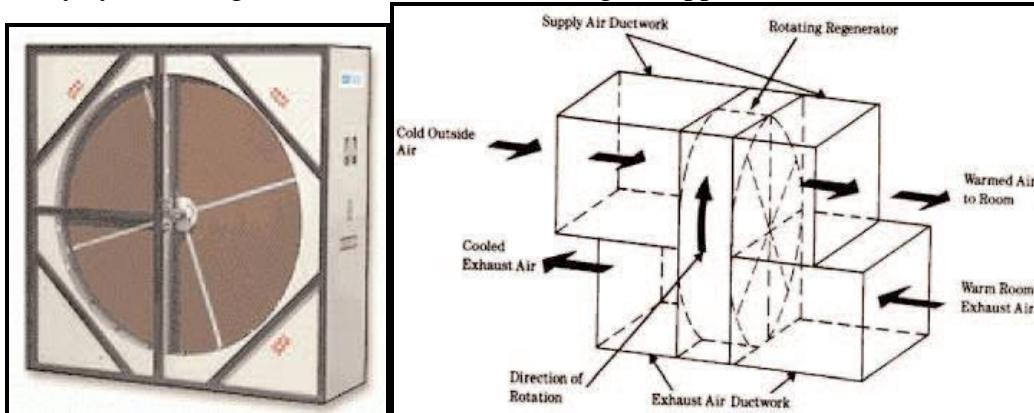


Figure 14: Heat wheel.

- It is a sizable porous disk, fabricated with material having a fairly high heat capacity, which rotates between two side-by-side ducts: one a cold gas duct, the other a hot gas duct. The axis of the disk is located parallel to, and on the partition between, the two ducts. As the disk slowly rotates, sensible heat (moisture that contains latent

heat) is transferred to the disk by the hot air and, as the disk rotates, from the disk to the cold air. The overall efficiency of sensible heat transfer for this kind of regenerator can be as high as 85 percent. Heat wheels have been built as large as 21 metres in diameter with air capacities up to $1130 \text{ m}^3/\text{min}$.

- A variation of the Heat Wheel is the rotary regenerator where the matrix is in a cylinder rotating across the waste gas and air streams. The heat or energy recovery wheel is a rotary gas heat regenerator, which can transfer heat from exhaust to incoming gases.
- Its main area of application is where heat exchange between large masses of air having small temperature differences is required. Heating and ventilation systems and recovery of heat from dryer exhaust air are typical applications.

Heat Pipe

- A heat pipe can transfer up to 100 times more thermal energy than copper, the best known conductor.
- In other words, heat pipe is a thermal energy absorbing and transferring system and have no moving parts and hence require minimum maintenance.
- The Heat Pipe comprises of three elements - a sealed container, a capillary wick structure and a working fluid. The capillary wick structure is integrally fabricated into the interior surface of the container tube and sealed under vacuum.

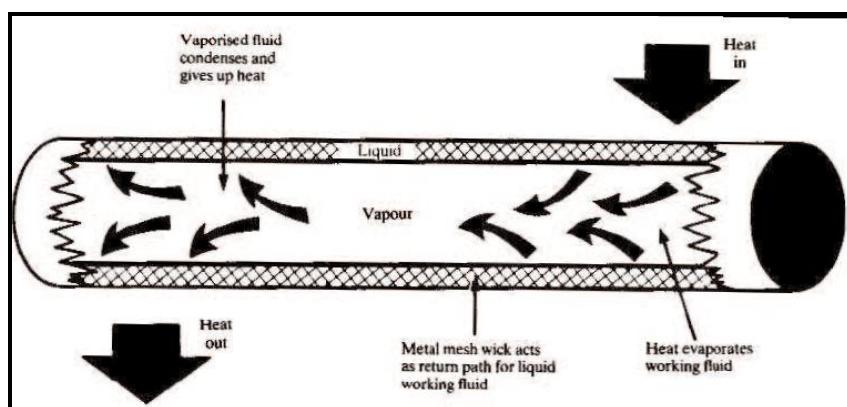


Figure 15: Heat wheel

- Thermal energy applied to the external surface of the heat pipe is in equilibrium with its own vapour as the container tube is sealed under vacuum. Thermal energy applied to the external surface of the heat pipe causes the working fluid near the surface to evaporate instantaneously. Vapour thus formed absorbs the latent heat of vaporization and this part of the heat pipe becomes an evaporator region. The vapour then travels to the other end of the pipe where the thermal energy is removed causing the vapour to condense into liquid again, thereby giving up the latent heat of the condensation. This part of the heat pipe works as the condenser region. The condensed liquid then flows back to the evaporated region. A figure of Heat pipe is shown in Figure 15.

Unit 3:

Recent Trends in Manufacturing in Industry

3.1 Smart Manufacturing

Smart manufacturing is a convergence of modern data science techniques and artificial intelligence to form the factory of the future. Smart manufacturing is about increasing efficiency and eliminating pain points in system. It's characterized by a highly connected, knowledge-enabled industrial enterprise where all organizations and operating systems are linked, leading to enhanced productivity, sustainability, and economic performance. Industry 4.0 demands smart systems integrated with intelligence to have a better human-machine interface.

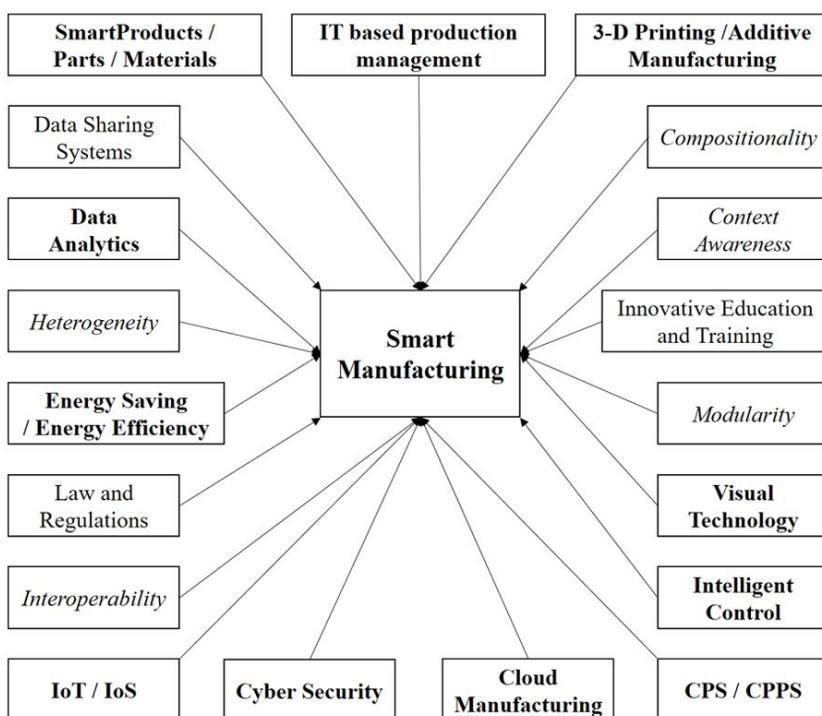


Figure 1 Smart Manufacturing

Industry analysts are predicting that the next decade of innovation, productivity and growth in manufacturing will be driven by the demand for mass customization and a convergence of technology advances that are enabling a new generation manufacturing infrastructure for “Smart Manufacturing” technology advances in connected factory automation, robotics, additive manufacturing, mobile, cloud, social and digital 3D product definition. In fact, this new era of manufacturing is dubbed the Fourth Industrial Revolution. The technology advances and integration standards behind the connectivity of the “Internet of Things” (IoT) empower devices from smart phones to smart shelves to sensor embedded automation controls to be active participants in a new connected digital reality. The coupling of IoT technologies with advances in plant floor automation and information systems is referred to as the “Industrial Internet of Things” (IIoT). The new generation of IIoT enabled smart machines for manufacturing will have onboard computers that directly support Internet protocols and allow direct communication with enterprise applications. Internet connectivity

methods let companies thread external web services like social and cloud platforms into their processes, and enable more ways to connect internal systems inside the firewall of corporate intranets to mobile and analytical applications. Emerging capabilities in additive manufacturing, advanced robotics, sensor enabled equipment and other new approaches to fabrication, open new process improvement opportunities both in the plant and across the supply chain. Sophisticated computer modeling and simulation tools are evolving to give engineers for greater scope in designing a manufacturing process before building the production lines. These new technologies and capabilities are dramatically changing the management of manufacturing operations. The next generation Smart Factory feeds real time information to a more empowered workforce through a combination of smart facilities, machines and equipment with built in sensors, self diagnostics and connection to other smart systems.

McKinsey and Company defined in a manner that added the power of big data, cloud computing and the wide-spread implementation of new technologies “ driven by four disruptions: the astonishing rise in data volumes, computational power, and improvements in transferring digital instructions to the physical world, such as advanced robotic sand 3-D printing”.

Smart Manufacturing Processes: Three Dimensions:

- (1) Demand Driven and Integrated Supply Chains
- (2) Dynamically Optimized Manufacturing Enterprises (plant + enterprise operations)
- (3) Real Time, Sustainable Resource Management

- **Smart design/Fabrication:** Digital Tools, Product Representation and Exchange Technologies and Standards, Agile (Additive) Manufacturing Systems and Standards. Mass Customization, Smart Machine Tools, Robotics and Automation (perception, manipulation, mobility, autonomy), Smart Perception, Sensor networks and Devices. Smart Communication systems Information, Mobility, Communication Technologies, Protocols, Cyber Physical Systems, the next generation of Embedded Systems and Networks, IT and OT convergence, co-creation and collaboration enablement.
- **Smart Applications:** Online Predictive Modeling, Monitoring and Intelligent Control of Machining/Manufacturing and Logistics/Supply Chain Processes, Smart Energy Management of manufacturing processes and facilities.
- **Smart and Empowered Workers:** Eliminating Errors and Omissions, Deskilling Operations, Improving Speed/Agility, Improving Information Capture/Traceability, Improving Intelligent Decision Making under uncertainty Assisted/Augmented Production, Assisted/Augmented Assembly, Assisted/Augmented Quality, Assisted/Augmented Maintenance, Assisted/Augmented

Historical Development of Smart Manufacturing:

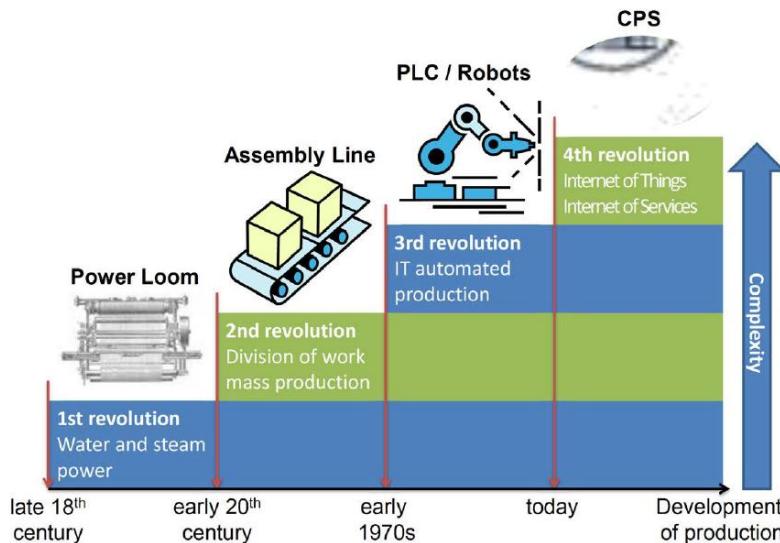


Figure 2 Industrial Revolution

- **The First Industrial Revolution:** This revolution also called conventional product cycle, no computer technology invented in this revolution. The first industrial revolution, which really was a revolution, and among others things to invention of steam machines, the usage of water and steam power and all sorts of other machines, would lead to the industrial transformation of society with trains, mechanization of manufacturing and loads of smog.
- **The Second Industrial Revolution:** This industrial revolution termed as CAD/CAM product cycle in which single alone CNC technology just begins. Manual CNC programming, transfer line was used for mass production. It was typically seen as the period where electricity and new manufacturing ‘Inventions’ which it enabled, such as the assembly line, led to the area of mass production and to some extent to automation.
- **The Third Industrial:** Revolution had everything to do with the rise of computers, computer networks (WAN, LAN, MAN), the just rise of robotics, FMS, Computer Integrated Manufacturing (CIM), Automation, Group Technology(GT) and Cellular Manufacturing in manufacturing, connectivity and obviously the birth of the Internet, that big game changer in the ways information is handled and shared, and the evolutions to digitalization.
 - **The Fourth Industrial Revolution:** We move from ‘just’ the Internet and the client-server model to ubiquitous mobility, the bridging of digital and physical environments (in manufacturing referred to as Cyber Physical Systems), the

convergence of IT and OT, and all the previously mentioned technologies (Internet of Things, Big Data, cloud, etc.) with additional accelerators such as advanced robotics and AI /cognitive which enable Industry 4.0 with automation and optimization in entirely new ways that lead to ample opportunities to innovate and truly fully automate and bring the industry to the next level.

Elements of Smart Manufacturing:

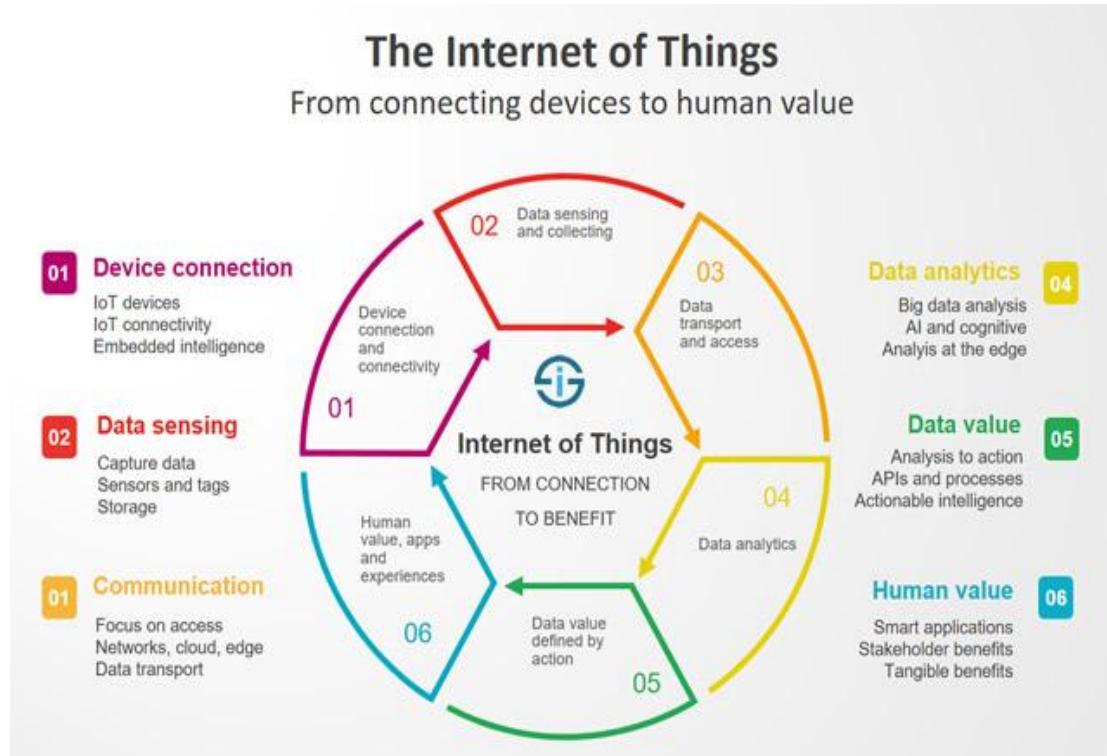
- Internet of Things(IoT)
- Digital Transformation
- Artificial Intelligent
- Cloud Computing
- Big Data (Advanced Data Analytics)

Internet of Things (IoT):

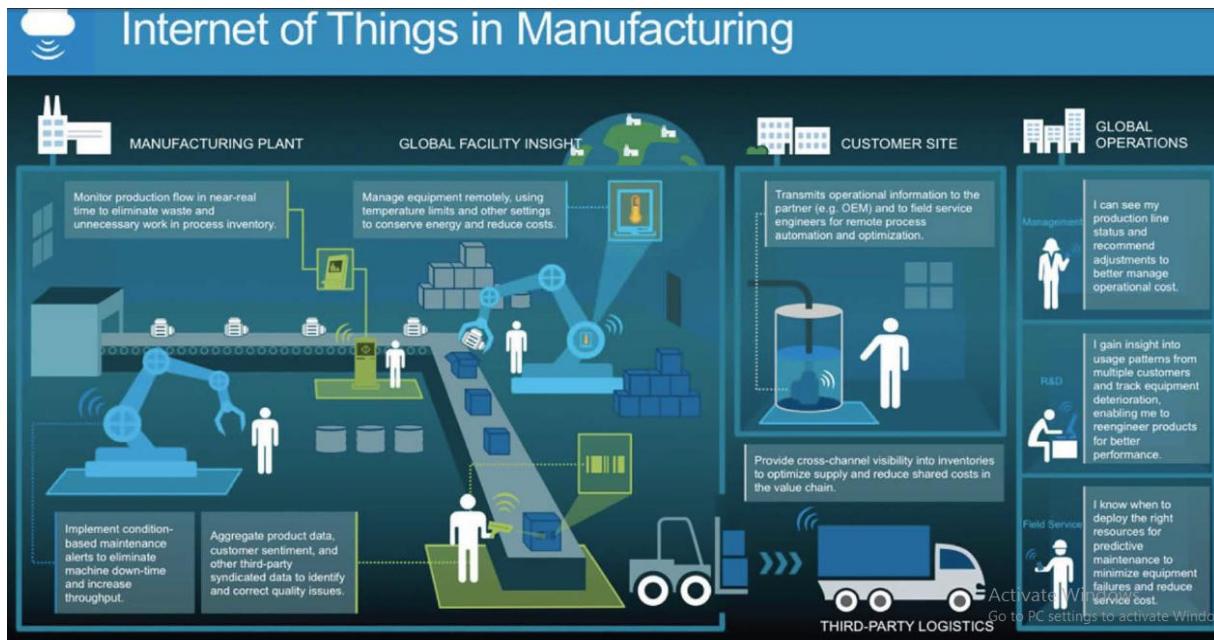
The IoT is the infrastructure of interconnection among objects. In manufacturing systems, each device is embedded with electronic software, sensors, and actuators and is connected to Internet networks. The IoT enables manufacturing devices to exchange data within manufacturing devices and between manufacturing devices and their service providers or consumers. From the technical point of view, we can describe the IoT as a combination of sensors such as RFID, other communication devices (i.e., embedded computers), CM applications, Enterprise Resource Planning (ERP) integration and business intelligence technology. Sensors are embedded in physical objects such as vehicles and heavy equipment (cranes, automated guided vehicles (AGVs), and loaders), machines, and robots. A standard communication protocol is an essential enabler of IoT deployment. The communication and foundation of the IoT are the inspiration for Cyber -Physical System (CPS).

Definition of IOT:

The Internet of Things (IoT) is a network of things which are connected to the Internet. These things include IoT devices and IoT-enabled physical assets. They range from consumer devices such as smart home solutions or pet trackers to sensor-equipped connected livestock and crop, industrial assets such as machines, robots, oil and gas facilities or even workers. The Internet of Things also has its own technology stack that starts from connecting things, capturing the data and communicating it and ends with applications. It's among others here that edge computing and fog computing come in. Also IoT gateways and IoT platforms play an important role in that stack as do many network standards with ever more wireless IoT connectivity options. We define the Internet of Things as a network of connected devices with 1) unique identifiers in the form of an IP address which 2) have embedded technologies or are equipped with technologies that enable them to sense, gather data and communicate about the environment in which they reside and/or themselves.

**Figure 3 Internet of Thing****Internet of Things characteristics:**

- **Connectivity:** This doesn't need much further explanation. Devices, sensors, they need to be connected to an item, to each other, actuator, a process and to 'the Internet' or another network.
- **Things:** Anything that can be tagged or connected as such as it's designed to be connected. From sensors and household appliances to tagged livestock. Devices can contain sensors or sensing materials can be attached to devices and items.
- **Data:** Data is the glue of the Internet of Things, the first step towards action and intelligence.
- **Communication:** Devices get connected so they can communicate data and this data can be analyzed.
- **Intelligence:** The aspect of intelligence as in the sensing capabilities in IoT devices and the intelligence gathered from data analytics (also artificial intelligence).
- **Action:** The consequence of intelligence. This can be manual action, action based upon debates regarding phenomena (for instance in climate change decisions) and automation, often the most important piece.
- **Ecosystem:** The place of the Internet of Things from a perspective of other technologies, communities, goals and the picture in which the Internet of Things fits. The Internet of Everything dimension, the platform dimension and the need for solid partnerships.

**Figure 5 IOT in Manufacturing****IoT Applications:**

- Predictive and preventative maintenance
- Supply chain management
- Inventories and logistics.
- Factory floor efficiency will have the largest impact
- Increasing productivity by as much as 25 percent.
- IoT + data analytics + machine learning

Digital Transformations:

Digital transformation is the process of using digital technologies to create new or modify existing business processes, culture, and customer experiences to meet changing business and market requirements. This reimaging of business in the digital age is digital transformation. The reasons for digital transformation are, Acceleration of Change – the pace of digital change is rising exponentially, making it very difficult to maintain a position of industry leadership, and requiring an acceleration of new digital solutions brought to market.

The branch of scientific or engineering knowledge that deals with the creation and practical use of digital or computerized devices, methods, systems, etc. advances in digital technology. Digital technologies are electronic tools, systems, devices and resources that generate store or process data. Well known examples include social media, online games, multimedia and mobile phones. Today, myriad devices are digital including a smart phone, tablet and smart watch. In contrast, there are numerous non-digital (analog) devices, such as a thermometer, electric fan and bicycle. Automobiles, washing machines and many other products are both digital and analog.

Digital transformation is the changes associated with digital technology application and integration into all aspects of human life and society. It is the move from the physical to digital. Digital transformation is the profound transformation of business and organizational

activities, processes, competencies and models to fully leverage the changes and opportunities of a mix of digital technologies and their accelerating impact across society in a strategic and prioritized way, with present and future. The end goal of digital transformation, however, is the ability to rapidly act and react to changing data, competitive conditions and strategies fast enough to succeed. In business, digitalization most often refers to enabling, improving and/or transforming business operations and/or business functions and/or business models/processes and/or activities, by leveraging digital technologies and a broader use and context of digitized data, turned into actionable, knowledge.

Digital Twin:

The applications of DT in Smart Manufacturing are directed as below.

- Designing and verifying of products: Some authors have developed a DT framework to support product design. Such framework enables the iterative optimization of design scheme to guide designers to adjust their expectation and improve the design model.
- Monitoring product over production life-cycle: Some authors view DT as a comprehensive digital representation of product from the early design stage to the end of product life-cycle.
- Designing and verifying of processes and production lines: Some authors have developed a
- DT to assist the design of process function and production line capabilities. This DT provides engineering analysis capabilities and supports decision-making over the system design and solution evaluation.
- Enhancing resources overhaul maintenance: Some authors have developed DT to trace resources digital behavior to diagnose and prognosticate faults, failure, and performance deviation. Once such problems are detected, the suitable action will be simulated in virtual model to evaluate the effectiveness of the correction action to avoid sudden downtime.

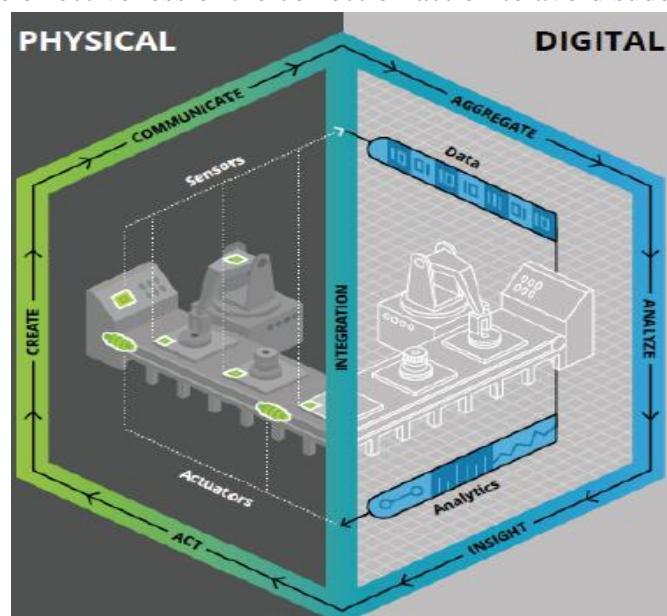


Figure 6 Digital twins

Artificial Intelligence:

Artificial intelligence (AI) is an area of computer science that emphasizes the creation of intelligent machines that work and reacts like humans. Some of the activities computers with artificial intelligence are designed for include: Speech recognition. Artificial Intelligence (AI) is the branch of computer sciences that emphasizes the development of intelligence machines, thinking and working like humans. For example, speech recognition, problem-solving, learning and planning. Theoretical AI says that Intelligence (be it natural or artificial) has three types.

- Artificial Narrow Intelligence (ANI)
- Artificial General Intelligence (AGI)
- Artificial Super Intelligence (ASI)

Artificial intelligence (AI) is the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions) and self-correction. Artificial intelligence is the use of computer science programming to imitate human thought and action by analyzing data and surroundings, solving or anticipating problems and learning or self-teaching to adapt to a variety of tasks. Artificial intelligence (AI) makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks.

Disadvantages of Artificial Intelligence:

- High Cost
- No Replicating Humans
- No Improvement with Experience
- No Original Creativity
- Unemployment

Artificial intelligence can be used to solve problems across the board.

- AI can help businesses increase sales, detect fraud, improve customer experience, automate work processes and provide predictive analysis. Logistics companies can use AI for better inventory and delivery management.
- Machine Learning: Machine Learning is the learning in which machine can learn by its own without being explicitly programmed. It is an application of AI that provides system the ability to automatically learn and improve from experience. Studying artificial intelligence opens a world of opportunities. Studying AI now can prepare you for a job as a software engineer researching neural networks, human-machine interfaces, and quantum artificial intelligence.
- Artificial intelligence (AI) in healthcare is the use of complex algorithms and software to estimate human cognition in the analysis of complicated medical data. The primary aim of health-related AI applications is to analyze relationships between prevention or treatment techniques and patient outcomes. It is seen as a subset of artificial intelligence. Machine learning algorithms build a mathematical model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to perform the task.

Cloud computing:

Cloud computing is the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer. Simply put, cloud computing is the delivery of computing services including servers, storage, databases, networking, software, analytics, and intelligence over the Internet (“the cloud”) to offer faster innovation, flexible resources, and economies of scale.

In the simplest terms, cloud computing means storing and accessing data and programs over the Internet instead of your computer's hard drive. The cloud is just a metaphor for the Internet. The cloud is also not about having dedicated network attached storage (NAS) hardware or server in residence. Cloud Computing is the use of hardware and software to deliver a service over a network (typically the Internet). With cloud computing, users can access files and use applications from any device that can access the Internet. An example of a Cloud Computing provider is Google's Gmail. Cloud computing is a type of computing that relies on shared computing resources rather than having local servers or personal devices to handle applications. The services are delivered and used over the Internet and are paid for by the cloud customer on an as-needed or pay-per-use business model.

Benefits of cloud computing:

- Reduced IT costs.
- Scalability.
- Business continuity.
- Collaboration efficiency.
- Flexibility of work practices.
- Access to automatic updates.

3.2 Automation

It is the technology by which a process or procedure is performed with nominal human assistance. Automation or automatic control is the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching on telephone networks, steering and stabilization of ships, aircraft and other applications and vehicles with minimal or reduced human intervention.

Automation in the industry provides the advantages of improving productivity and quality while reducing errors and waste, increasing safety, and adding flexibility to the manufacturing process. In the end, industrial automation yields increased safety, reliability, and profitability.

Automation covers applications ranging from a household thermostat controlling a boiler, to a large industrial control system with tens of thousands of input measurements and output control signals. In control complexity, it can range from simple on-off control to multi-variable high-level algorithms.

Needs of Automation

The industrial world is facing many technological changes which increased the urgent demand for the premium quality products and services that can only be supplied by a high level of productivity. This requirement needs process engineering systems, automated manufacturing, and industrial automation. Following are the some of the important points due to which it is needed in industrial workplace.

- **Globalization** – Global industrial automation market demands superior and practical services.
- **Productivity** – Automation enhances the productivity of Industry. Industrial automation is all about working smarter, faster, and proficiently. This makes automation more powerful and that's why customers are looking for pioneering, end-to-end technologies with open, modern architecture and new data from new connections. As the industrial automation industry comprehends the advantages of the Internet of Things (IoT), it is becoming essential that organizations adopt these technologies.

- **Industrial Automation Becomes a ‘Solutions’ Business:**

Industrial automation refers the categorization of software and hardware and a mechanism that combines them (hardware & software). Automation can be achieved by installing automated devices or embedded systems as well as automation software performing the logical tasks and control the operation processes.

- **Reduce Worker Fatigue and Effort or Labor Intensive Operation –**

Humans dislike ordinary, repetitive tasks. However, computer systems perform them without complaint. If the task requires conditions not suited to human comfort or focus, consider automation.

- **Prevent Products or Materials from Being Damaged or Destroyed –**

Human being may make mistakes when they tired. This represents the sentiment of the “human condition.” Mistakes using tools mean damaging raw materials, components, assemblies, and end products.

- **Prevent Non-conforming Product from Shipment –**

Computers controlling robots do not forget steps. Automated systems will not violate the instruction set. Moreover, automated systems may employ inspection capabilities. Tune the system and allow the data to roll in without preference or bias.

- **Save Money –**

Inventing in industrial automation yields cost savings through making processes more regular and collecting data for making confident decisions.

3. Basic elements of automated system

An automated system consists of three basic elements:

- (1) **Power** to accomplish the process and operate the system.
- (2) **Program of instructions** of instructions to direct the process, and
- (3) **Control system** to actuate the instructions.

The relationship amongst these elements is illustrated in Figure 7

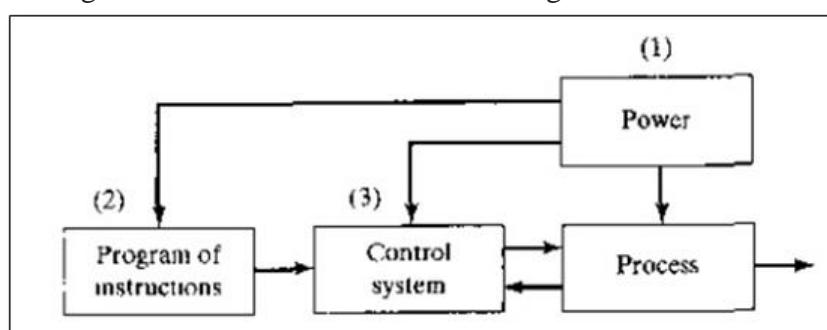


Figure 7 – Elements of Automated system.

An automated system is used to operate some process, and power is required to drive the program instructions as well as the controls. The principal source of power in automated systems is electricity. Electric power has many advantages in automated as well as non-automated processes

1. Power source: An automated system is used to operate some process and power is required to drive the process as well as controls. There are many sources of power available, but the most commonly used power is electricity. The actions performed by automated systems are generally of two types:

- (a) Processing
- (b) Transfer and positioning

2. Program of instructions: The actions performed by an automated process are defined by a set of instructions known as process. The programmed instructions determine the set of actions that is to be done automatically by the system. The program specifies what automated system should do and how its various components must function in order to accomplish the desired results.

3. Control system: The control element of the automated system executes the program of instructions. The controls in an automated system can be:

- (a) Closed loop
- (b) Open loop.

(a) Closed loop control system: It is also known as a feedback control system. In this system the output variable is compared with an input parameter and any difference between the two is used to drive the output into agreement with input.

1. **Input parameter:** as set point, represents the desired value of output.
2. **Output variables:** actual value of parameter.
3. **Sensors:** A sensor is used to measure the output variable and close the loop
4. **Between input and output:** It performs feedback function.
5. **Controller:** The controller compares the output with the input and makes the required adjustment in the process to reduce the difference between them.
6. **Actuator:** The adjustment being done with one or more actuator which are the hardware devices that physically carry out the control actions such as electric motor, cylinder etc.

(b) Open loop control system: It is without the feedback loop. In this case the controls operates without measuring the output variables, so no comparison is made between the actual value of the output and desired input parameters. There is always risk that the actuator will not have intended effect on the process.

4. Automation Principles and Strategies

The USA Principle is a common sense approach to automation projects. Similar procedures have been suggested in the manufacturing and automation trade literature, but none has a more appealing title than this one. USA stands for:

1. Understand the existing process
2. Simplify the process
3. Automate the process.

1. Understand the existing process

USA approach is to understand the current process in all of its details.

- a. What are the inputs? What are the outputs?
- b. What exactly happens to the work unit between input and output?
- c. What is the function of the process?
- d. How does it add value to the product?
- e. What are the upstream and downstream operations in the production sequence, and can they be combined with the process under consideration?

2. Simplify the process

Once the existing process is understood, then the search can begin for ways to simplify. This often involves a checklist of questions about the existing process.

- a. What is the purpose of this step or this transport?
- b. Is this step necessary?
- c. Can this step be eliminated?
- d. Is the most appropriate technology being used in this step?
- e. How can this step be simplified?
- f. Are there unnecessary steps in the process that might be eliminated without detracting from function?

3. Automate the Process.

Once the process has been reduced to its simplest form, then automation can be considered. The possible forms of automation include strategies discussed below.

5. Strategies of Automation

TEN Strategies for Automation and Process Improvement

1. Specialization of operations
2. Combined operations
3. Simultaneous operations
4. Integration of operations
5. Increased flexibility
6. Improved material handling and storage
7. On-line inspection
8. Process control and optimization
9. Plant operation control
10. CIM

1. Specialization of operations

The first strategy involves the use of special-purpose equipment designed to perform one operation with the greatest possible efficiency. This is analogous to the concept of labor specialization, which is employed to improve labor productivity.

2. Combined operations

Production occurs as a sequence of operations. Complex parts may require dozens, or even hundreds, of processing steps. The strategy of combined operations involves reducing the number of distinct production machines or workstations through which the part must be routed. This is accomplished by performing more than one operation at a given machine, thereby reducing the number of separate machines needed.

3. Simultaneous operations

A logical extension of the combined operations strategy is to simultaneously perform the operations that are combined at one workstation. In effect, two or more processing (or

assembly) operations are being performed simultaneously on the same work part, thus reducing total processing time.

4. Integration of operations.

Another strategy is to link several workstations together into a single integrated mechanism, using automated work handling devices to transfer parts between stations. In effect, this reduces the number of separate machines through which the product must be scheduled. With more than one workstation, several parts can be processed simultaneously, thereby increasing the overall output of the system.

5. Increased flexibility.

This strategy attempts to achieve maximum utilization of equipment for job shop and medium volume situations by using the same equipment for a variety of parts or products. It involves the use of the flexible automation concepts. Prime objectives are to reduce setup time and programming time for the production machine. This normally translates into lower manufacturing lead time and less work-in-process.

6. Improved material handling and storage.

A great opportunity for reducing nonproductive time exists in the use of automated material handling and storage systems. Typical benefits include reduced work-in-process and shorter manufacturing lead times.

7. Online inspection.

Inspection for quality of work is traditionally performed after the process is completed. This means that any poor quality product has already been produced by the time it is inspected. Incorporating inspection into the manufacturing process permits corrections to the process as the product is being made. This reduces scrap and brings the overall quality of product closer to the nominal specifications intended by the designer.

8. Process control and optimization.

This includes a wide range of control schemes intended to operate the individual processes and associated equipment more efficiently. By this strategy, the individual process times can be reduced and product quality improved.

9. Plant operations control.

Whereas the previous strategy was concerned with the control of the individual manufacturing process, this strategy is concerned with control at the plant level. It attempts to manage and coordinate the aggregate operations in the plant more efficiently. Its implementation usually involves a high level of computer networking within the factory.

10. Computer Integrated Manufacturing (CIM).

Taking the previous strategy one level higher, we have the integration of factory operations with engineering design and the business functions of the firm. CIM involves extensive use of computer applications, computer data bases, and computer networking throughout the enterprise.

Automation Migration Strategy

Formalized planned for evolving the manufacturing systems used to produce new products as demand grows.

A typical automation migration strategy is the following:

Phase 1: Manual production using single station manned cells operating independently. This is used for introduction of the new product for reasons already mentioned: quick and low cost tooling to get started.

Phase 2: Automated production using single station automated cells operating independently. As demand for the product grows, and it becomes clear that automation can be justified, then the single stations are automated to reduce labor and increase production rate. Work units are still moved between workstations manually.

Phase 3: Automated integrated production using a multi-station automated system with serial operations and automated transfer of work units between stations. When the company is certain that the product will be produced in mass quantities and for several years, then integration of the single station automated cells is warranted to further reduce labor and increase production rate.

Merits and Demerits of Automation

Perhaps the most cited advantage of automation in industry is that it is associated with faster production and cheaper labor costs. Another benefit could be that it replaces hard, physical, or repetitive work. Additionally, tasks that take place in hazardous environments or that are otherwise beyond human capabilities can be done by machines, as machines can operate even under extreme temperatures or in atmospheres that are radioactive or toxic. They can also be maintained with simple quality checks. However, at the time being, not all tasks can be automated, and some tasks are more expensive to automate than others. Initial costs of installing the machinery in factory settings are high, and failure to maintain a system could result in the loss of the product itself. Moreover, some studies seem to indicate that industrial automation could impose ill effects beyond operational concerns, including worker displacement due to systemic loss of employment and compounded environmental damage; however, these findings are both convoluted and controversial in nature, and could potentially be avoided.

The main Merits of Automation are -

- Increased throughput or productivity.
- Improved quality or increased predictability of quality.
- Improved healthiness of processes or product.
- Increased consistency of output.
- Reduced direct human labor costs and expenses.
- Installation in operations reduces cycle time.
- Can complete tasks where a high degree of accuracy is required.
- Replaces human operators in tasks that involve hard physical or monotonous work (e.g., using one forklift with a single driver instead of a team of multiple workers to lift a heavy object)
- Reduces some work-related injuries (e.g., fewer strained backs from lifting heavy objects)
- Replaces humans in tasks done in dangerous environments (i.e. fire, space, volcanoes, nuclear facilities, underwater, etc.)
- Performs tasks that are beyond human capabilities of size, weight, speed, endurance, etc.
- Reduces operation time and work handling time significantly.
- Frees up workers to take on other roles.

- Provides higher level jobs in the development, deployment, maintenance and running of the automated processes.

6.2 The main Demerits of Automation are -

- Possible security threats/vulnerability
- Due to increased relative susceptibility for committing errors.
- Unpredictable or excessive development costs.
- High initial cost.
- Displaces workers due to job replacement.

3.3 Types of Automation

Automated production systems are classified into three basic types:

1. Fixed automation,
2. Programmable automation, and
3. Flexible automation.

Fixed Automation

It is a system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration. The operations in the sequence are usually simple. It is the integration and coordination of many such operations into one piece of equipment that makes the system complex. The typical features of fixed automation are:

- a. High initial investment for custom-Engineered equipment;
- b. High production rates; and
- c. Relatively inflexible in accommodating product changes.

Programmable Automation

In this the production equipment is designed with the capability to change the sequence of operations to accommodate different product configurations. The operation sequence is controlled by a program, which is a set of instructions coded so that the system can read and interpret them. New programs can be prepared and entered into the equipment to produce new products. Some of the features that characterize programmable automation are:

- a. High investment in general-purpose equipment;
- b. Low production rates relative to fixed automation;
- c. Flexibility to deal with changes in product configuration; and
- d. Most suitable for batch production.

Flexible Automation.

It is an extension of programmable automation. A flexible automated system is one that is capable of producing a variety of products with virtually no time lost for changeovers from one product to the next. There is no production time lost while reprogramming the system and altering the physical setup. Consequently, the system can produce various combinations and schedules of products instead of requiring that they be made in separate batches. The features of flexible automation can be summarized as follows:

- a. High investment for a custom-engineered system.
- b. Continuous production of variable mixtures of products.
- c. Medium production rates.
- d. Flexibility to deal with product design variations.

The essential features that distinguish flexible automation from programmable automation are:

1. The capacity to change part programs with no lost production time; and
2. The capability to changeover the physical setup, again with no lost production time.

These features allow the automated production system to continue production without the downtime between batches that is characteristic of programmable automation.

The relative positions of the three types of automation for different production volumes and product variations are depicted in the following figure.

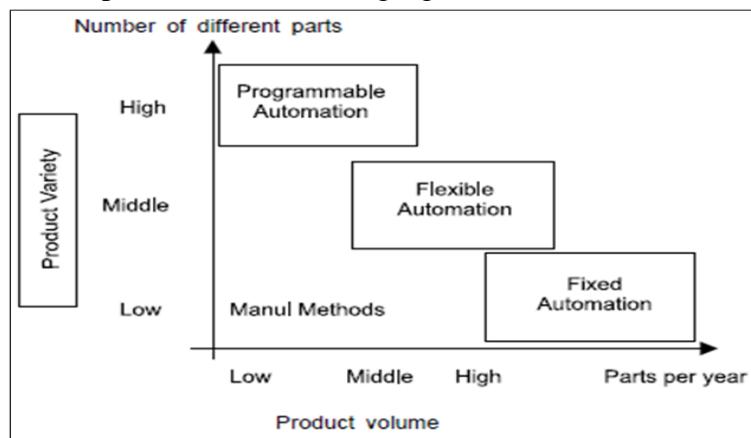


Figure 8 Types of Automation

Hard and Soft Automation

Soft or Programmable Automation is the more developed cousin to Hard Automation. It includes equipment that has been designed to accommodate a variety of product configurations. If you have facility that manufactures a limited range of similar products that are run in batches, Soft Automation may be your best choice.

a. Hard Automation

Hard automation is used for a specific production purpose where the processes are fixed. It is best suited for automated equipment that mass produced high volume products with few alterations or little changeovers. This type of automation has a high initial investment and high production rates, most typically automated assembly line machines.

The Society of Mechatronics Engineering & Technology (SOMETECH) points out that each of the operations in a fixed sequence is usually simple and involves a plain linear or rotational motion, for example, or a combination of two such motions. Despite the simple operations involved, it is relatively difficult to make changes in the product design.

Advantages of hard automation, according to SOMETECH, include low unit cost, automated material handling and a high production rate.

The disadvantages are a high initial investment and the relative inflexibility in accommodating product changes.

b. Soft Automation

Soft automation can be used to produce a variety of parts with virtually no time lost for changeovers from one part style to another or for multiple small batches of a single product. No lost production time results when reprogramming the system.

Advantages include continuous production of variable mixtures of product and flexibility to accommodate varying product designs.

Disadvantages are a medium production rate, high long term production costs and a high unit cost compared with hard automation.

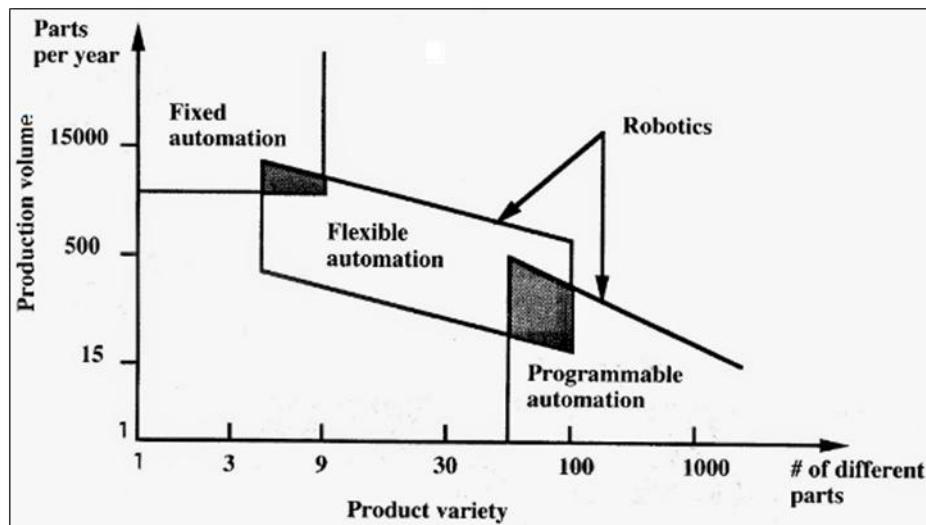


Figure 9

Recent and Emerging applications of Automation.

- **Automated power production**

Technologies like solar panels, wind turbines, and other renewable energy sources, together with smart grids, micro-grids, battery storage - can automate power production.

- **Automated retail Food and drink industry**

The food retail industry has started to apply automation to the ordering process; McDonald's has introduced touch screen ordering and payment systems in many of its restaurants, reducing the need for as many cashier employees. Some Cafes and restaurants have utilized mobile and tablet "apps" to make the ordering process more efficient by customers ordering and paying on their device. Some restaurants have automated food delivery to customer's tables using a Conveyor belt system. The use of robots is sometimes employed to replace waiting staff.

- **Automated mining**

Automated mining involves the removal of human labor from the mining process. The mining industry is currently in the transition towards automation. Currently, it can still require a large amount of human capital, particularly in the third world where labor costs are low so there is less incentive for increasing efficiency through automation.

- **Automated video surveillance**

Automated video surveillance monitors people and vehicles in real time within a busy environment. Existing automated surveillance systems are based on the environment they are primarily designed to observe, i.e., indoor, outdoor or airborne, the number of sensors that the automated system can handle and the mobility of sensor, i.e., stationary camera vs. mobile camera. The purpose of a surveillance system is to record properties and trajectories of objects in a given area, generate warnings or notify designated authority in case of occurrence of particular events.

- **Automated highway systems**

As demands for safety and mobility have grown and technological possibilities have multiplied, interest in automation has grown.

- **Automated waste management**

Automated waste collection trucks prevent the need for as many workers as well as easing the level of labor required to provide the service.

- **Business process automation**

Business process automation (BPA) is the technology-enabled automation of complex business processes. It can help to streamline a business for simplicity, achieve digital transformation, increase service quality, improve service delivery or contain costs.

- **Home automation**

Home automation designates an emerging practice of increased automation of household appliances and features in residential dwellings, particularly through electronic means that allow for things impracticable, overly expensive or simply not possible in recent past decades. The rise in the usage of home automation solutions has taken a turn reflecting the increased dependency of people on such automation solutions. However, the increased comfort that gets added through these automation solutions is remarkable.

- **Laboratory automation**

Automation is essential for many scientific and clinical applications. Therefore, automation has been extensively employed in laboratories.

- **Industrial automation**

Industrial automation deals primarily with the automation of manufacturing, quality control and material handling processes. General purpose controllers for industrial processes include Programmable logic controllers, stand-alone I/O modules, and computers. Industrial automation is to replace the decision making of humans and manual command-response activities with the use of mechanized equipment and logical programming commands.

3.4 Industrial Robotics-

Industrial robots (tough and tireless) are capable of handling a variety of jobs right from material handling to complex assembly tasks. They perform hazardous and monotonous tasks with tireless precision. They improve productivity and reduce manufacturing costs. They can perform complex jobs. They can even cope with changing conditions in the workplace, when fitted with sensors and adaptive controls.

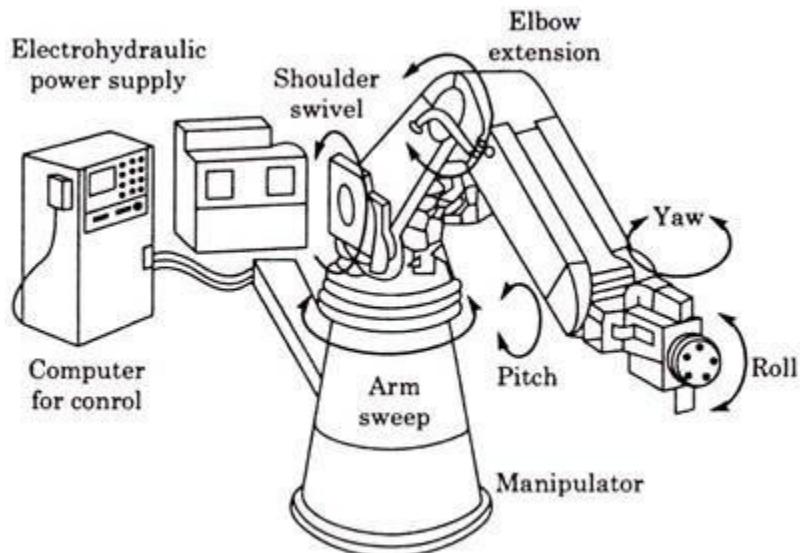


Figure 10 Industrial robot

Robot anatomy-

The anatomy of robot is also known as structure of robot. The RIA (Robotics Industries Association) has officially given the definition for Industrial Robots, “A general-purpose, programmable machine possessing certain anthropomorphic characteristics “

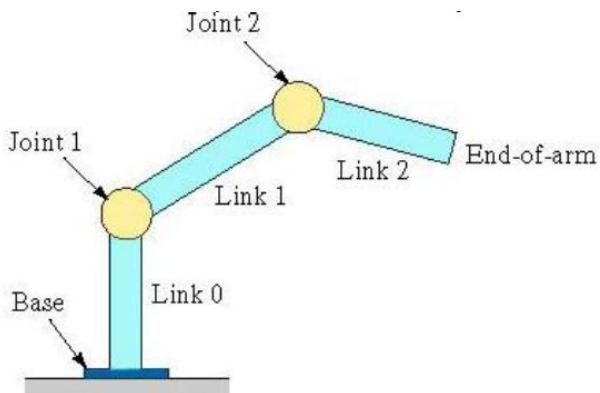
Importance of robotics:

- Robots can substitute for humans in hazardous work environments
- Consistency and accuracy not attainable by humans
- Can be reprogrammed
- Most robots are controlled by computers and can therefore be interfaced to other computer systems

The anatomy of industrial robots deals with the assembling of outer components of a robot such as wrist, arm and body components of a robot

1. **Manipulator-** The manipulator comprising of base, arm and wrist are the most obvious parts of the robot. The robot's movements are executed by the mechanical parts like links, power joints, and transmission system along with internal sensors housed within the manipulator. It consist of

- Joints provide relative motion
- Links are rigid members between joints
- Various joint types: linear and rotary
- Each joint provides a “degree-of-freedom”
- Most robots possess five or six degrees-of-freedom
- Robot manipulator consists of two sections:
- Body-and-arm – for positioning of objects in the robot's work volume
- Wrist assembly – for orientation of objects

**Figure 11 - Manipulator**

The controller acts like a brain of robot. It performs the functions of storing and sequencing data in memory, initiating and stopping the motions of the manipulator, and interacting with the environment.

2. **Robot Control system-** The controller is the "brain" of the industrial robotic arm and allows the parts of the robot to operate together. It works as a computer and allows the robot to be connected to other systems. The robotic arm controller runs a set of instructions written in code called a program. The program is inputted with a teach pendant. Many of today's industrial robot arms use an interface that resembles or is built on the Windows operating system

Robot Programming -

- Lead through programming - work cycle is taught to robot by moving the manipulator through the required motion cycle and simultaneously entering the program into controller memory for later playback.
- Robot programming languages - uses textual programming language to enter commands into robot controller.
- Simulation and off-line programming – program is prepared at a remote computer terminal and downloaded to robot controller for execution without need for lead through methods.

Programming Languages used for Robot controlling

- C/C++** - C and C++ is the best start for an aspiring robotics as it is a general purpose programming language that contains imperative, object-oriented and generic programming features. C++ allows interaction with low level hardware, and also real time performance. C and C++ are very mature programming languages. To ensure the best performance of a robot, it will be better to use C++.
- Python**- Python is the high-level programming language and it plays a key role in building and testing robots. Python is a good platform to automate, teach, and post-process robot programs.
- Java**- To perform human-like tasks, robotics systems must be included with functions via programming languages. To enable robots with these functions, Java language can be used as it offers an array of APIs that are tailor-made to the needs of the robotics realm.
- MATLAB** - MATLAB is not a programming language but it is a tool with which you can find engineering solutions based on mathematics. Robotic developers need to learn MATLAB if they want to analyze data, produce advanced graphs or implement control system

3. **End effector-** In robotics, an end effector is the device at the end of a robotic arm, designed to interact with the environment. The exact nature of this device depends on the application of the robot.

Types of End effectors -

- Impactive –jaws or claws which physically grasp by direct impact upon the object.
- Ingressive –pins, needles or hackles which physically penetrate the surface of the object (used in textile, carbon and glass fibre handling).
- Astrictive –suction forces applied to the objects surface (whether by vacuum, magneto–or electro adhesion).
- Contiguities –requiring direct contact for adhesion to take place (such as glue, surface tension or freezing)

4. **Sensors** to sense the environment are essential for intelligent robots.

- **Light Sensor** - Light sensor is a transducer used for detecting light and creates a voltage difference equivalent to the light intensity fall on a light sensor. The two main light sensors used in robots are Photovoltaic cells and Photo resistor.
- **Proximity Sensor**- Proximity sensor can detect the presence of nearby object without any physical contact. The working of a proximity sensor is simple. In proximity sensor transmitter transmits an electromagnetic radiation and receiver receives and analyzes the return signal for interruptions. Therefore the amount of light receiver receives by surrounding can be used for detecting the presence of nearby object
- **Sound Sensor**- Sound sensors are generally a microphone used to detect sound and return a voltage equivalent to the sound level. Using sound sensor a simple robot can be designed to navigate based on the sound receives.
- **Temperature Sensor**- Temperature sensors are used for sensing the change in temperature of the surrounding. It is based on the principle of change in voltage difference for a change in temperature this change in voltage will provide the equivalent temperature value of the surrounding.
- **Acceleration Sensor**- Acceleration sensor is used for measuring acceleration and tilt. An accelerometer is a device used for measuring acceleration.

Industrial Robot Application-

1. Arc Welding- Robot welding is improving the safety of workers from arc burn and inhaling hazardous fumes.
2. Spot Welding – Robotic Spot welding joins two contacting metal surfaces by directing a large current through the spot, which melts the metal and forms the weld delivered to the spot in a very short time (approximately ten milliseconds).
3. Materials Handling - Materials handling robots are utilized to move, pack and select products. They also can automate functions involved in the transferring of parts from one piece of equipment to another. Direct labour costs are reduced and much of the tedious and hazardous activities traditionally performed by human labour are eliminated.
4. Machine Tending - Robotic automation for machine tending is the process of loading and unloading raw materials into machinery for processing and overseeing the machine while it does a job.
5. Painting- Robotic painting is used in automotive production and many other industries as it increases the quality and consistency of the product. Cost savings are also realized through less rework.
6. Picking, Packing and Palletizing - Most products are handled multiple times prior to final shipping. Robotic picking and packaging increases speed and accuracy along with lowering production costs.
7. Assembly- Robots routinely assemble products, eliminating tedious and tiresome tasks. Robots increase output and reduce operational costs.
8. Mechanical Cutting, Grinding, Deburring and Polishing - Buffing and polishing a hip joint by hand can normally take 45-90 minutes while a robot can perform the same function in just a few minutes.
9. Gluing, Adhesive Sealing and Spraying Materials -Sealer robots are built with numerous arm configurations that enable the robot to apply adhesives to any type of product. The primary benefit in this application is increased quality, speed and consistency of the final product.

3.5.1 4 D Printing Technology

4D printing is also known as 4D bio-printing or shape changing systems. It uses the same techniques of 3D printing (Adaptive Manufacturing) through computer-programmed deposition of material in successive layers to create a three-dimensional object. However, 4D printing adds the dimension of renovation over time. It is therefore a type of programmable matter, wherein after the fabrication process, the printed product reacts with parameters within the environment (i.e. water, humidity, temperature, wind, etc.,) and changes its form accordingly. The ability to do so arises from the near infinite configurations at a micrometer resolution, creating solids with engineered molecular spatial distributions and thus allowing unprecedented multifunctional performance. 4D printing is a relatively new advance in bio-fabrication technology, rapidly emerging as a new model in disciplines such as materials science, bioengineering, chemistry, and computer sciences.

4D printing Techniques

Stereo lithography is a 3D-printing technique that uses photo polymerization to bind substrate that has been laid layer upon layer, creating a polymeric network. As opposed to fused-

deposition modelling, where the extruded material hardens immediately to form layers, 4D printing is fundamentally based in stereo lithography, where in most cases ultraviolet light is used to cure the layered materials after the printing process has completed. Anisotropy is vital in engineering the direction and magnitude of transformations under a given condition, by arranging the micro materials in a way so that there is an embedded directionality to the finished print.

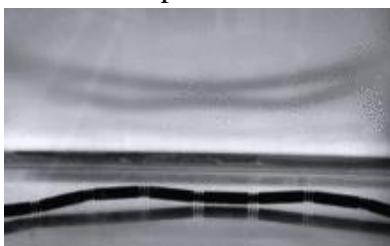
c. Pattern-driven 4D Printing

4D printing helps to achieve rapid and accurate manufacturing methods for controlling spatial self-bending actuation in custom-designed soft structures. Spatial and temporal transformations can be realized through several actuation mechanisms such as liquid crystal gel phase transition, thermal expansion coefficient, thermal conductivity discrepancies, and the different swelling and de-swelling ratios of bi-layer or composite beams. One approach to model 4D printing is to control 3D-printing parameters, such as different spatial patterns of hinges affecting the response time and bending angle of the 4D print products. A parametric model of physical properties of shape memory polymer panes incorporating 3D printed patterns was developed to that end. The proposed model predicts the final shape of the actuator with an excellent qualitative agreement with experimental studies. These validated results can guide the design of functional pattern-driven 4D printings.

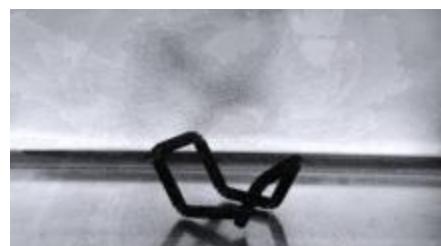
Smart Materials Used for 4D Printing

Fibber architecture

Most 4D printing systems utilize a network of fibres that vary in size and material properties. 4D printed components can be designed on the macro scale as well as the micro scale. Micro scale design is achieved through complex molecular/fibre simulations that approximate the aggregated material properties of all the materials used in the sample. The size, shape, modulus, and connection pattern of these material building blocks have a direct relationship to the deformation shape under stimulus activation.



(a) Before activation



(b) After activation

Figure12 - One of the composite polymers printed, reacting when submerged underwater.

Digital Shape-Memory Polymers

Shape-memory polymers (SMPs) are able to recover their original shape from a deformed shape under certain circumstances, such as when exposed to a temperature for a period of time. Depending on the polymer, there may be a variety of configurations that the material may take in a number of temperature conditions. Digital SMPs utilize 3D-printing technology to precisely engineer the placement, geometry, and mixing and curing ratios of SMPs with differing properties, such as glass transition or crystal-melt transition temperatures. In this

technique a series of digital SMP hinges that have differing prescribed thermo-mechanical and shape memory behaviors, which are grafted onto rigid, non-active materials. Thus, develop a self-folding sample that could fold without interfering with itself, and even interlock to create a more robust structure. One of the projects include a self-folding box modeled after a USPS mailbox is shown in the figure.

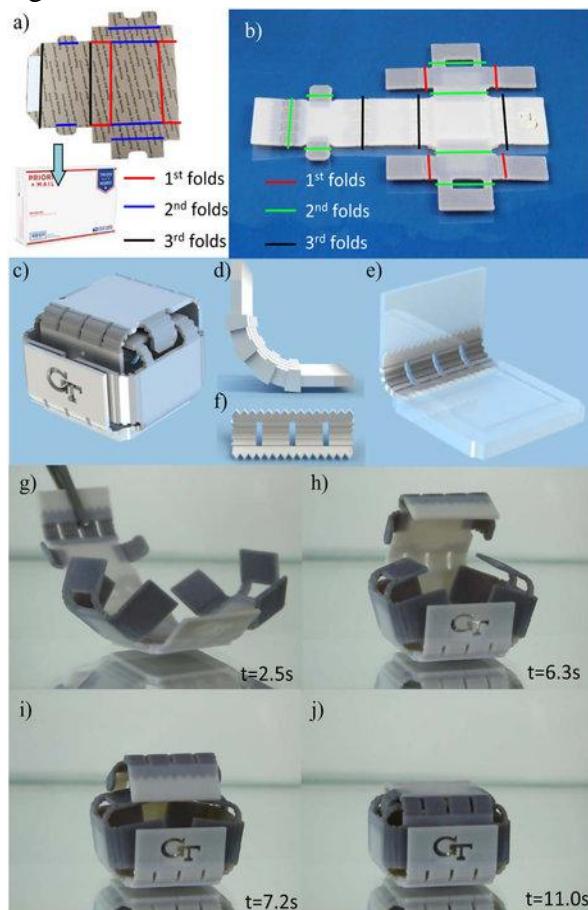


Figure - An interlocking and self-folding SMP simulating the folding procedure of a USPS mailbox.

Liquid Crystalline Elastomers

Liquid crystal elastomers (LCEs) are a class of soft-active materials which can achieve rapid and reversible shape changes. This is in contrast to SMPs which typically require a programming step and thus the actuation is generally one-time and non-reversible. Hydrogels, on the other hand, can yield large and reversible volume change, however, their response speed is relatively slow. LCEs achieve their actuation through a transition of the molecular chains between an ordered liquid crystal (nematic) state and a random (isotropic) state in response to light, heat, electrical, or magnetic fields.

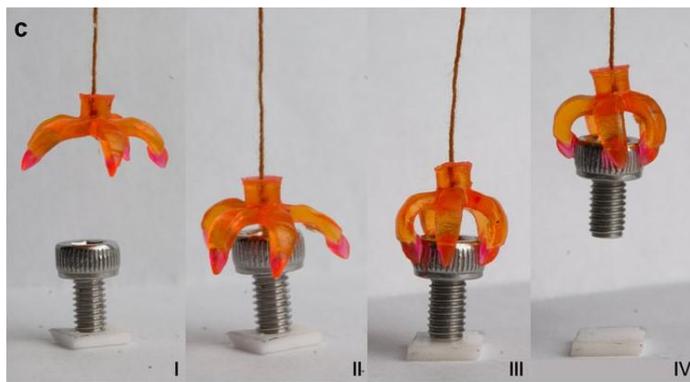


Figure 13 - A time-lapse of an SMP gripper developed for grabbing and releasing an object.

E Multi-Material 4D Printing using LCEs

The concept of utilizing multi-material 4D printing using LCE to create reversible actuation of complicated structures. Here, a three layer hinge was created by placing prefabricated LCE on a 3D printed silver wire and elastomer structure. Joule heating was then used to heat the LCE past its transition temperature (TNI). The basic hinge design is entirely 3D printed and utilized to create structures that could achieve complex folding and activation sequences. Among other demonstrations, a hand was 3D printed such that each finger could be activated separately to produce letters from the American Sign Language alphabet.

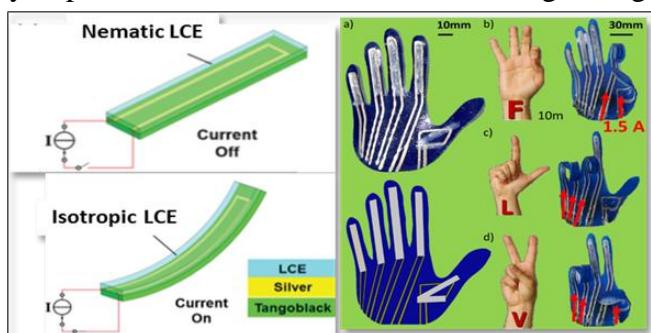


Figure 14 - Multi-material 4D printing using LCE-based actuation .

Current Applications of 4D printing

- **Architecture**

Common adaptive frontages and opening roofs require complex mechanical systems to operate which are often difficult to install and frequently malfunction. 4D printed frontages would offer simplicity of installation and direct actuation caused by weather conditions, eliminating any need for a larger controlling system or input energy.

- **Biomedical**

4D-printable, photo-curable liquid resin is made of a renewable soybean-oil epoxidized acrylate compound that is also biocompatible. This resin adds to the small group of 3D-printable resins and is one of the few that are biocompatible. A laser 3D-printed sample of this resin was subjected to temperature fluctuations from -18 °C to 37 °C and exhibited full recovery of its original shape. Printed skeletons of this material proved to be successful foundations for human bone marrow mesenchymal stem cell (hMSCs) growth. This material's strong qualities of shape memory effect and biocompatibility lead researchers to believe that it will strongly advance the development of biomedical frameworks. The use of plant oil polymers as liquid resins for stereolithography production in biomedical applications.

- **Other Possible Applications**

There are some existing techniques/technologies that could potentially be applied and adjusted for 4D printing.

- **Cell Traction Force**

Cell Traction Force (CTF) is a technique wherein living cells fold and move microstructures into their designed shape. This is possible through the contraction that occurs from actin (multifunctional proteins) polymerization and actomyosin (group of muscle cells) interactions within the cell. In natural processes, CTF regulates wound healing, angiogenesis, metastasis, and inflammation. Seeding of cells across two microplates, and when the glass structure was removed the cells would bridge the gap across the microplate and thus initiate self-folding.

- **Electrical and Magnetic Smart Materials**

The electrical responsive materials that exist today change their size and shape depending on the intensity and/or direction of an external electric field. Polyaniline and polypyrrole (PPy) are, in particular, good conducting materials and can be doped with tetrafluoroborate to contract and expand under an electric stimulus. A robot made of these materials was made to move using an electric pulse of 3V for 5 seconds, causing one leg to extend, then removing the stimulus for 10 seconds, causing the other leg to move forward. Research on carbon nanotubes, which are biocompatible and highly conductive, indicates that a composite made of carbon nanotube and a shape memory specimen has a higher electrical conductivity and speed of electro-active response than either specimen alone. Magnetically responsive ferrogels contract in the presence of a strong magnetic field and thus have applications in drug and cell delivery. The combination of carbon nanotubes and magnetically responsive particles has been bioprinted for use in promoting cell growth and adhesion, while still maintaining a strong conductivity.

- **Commerce and transportation**

Future applications of 4D-printed materials as programmable products that can be tailored to specific environments and respond to factors such as the temperature, humidity, pressure, and sound of one's body or environment. Some study also mentions the advantage of 4D-printing for shipping applications - it will allow products to be packaged flat to later have their designed shape activated on site by a simple stimulus. There is also the possibility of 4D-printed shipping containers that react to forces in transit to uniformly distribute loads. It is very likely that 4D-printed materials will be able to repair themselves after failure. These materials will be able to self-disassemble, making their constituent parts easy to recycle.

- **Medical Devices**

The idea of 4D printing technology is very suitable for the medical stents industry because the stents are placed into blood vessels. Blood vessels are soft tissues that change their size according to age, health condition, blood flow, etc. Now imagine a new stent or any other kind of implant that can be designed to change its shape after exposure to stimuli. Another example, drug capsules that release medicine when there is the first sign of infection, such as change of body temperature.

- **Can Create Smart Structures by using Smart Materials**

The fundamental concept of 4D printing is a smart structure that consists of rigid materials connected with expandable elements, or it can also be a whole structure made from expandable materials. It depends what materials properties are needed and what is the application. The expandable elements can change their shape when exposed to certain stimuli, and this causes the rigid parts to move or rotate, and then the whole structure is transformed into a new form. You can imagine these expandable materials as they are joints of the structure.

- Clothes and Footwear - New products that can transform themselves according to the user's requirements
- Implants for human and animals made from biocompatible materials.
- Soft robots – activation without reliance on an electric device.
- Smart valves and sensors for infrastructure lines.

Difference between 3D Printing and 4D Printing.

The difference between 3D and 4D printing is that 4D printed objects can transform themselves over time, while 3D printed objects maintain fixed shape like any plastic or metal parts. The fourth dimension of 4D is the transformation over time.

3D printing technology offers production of objects with relatively new manufacturing techniques, such as FDM and SLA, which are alternatives to primary manufacturing methods of metal and plastic parts, such as CNC machining, Plastic injection, Casting, etc. The shape of the parts produced by the 3D printer is permanent and will not change after production. 4D printing technology offers an output of smart structures by using new manufacturing techniques of 3D printing, advanced materials and customized design for the required structural transformation. 4D printed objects need a stimulus to start the deformation phase; the trigger can be an exposure to water, heat or light.

3D printing is a process that creates a 3D object by printing layer by layer from a CAD model (computer 3D model). This technology also is also known as additive manufacturing because the product is made by adding material rather than subtracting material or shaping material by cold and hot techniques. 3D printing parts are made from different kinds of raw materials such as PLA, ABS, Polycarbonate, Nylon, Carbon and more.

4D printing is a process that creates a smart 3D object from a material that can change its shape over time if exposed to water, heat, light or magnetic field. The fourth dimension is the transformation over time. The structure of the 4D print is preprogrammed in details according to the desired change of shape. The 4D printing technology is a combination of 3D printing + smart materials + customized design for the required transformation. The self-transformation

of the structure also called self-assembly as the structure can be designed to assemble itself. The 4D printing is based on Stereolithography (SLA), a technique that uses photo-polymeric liquid to build 3D object layer upon layer.

Objects created with a 3D printer can be rigid or flexible, it depends on the printing material, but even if you use the flexible material, it will keep its original shape after you remove load from it. For example, when you pull a rubber band, you change the form of the object, but as soon as you release it, the rubber band returns to its original shape. However, 4D printing offers an entirely different concept. The smart structure can make a real transformation by itself when exposed to stimuli.

3.5.2 3-D Scanning Technology

A 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and its appearance (i.e. color). The collected data then can be used to construct high resolution, accurate, digital 3D models. 3D scanners are very analogous to cameras. Like cameras, they can only collect information about surfaces that are not covered. While a camera collects color information about surfaces within its field of view, a 3D scanner collects distance information about surfaces within its field of view. Some 3D scanners can simultaneously collect shape and color data. A 3D scanned color surface is called a texture.

3D Scanning

3D scanning is a technique used to capture the shape of an object using a 3D scanner. The result is a 3D file of the object which can be saved, edited, and even 3D printed. Many different 3D scanning technologies exist to 3D scan objects, environments, and people. Each 3D scanning technology comes with its own limitations, advantages, and costs.

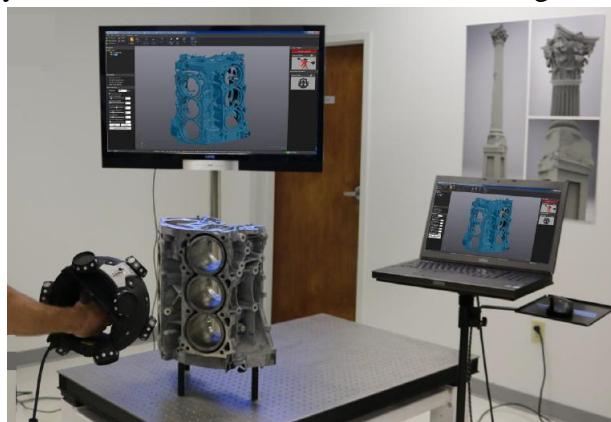


Figure 15 Creaform MetraSCAN optically tracked 3D scanning and probing system



Figure 16 Making a 3D-model of a Viking belt buckle using a hand held VIU scan 3D laser scanner.

3D scanning working-

There are two major categories of scanners based on the way they capture data:

- White-light and structured-light systems that take single snapshots/scans
- Scan arms and portable handheld scanners that capture multiple images continuously.

Scanning results are represented using free-form, unstructured three-dimensional data, usually in the form of a point cloud or a triangle mesh. Certain types of scanners also acquire color information for applications where this is important.

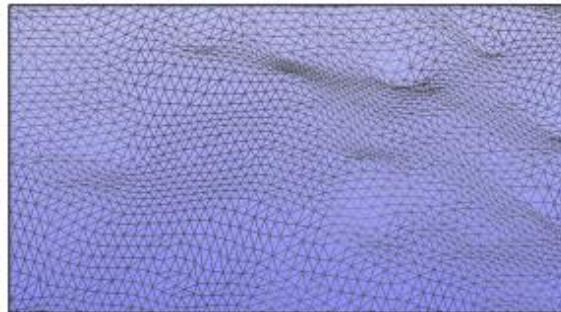


Figure 17: Triangulated mesh representation

Images or scans are brought into a common reference system, where data is merged into a complete model. This process called alignment or registration can be performed during the scan itself, called dynamic referencing, or as a post-processing step.

3D scans are compatible with Computer Aided Design (CAD) software and also 3D printing, after a little preparation on the computer software. A 3D scan can give a lot of information about the design of an object, in a process called reverse engineering.

Functions of 3D scanning

The purpose of 3D scanning is

- To collect data of a real-world object or environment
- To recreate design in the form a digital 3D model.
- It bridges a gap between Physical world and Digital world.

This 3D model has many applications, ranging from industrial product design to production quality control and movie productions. 3D scanners are powerful tools for professionals in several industries, such as automotive, aeronautics, dental, jewelry making, as well as video gaming special effects, and animation movies.

Types of 3D Scanning Processes

- 1) Contact
- 2) Non-contact
 - a) Active
 - (i) Time-of-flight
 - (ii) Triangulation
 - (iii) Structured light
 - (iv) Industrial Computed Tomography (CT)
 - b) Passive
 - (i) Stereoscopic
 - (ii) Photometric
 - (iii) Silhouette

Contact type 3D Scanning

3D contact scanners, generally calibrated to operate on a fixed platform, often contain a probe located at the end of an articulated mechanical arm. The arm may be robotically or manually manipulated over the part's surface. As the probe contacts the object's surface the scanner records the X,Y,Z position of the probe by taking positional measurements of the armature. The recorded positions form a point cloud, which can be used to calculate a 3D mesh. Some highly accurate 3D scanners called Coordinate Measuring Machines (CMMs) are often used by the manufacturing industry to inspect parts for early indications of assembly problems. This device is used for measuring the physical geometrical characteristics of an object. Measurements are defined by a probe attached to the third moving axis of this machine. Probes may be mechanical, optical, laser, or white light, amongst others.

Non-Contact Active type 3D Scanning

In Non-Contact Active Scanning processes, scanners emit some kind of radiation or light and detect its reflection or radiation passing through object in order to review an object or environment. Possible types of emissions used include light, ultrasound, or x-ray.



A 3D scanner in action (source: Artec).

Active methods, i.e. range data methods, given the depth map, reconstruct the 3D profile by numerical approximation approach and build the object in scenario based on model. These methods actively interfere with the reconstructed object, either mechanically or radiometrically using rangefinders, in order to acquire the depth map, e.g. structured light, laser range finder and other active sensing techniques. A simple example of a mechanical method would use a depth gauge to measure a distance to a rotating object put on a turntable. More applicable radiometric methods emit radiance towards the object and then measure its reflected part. Examples range from moving light sources, colored visible light, time-of-flight lasers to microwaves or ultrasound.

Non-contact passive type 3D Scanning

Passive 3D imaging solutions do not emit any kind of radiation themselves, but instead depend on detecting reflected ambient radiation. Most solutions of this type detect visible light because it is a readily available ambient radiation. Other types of radiation, such as infra-

red could also be used. Passive methods can be very cheap, because in most cases they do not need particular hardware but simple digital cameras.

Passive methods of 3D reconstruction do not interfere with the reconstructed object; they only use a sensor to measure the radiance reflected or emitted by the object's surface to infer its 3D structure through image understanding. Typically, the sensor is an image sensor in a camera sensitive to visible light and the input to the method is a set of digital images (one, two or more) or video. In this case we talk about image-based reconstruction and the output is a 3D model. By comparison to active methods, passive methods can be applied to a wider range of situations.

Applications of 3D Scanning

a. Education

3D scanning is starting to become predominant in classrooms all around the world. By using shaping clay or a similar medium, students with very limited 3D CAD modelling skills are able to create and 3D print completely unique models that would be near impossible to produce using software only.

b. Mechanical Engineering / Reverse engineering

Another area with huge potential for 3D scanning is engineering. The ability to scan any object and then use CAD for modification makes both reverse engineering and rapid prototyping an extremely streamlined process. Detailed measurements can be performed and investigation into mechanical properties is simplified.



Figure 18 - 3 D scanning

Reverse engineering of a mechanical component requires a precise digital model of the objects to be reproduced. Rather than a set of points a precise digital model can be represented by a polygon mesh, a set of flat or curved NURBS surfaces, or ideally for mechanical components, a CAD solid model. A 3D scanner can be used to digitize free-form or gradually changing shaped components as well as prismatic geometries whereas a coordinate measuring machine is usually used only to determine simple dimensions of a highly prismatic model. These data points are then processed to create a usable digital model, usually using specialized reverse engineering software.

c. Design process

- Increasing accuracy of working with complex parts and shapes,
- Coordinating product design using parts from multiple sources,
- Updating old CAD scans with those from more current technology,
- Replacing missing or older parts,

- Creating cost savings by allowing as-built design services, for example in automotive manufacturing plants,
- "Bringing the plant to the engineers" with web shared scans, and
- Saving travel costs.

d. Quality assurance and industrial metrology

The digitalization of real-world objects is of vital importance in various application domains. This method is especially applied in industrial quality assurance to measure the geometric dimension accuracy. Industrial processes such as assembly are complex, highly automated and typically based on CAD (Computer Aided Design) data. The problem is that the same degree of automation is also required for quality assurance. It is, for example, a very complex task to assemble a modern car, since it consists of many parts that must fit together at the very end of the production line. The optimal performance of this process is guaranteed by quality assurance systems. Especially the geometry of the metal parts must be checked in order to assure that they have the correct dimensions, fit together and finally work reliably.

e. Architecture

The ability to scan and analyze buildings in high detail makes 3D scanning a hugely attractive intention when conducting architectural surveys. 3D scanning provides the user with extremely accurate measurements and the ability to fully utilize, visualize and modify data with CAD.

f. Construction industry and Civil Engineering

- Robotic control: e.g. a laser scanner may function as the "eye" of a robot.
- As-built drawings of bridges, industrial plants, and memorials
- Documentation of historical sites
- Site modelling and lay outing
- Quality control
- Quantity surveys
- Payload monitoring
- Freeway redesign
- Establishing a bench mark of pre-existing shape/state in order to detect structural changes resulting from exposure to extreme loadings such as earthquake, vessel/truck impact or fire.
- Create GIS (geographic information system) maps and geomatics.
- Subsurface laser scanning in mines and Karst voids.
- Forensic documentation

g. Entertainment / Virtual Reality / Animation

3D scanners are used by the entertainment industry to create digital 3D models for movies, video games. The gaming industry is currently experiencing rapid advancement and 3D scanning appears to be playing a key role in this growth. The scanning of both people and environments is being performed to provide realistic simulation through gamification.



Figure 19 - Animation

h. 3D photography

3D scanners are evolving for the use of cameras to represent 3D objects in an accurate manner. Companies are emerging to create 3D portraits of people (3D figurines or 3D selfies).



Figure 20 – 3 D Photography

3D selfie in 1:20 scale printed by Shapeways using gypsum-based printing, created by Madurodam miniature park from 2D pictures taken at its Fantasitron photo booth.



Figure 21 - Fantasitron 3D photo booth at Madurodam

i. Law enforcement

3D laser scanning is used by the law implementation agencies around the world. 3D Models are used for on-site documentation of:

- Crime scenes
- Bullet trajectories
- Bloodstain pattern analysis
- Accident reconstruction
- Bombings
- Plane crashes, and more

7.10 Real estate

Land or buildings can be scanned into a 3d model, which allows buyers to tour and inspect the property remotely, anywhere, without having to be present at the property. A typical virtual tour would consist of dollhouse view, inside view, as well as a floor plan.

j. Cultural heritage

There have been many research projects undertaken via the scanning of historical sites and artifacts both for documentation and analysis purposes.

The combined use of 3D scanning and 3D printing technologies allows the replication of real objects without the use of traditional plaster casting techniques that in many cases can be too offensive for being performed on precious or delicate cultural heritage artifacts.

k. Medical CAD/CAM

3D scanners are used to capture the 3D shape of a patient in orthotics and dentistry. It gradually supplants tedious plaster cast. CAD/CAM software are then used to design and manufacture the orthosis, prosthesis or dental implants. 3D scanning is also being used for detailed study of body parts, for example prior to a surgical procedure. Thorough planning and preparation of the location gives doctors and surgeons the opportunity for more informed decisions and improved rates of surgical success.



Unit 4: Energy Audit and Management

Introduction

Energy Audit :According to Energy Conservation Act 2001 “**Energy Audit**” means the verification, monitoring, analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.

Energy management: The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems.

Energy Audit

- Energy audit is refers to the inspecting, examining and analyzing on the physical and the financial activities processes of enterprises and other high energy-using units according to relevant state regulations and standards of energy-saving.
- An energy audit is an assessment of how much energy a facility consumes and the development of a plan to make the facility more energy efficient.
- An energy audit cannot only reveal ways to help conserve precious energy; it can also save you significant amounts of money by maximizing energy efficiency.
- Energy audit is conducted by energy utilization units or its competent authorities or entrusted specialist agencies.
- Energy audit is a kind of scientific management method of energy. Its main content is objectively inspecting on the energy efficiency, energy consumption level and the economic benefit of the energy unit and proposing the energy-saving measures for energy-using units by means of statistical analysis, inspection testing, and diagnostic evaluation.
- During an audit, an expert examines the facility for energy leakages (such as air leaks) as well as ways to maximize energy usage (such as with more efficient lighting and heating/cooling systems).
- The targets of energy audit are investigating problem and weaknesses in using energy, tapping the energy-saving potential, giving rectification measures, formulating energy saving goals and plan through the inspecting, examining, diagnosing and evaluating of the enterprise energy management level, energy consumption situation, energy consumption index, financial process, comprehensive utilization of energy.
- The ultimate aim of energy audit is to encourage enterprises to save energy, reduce production costs and increase economic benefit.

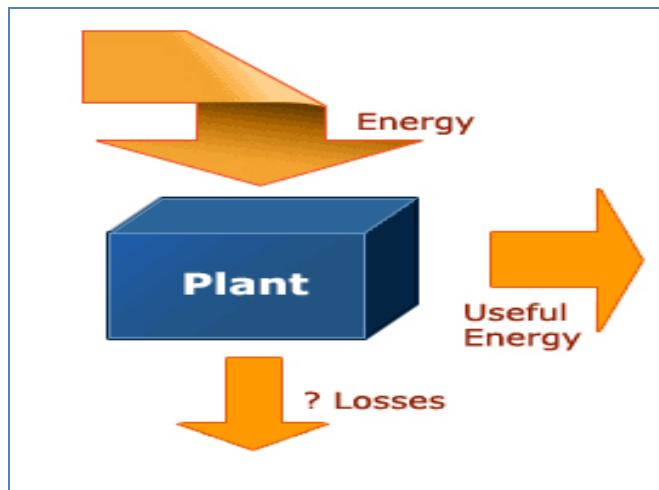


Figure 1 Energy Distribution

4.3 Energy Management

- Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meet them.
- The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect.
- **Definition of Energy Management** given by Cape Hart, Turner and Kennedy is "The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions".
- Also it can be said as "The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems".
- Energy Audit is the key to a systematic approach for decision-making in the area of energy management.

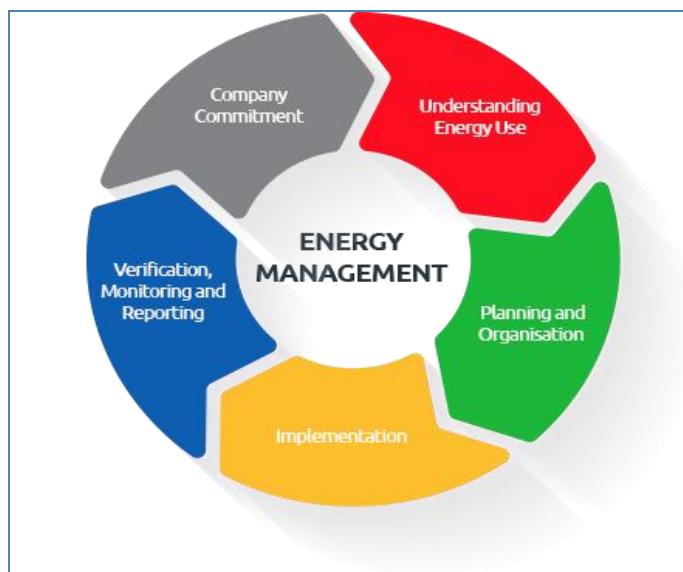


Figure 2 - Energy Management

- It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions.
- Energy management in the form of implementing new energy efficiency technologies, new materials and new manufacturing processes and the use of new technologies in equipment and materials for business and industry is also helping companies improve their productivity and increase their product or service quality.
- Often, the energy savings is not the main driving factor when companies decide to purchase new equipment, use new processes, and use new high-tech materials.
- However, the combination of increased productivity, increased quality, reduced environmental emissions, and reduced energy costs provides a powerful incentive for companies and organizations to implement these new technologies.

The objective of Energy Management is

- To achieve and maintain optimum energy procurement and utilization, throughout the organization and
- To minimize energy costs / waste without affecting production & quality
- To minimize environmental effects.

4.1 Standards and Labelling standard (HVAC)

Standards and Labeling (S & L) has been identified as a key activity for energy efficiency improvement..

The main provisions of EC act on standards and labeling are:

- Evolve minimum energy consumption and performance standards for notified equipment and appliances
- prohibit manufacture, sale and import of such equipment, which does not conform to the standards
- Introduce a mandatory labeling scheme for notified equipment appliances to enable consumers to make informed choices disseminate information on the benefits to consumers

Bureau of Energy Efficiency (BEE)

- The Government of India has set up the Bureau of Energy Efficiency (BEE), also referred to as 'BEE' under the provisions of the EC Act, 2001 with the primary objective of reducing energy intensity of the Indian economy.
- The Standards and Labeling Scheme (S&L) is one of the major thrust areas of BEE. The scheme was launched on May, 2006, with the objective of giving the consumer an informed choice about the energy saving and thereby cost saving potential of the relevant marketed product,
- The scheme provides for display of energy performance labels on high energy end use equipment & appliances and lays down minimum energy performance standards.
- A star rating, ranging from 1 to 5 in the ascending order of energy efficiency is provided to the products registered with BEE.
- The Star or Energy labeling is based on Standards that prescribe limits on energy performance (usually maximum use or minimum efficiency) based on specified test protocols.
- The informative labels affixed to products describe energy performance usually in the form of energy use, efficiency, or energy cost.

Standards.

1. Prescribe limits on the energy consumption (or minimum levels of the energy efficiency) of manufactured products.
2. “Standards” commonly encompasses two possible meanings:
3. well-defined test protocols to obtain a sufficiently accurate estimate
4. target limits on energy performance

Label

1. Describes energy performance (in the form of energy use, efficiency or energy cost)
 2. “Labels” mainly give consumers the necessary information to make informed purchase.
- There are two types of labels:

Comparative Label	Endorsement Label
Allow consumers to compare the energy consumption of similar products, and factor lifetime running cost into their purchasing decision	Provide a ‘certification’ to inform prospective purchasers that the product is highly energy efficient for its category.

- Energy labels can be used stand alone or complement energy standards. In addition to giving information that allows consumers who care to select efficient models, labels also provide a common energy-efficiency benchmark that can work in association with other policy measures such as procurement programs, financial incentives etc.
- The effectiveness of energy labels is heavily dependent on how they present information to the consumer and on how they are supported by information to the consumer and how they are supported by information campaigns, financial incentives, and other related programs.

The appliances covered under the S&L scheme are as follows:

Products on which Labeling is mandatory

1. Frost Free (No-Frost) Refrigerator
2. Tubular Florescent Lamps
3. Room Air-conditioners
4. Distribution Transformers
5. Room Air Conditioners (Cassette, Floor Standing Tower, Ceiling, Corner AC)
6. Direct Cool Refrigerator
7. Colour TV

Products on which Labeling is voluntary

1. Electric Geysers
2. Induction Motors
3. Agricultural Pump Sets
4. Ceiling Fans
5. LPG Stoves
6. Washing Machines
7. Laptops/Notebooks
8. Office Equipment's
9. Ballast
10. Diesel Engine Driven Monoset Pumps for Agricultural Purposes

11. Solid State Inverters
12. Diesel Generator
13. Variable Capacity Air Conditioner (Inverter AC's)
14. LED Retrofit lamps

Application for Registration

For each product under the S&L Scheme, BEE uploads the following information on the S&L web portal:

1. Schedule/regulation of BEE for respective product
2. Procedure for obtaining a Label
3. List of documents required to be submitted along with the application
4. Financial obligations involved
 - An applicant is required to apply online through the S&L web portal and subsequently submit hard copies of the application along with supporting documents to BEE
 - Registration is done in two stages:
 - Company Registration
 - Model Registration

A. General Guidelines for Company Registration

- a. Each and every document submitted to BEE (either in hard copy or uploaded online) must bear the sign and stamp of the authorized signatory in original.
- b. All the documents must be submitted in the given sequence (as mentioned in below) and kept in file in a proper way.
- c. Documents without proper filing or loose or clipped or only stapled will not be accepted
- d. Deviation from the process would be treated as non-compliance to the application

B. Sequence of Documents to be attached for the purpose of Company registration

1. **Covering Letter**, as given in Annexure-1 & Annexure-2 for the fresh application and resubmission respectively
2. **One time Company Registration fee** of Rs.100000/- for large scale industry and Rs. 25000/- for small scale industry (SSI) is applicable for the registration of one product and respective brand. Payment can be made through Bank Demand draft or through online
3. **Print out of the Online Company Registration Form** (properly signed and stamped with company seal with all filled in details)
4. **Agreement** between BEE & User of Label on Rs.100 Non Judicial Stamp Paper (For voluntary scheme only. Separate agreement for each product type)

5. One set of General Documents as under

- a. **Trade Marks certificate** (In the Name of the User of Label)
- b. **SSI certificate** (If Small Scale Industry and applying for first time)
- c. **Quality Management System Certificate** (ISO 9001) (issued in the name and address of the manufacturing facility mentioned in company registration form of Manufacturer). In case of multiple manufacturing facilities, ISO of all the manufacturing facilities must be enclosed.
- d. **Authorized Signatory Letter** (On Company Letter Head mentioning the Name and specimen signature of the Authorized signatory/signatories and the company head)
- e. **BIS License** (With Validity date and endorsement Letter showing all applied models. The Models applied to BEE should be highlighted in the endorsement Sheet) (If applicable)

Sequence of Documents to be attached for the purpose of Model registration

1. **Model Registration fee** for each model of Rs.1000/. Payment can be made through Bank Demand draft or through online
2. **Print out of the Online Application form** (properly signed and stamped with company seal)
3. **Print out of the Mandatory Form** and its **Annexure form** (For mandatory products only)
4. **Test Report** (properly signed and stamped with company seal) from NABL accredited Lab. Rated values must be declared in test report. In house test lab reports are accepted provided the lab is accredited by NABL
5. **Sample Label** (Printed Waterproof Adhesive or Metallic as applicable) of each model must be stapled along with online application form of that particular model. The design & color parameters of sample label should strictly match with the specifications given in schedule of the respective equipment.

Please refer to following links for more detailed information:

- BEE Star Labeling Website
- Scheme for Energy Efficiency Labeling (guidelines for permittee)
- Important Instructions Before E- Filing
- Colour Scheme / Dimensions of the Label
- Product list under Mandatory Labeling
- Product List under Voluntary Labeling

BEE Star Rating:

- Star ratings are provided to all the major kind of appliances in the form of labels. These star ratings are given out of 5 and they provide a basic sense of how energy efficient each product is, just in a single glance.
- The manufacturers are officially required to put these labels as per **the Standards and Labeling Program introduced in 2006**.

Importance of BEE Star Rating labels.

- The prime importance of these Star Ratings is to educate and inform consumers about how energy efficient each product is. This also makes the manufacturer responsible for creating products which are highly energy efficient as consumers may eventually prefer better rated products.

BEE Star Ratings purpose-

- One of the most common myths about the BEE Star Rating is that it is solely based on the appliance's power consumption. A lot of factors contribute into formulating the final star rating on the product.
- Although the manufacturers rate and label the product, BEE sets all the standards and norms which need to be followed while rating an appliance. While some category of appliances necessarily have to be given a star rating, for others it's optional.
- Appliances which need to have an energy rating label mandatorily: Frost-free refrigerator, Tubular Fluorescent Lamps, Room Air-Conditioners, Distribution Transformer, Colour TV, CST AC, Direct Cool Refrigerator and Electric Geyser.
- The appliances with the lowest energy consumption in a product category are given the most stars and those with the highest energy consumption are given the least.

There are two variants of these labels, a big one and a smaller version:

1. Big label:

- The big energy rating label is aimed at appliances which have a constant usage and consume more electricity.
- These labels show additional information such as the yearly energy consumption of the product, brand name, product category and much more.
- For consumers, this big label is helpful as it allows you to calculate the actual money you would spend in electricity bills for that particular product.
- Products with a big label: Refrigerators, air-conditioners, geysers and washing machines.



Figure 3 BEE Star Label

2. Small Label:

- Small labels can be found in appliances which usually **don't consume more energy**. These labels just give you a visual representation of the energy consumption levels by showing star ratings.
- Products with a small label: Ceiling fans, tube lights, computers/laptops and televisions.



Figure 4 Sample Label

Power Saving Guide -

- Whenever we go to buy a new air conditioner, we find a label on the same. This is probably the most important factor apart from the cost, which determines the selection of an air conditioner.
- Bureau of Energy Efficiency (BEE) mandates every air conditioner to have this label. A representation of the same is given below:

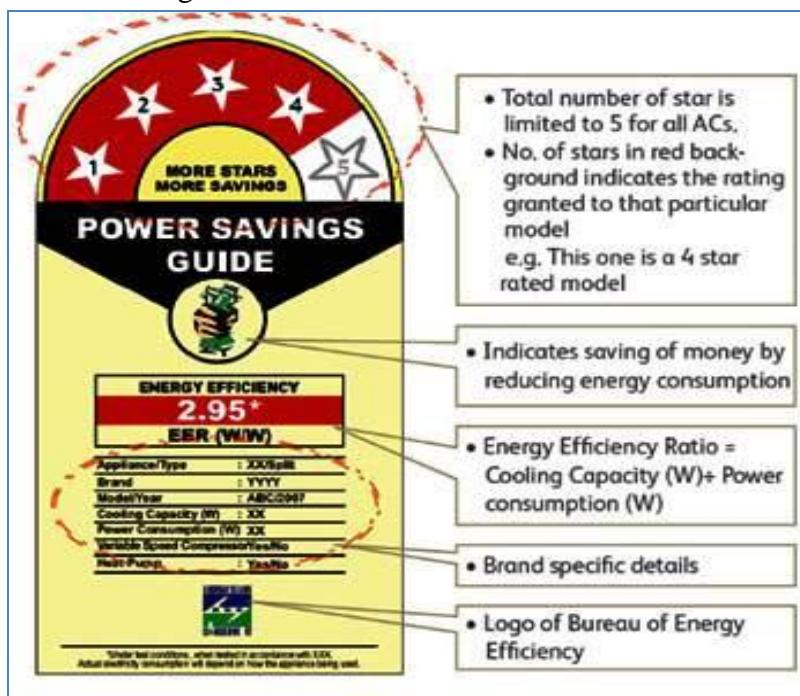


Figure 5 Power Saving guide

- Higher the number of stars, greater will be the efficiency or EER.
- One important thing to be noted here is that EER is given by W/W (which is also the same as COP) whereas we have defined EER by BTU/hr/W. Hence,

$$\text{EER in BTU/hr/W} = 3.413 * \text{EER in W/W}$$

- BEE has revised the star rating of air conditioners from time to time. Hence, a 5 star AC in the previous year may become a 3 star AC the next year after revision of rating takes place. You may recognize the validity of the label from the 'label period' section printed on the label.
- Below you will find the star rating (w.e.f. 1st January 2014).

New BEE Energy Efficiency Ratings (EER) for Room Air Conditioners						
STAR RATING LEVELS - Jan 1, 2014 - Dec 31, 2015						
EER (W/W)						
WINDOW AC				SPLIT AC		
Star Rating	Minimum	Maximum	Star Rating	Minimum	Maximum	
1 Star ★	2.50	2.69	1 Star ★	2.70	2.89	
2 Star ★★	2.70	2.89	2 Star ★★	2.90	3.09	
3 Star ★★★	2.90	3.09	3 Star ★★★	3.10	3.29	
4 Star ★★★★	3.10	3.29	4 Star ★★★★	3.30	3.49	
5 Star ★★★★★	3.30	-	5 Star ★★★★★	3.50	-	

Figure 6 Star Rating

Star Rating LEVELS

• Star rating (29.06.2015 to 31.12.2017)	• Star rating (01.01.2018 to 31.12.2019)
Star Rating	Star Rating
Minimum EER	Minimum EER
1-Star	1-Star
3.10	3.10
2-Star	2-Star
3.30	3.30
3-Star	3-Star
3.50	3.50
4-Star	4-Star
4.00	4.00
5-Star	5-Star
4.50	4.50

Figure 7 EER

* **ISEER** stands for **Indian Seasonal Energy Efficiency Ratio**.

(**ISEER** is the Ratio of the total annual amount of heat that the equipment can remove from the indoor air when operated for cooling in active mode to the total annual amount of energy consumed by the equipment during the same period.)

- As you can see that each star rating is a range of EER. So it is possible that as AC with EER of 3.29 is rated as BEE 3 star and another of 3.3 is rated as BEE 4 star. It is also possible that AC with EER 3.1 is BEE 3 star and another of 3.49 is BEE 4 star. Thus it is very important that while looking at BEE star rating, **you also look at the EER of the AC**.
- If we take the numbers above, we can see that with increase of every star rating there is a possibility of saving up to 14%. So a BEE 5 star rated AC can be up to 35% or more efficient than a BEE 1 star AC and 15-20% more efficient than BEE 3 star AC.
- The ratings above are based on savings in machinery. In comparison an Inverter tech AC being flexible tonnage AC can save more over BEE 5 star AC. The reason being it not just saves on using efficient machinery but also on flexible tonnage.
- So the savings can be at least 15-20% more over BEE 5 star rated AC because of savings in changing heat load between seasons and days and nights, and additional saving can be achieved because when you buy a fixed speed AC you oversize even for the peak summer day.
- And that is why some manufacturers claim up to 60% savings on inverter tech AC (although achieving 60% will depend on how you size the AC).

More Stars, More Savings

- It is true that everything comes with a cost. A 5 star air conditioner will definitely be costlier than a 1 star air conditioner of the same company. And Inverter technology AC costs further more. However, it is also true that the same 5 star air conditioner is much more efficient than a 1 star air conditioner.
- Hence, a 5 star air conditioner will provide the same amount of cooling using lesser power than a 1 star air conditioner of same tonnage. This leads to savings in operating cost. You may recover the incremental capital cost used to purchase a higher star rated air conditioner in a matter of few years.
- We recommend for a BEE 5 star rated AC or further Inverter Tech AC if usage of AC is more than 1000 hours in a year and per unit cost of electricity is more than Rs 5 per unit (if the per unit cost is higher, it is recommended for lower the yearly usage also).

'Watt' is the tip!!

1. Kindly ensure that you select the right tonnage of air conditioners. Over sizing or under sizing may either burn your pockets or may not provide you the right comfort level.
2. Ensure that the new air conditioners have the revised star rating labels. (Refer 'label period' section on the label).
3. Kindly note that the EER rating on the label is given in W/W. Whereas sometimes on the internet you will find EER rating given in BTU/hr/W. (we have given the relation between the two above.)
4. Although 'more stars, more cost' is true, 'more stars, more savings' is also true. After all, when it comes to efficiency, 'operating cost matters more than capital cost'.

4.2 Energy Monitoring and Targeting

Definition

- Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures.
- It builds on the principle "**you can't manage what you don't measure**". It essentially combines the principles of energy use and statistics.
- While, monitoring is essentially aimed at establishing the existing pattern of energy consumption, targeting is the identification of energy consumption level which is desirable as a management goal to work towards energy conservation.
- Monitoring and Targeting is a management technique in which all plant and building utilities such as fuel, steam, refrigeration, compressed air, water, effluent, and electricity are managed as controllable resources in the same way that raw materials, finished product inventory, building occupancy, personnel and capital are managed.
- It involves a systematic, disciplined division of the facility into Energy Cost Centers. The utilities used in each centre are closely monitored, and the energy used is compared with production volume or any other suitable measure of operation.
- Once this information is available on a regular basis, targets can be set, variances can be spotted and interpreted, and remedial actions can be taken and implemented.
- The Monitoring and Targeting programs have been so effective that they show typical reductions in annual energy costs in various industrial sectors between 5 and 20%.

Elements of Monitoring & Targeting System

The essential elements of M&T system are:

- **Recording** -Measuring and recording energy consumption
- **Analyzing** -Correlating energy consumption to a measured output, such as production quantity
- **Comparing** -Comparing energy consumption to an appropriate standard or benchmark
- **Setting Targets** -Setting targets to reduce or control energy consumption
- **Monitoring** -Comparing energy consumption to the set target on a regular basis
- **Reporting** -Reporting the results including any variances from the targets which have been set
- **Controlling** -Implementing management measures to correct any variances, which may have occurred.

Particularly M&T system will involve the following:

- **Checking** the accuracy of energy invoices
- **Allocating** energy costs to specific departments (Energy Accounting Centres)
- **Determining** energy performance/efficiency
- **Recording** energy use, so that projects intended to improve energy efficiency can be checked
- **Highlighting** performance problems in equipment or systems

A Rationale for Monitoring, Targeting and Reporting

- The energy used by any business varies with production processes, volumes and input. Determining the relationship of energy use to key performance indicators will allow you to determine:
 - Whether your current energy is better or worse than before
 - Trends in energy consumption that reflects seasonal, weekly, and other operational parameters
 - How much your future energy use is likely to vary if you change aspects of your business
 - Specific areas of wasted energy
 - Comparison with other business with similar characteristics - This "benchmarking" process will provide valuable indications of effectiveness of your operations as well as energy use
 - How much your business has reacted to changes in the past
 - How to develop performance targets for an energy management program

Information related to energy use may be obtained from following sources:

- Plant level information can be derived from financial accounting systems-utilities cost centre
- Plant department level information can be found in comparative energy consumption data for a group of similar facilities, service entrance meter readings etc.
- System level (for example, boiler plant) performance data can be determined from sub-metering data
- Equipment level information can be obtained from nameplate data, run-time and schedule information, sub-metered data on specific energy consuming equipment.

The important point to be made here is that all of these data are useful and can be processed to yield information about facility performance.

Data and Information Analysis

- Electricity bills and other fuel bills should be collected periodically and analysed as below.
- A typical format for monitoring plant level information is given below in the Table.

TABLE 1 ANNUAL ENERGY COST SHEET									
	Thermal Energy Bill				Electricity Bill				Total Energy Bill
Month	Fuel 1	Fuel 2	Fuel 3	Total Rs. Lakh	Day kWh	Night kWh	Maximum Demand	Total Rs. Lakh	Rs.Lakh
1									
2									
3									
4									
Sub-Total									
%									

Figure 8 Annual Energy cost Sheet

After obtaining the respective annual energy cost, a pie chart can be drawn as shown below:

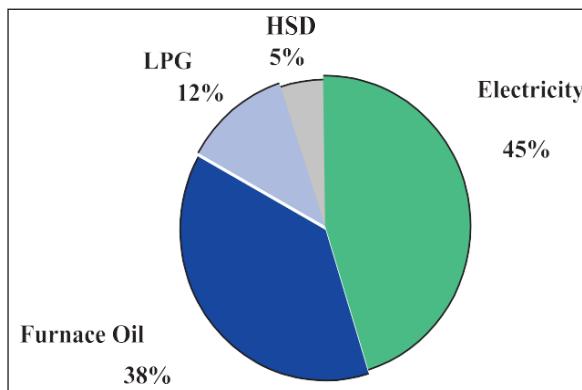


Figure.9 . % Share of Fuels Based on Energy Bill

Pie Chart on Energy Consumption

- All the fuels purchased by the plant should be converted into common units such as kCal. The following Table below is for that purpose.

TABLE .2 FUEL CONVERSION DATA		
Energy source	Supply unit	Conversion Factor to Kcal
Electricity	kWh	860

HSD	kg	10,500
Furnace Oil	kg	10,200
LPG	kg	12,000

Table 2 Fuel Conversion Data

After conversion to a common unit, a pie chart can be drawn showing the percentage distribution of energy consumption as shown in Figure 10.

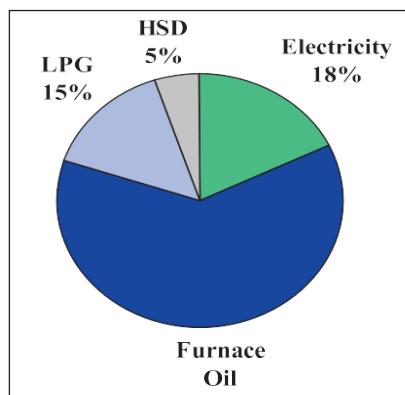


Figure 10 %Share of Fuels Based on Consumption in kCals

Relating Energy Consumption and Production.

Graphing the Data

- A critical feature of M&T is to understand what drives energy consumption. Is it production, hours of operation or weather? Knowing this, we can then start to analyse the data to see how good our energy management is.
- After collection of energy consumption, energy cost and production data, the next stage of the monitoring process is to study and analyse the data to understand what is happening in the plant.
- It is strongly recommended that the data be presented graphically. A better appreciation of variations is almost always obtained from a visual presentation, rather than from a table of numbers.
- Graphs generally provide an effective means of developing the energy-production relationships, which explain what is going on in the plant.

Use of Bar Chart

- The energy data is then entered into a spreadsheet. It is hard to envisage what is happening from plain data, so we need to present the data using bar chart. The starting point is to collect and collate 24/12 months of energy bills.

Bar Chart showing the energy per month for this year and last year

- The most common bar chart application used in energy management is one showing the energy per month for this year and last year (see Figure) - however, it does not tell us the full story about what is happening. We will also need production data for the same 24/12-month period.
- Having more than twelve months of production and energy data, we can plot a moving

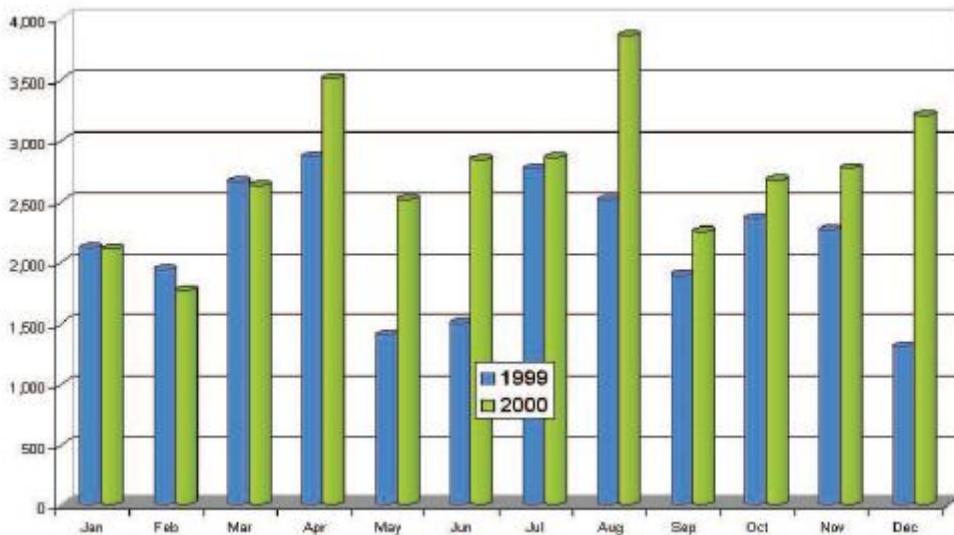


Figure .11 Energy Consumption :Current Year(2000) Vs. Previous year(1999)

annual total. For this chart, each point represents the sum of the previous twelve months of data.

- In this way, each point covers a full range of the seasons, holidays, etc. The Figure 8.4 shows a moving annual total for energy and production data.

Annual total for energy and production

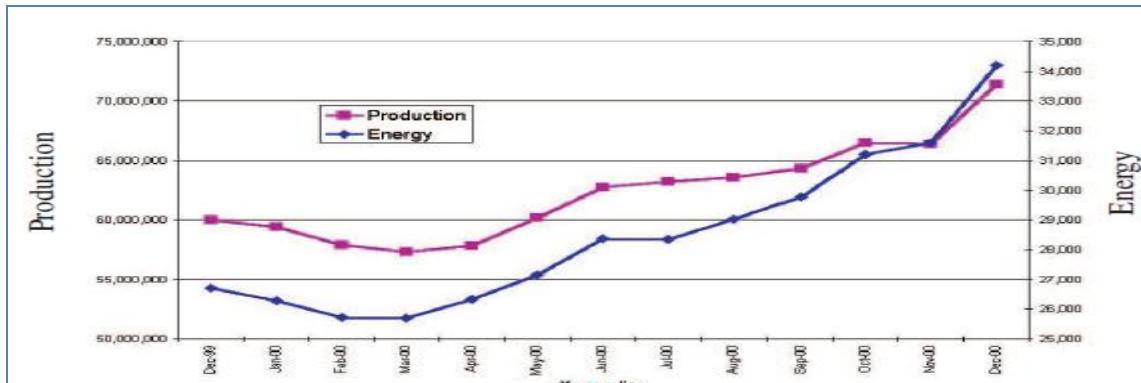
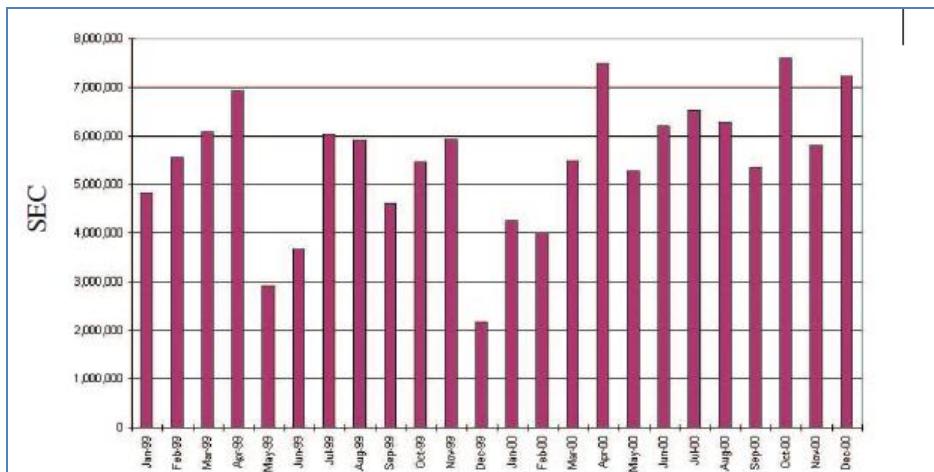
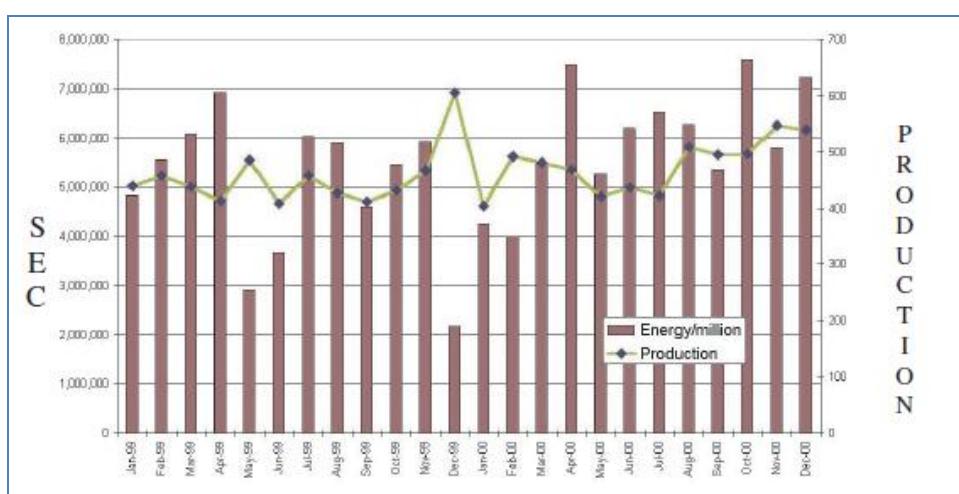


Figure .12 Moving Annual Total - Energy and Production

- This technique also smoothens out errors in the timing of meter readings. If we just plot energy we are only seeing part of the story - so we plot both energy and production on the same chart - most likely using two y-axes.
- Looking at these charts, both energy and productions seem to be "tracking" each other - this suggests there is no major cause for concern. But we will need to watch for a deviation of the energy line to pick up early warning of waste or to confirm whether energy efficiency measures are making an impact.

**Figure .13 : Monthly Specific Energy Consumption****Specific Energy Consumption (SEC) with production**

- For any company, we also know that energy should directly relate to production. Knowing this, we can calculate Specific Energy Consumption (SEC), which is energy consumption per unit of production. So we now plot a chart of SEC (see Figure .5).
- At this point it is worth noting that the quality of your M&T system will only be as good as the quality of your data - both energy and production. The chart shows some variation - an all time low in December 99 followed by a rising trend in SEC.
- We also know that the level of production may have an effect on the specific consumption. If we add the production data to the SEC chart, it helps to explain some of the features.
- For example, the very low SEC occurred when there was a record level of production. This indicates that there might be fixed energy consumption - i.e. consumption that occurs regardless of production levels. Refer Figure .6.

**Figure 14 SEC With Production****Relationship of energy and production**

- The next step is to gain more understanding of the relationship of energy and production, and to provide us with some basis for performance measurement.

- To do this we plot energy against production - In Microsoft Excel Worksheet, this is an XY chart option.
- We then add a trend line to the data set on the chart. (In practice what we have done is carried out a single variable regression analysis!). The Figure 7 shown is based on the data for 1999.

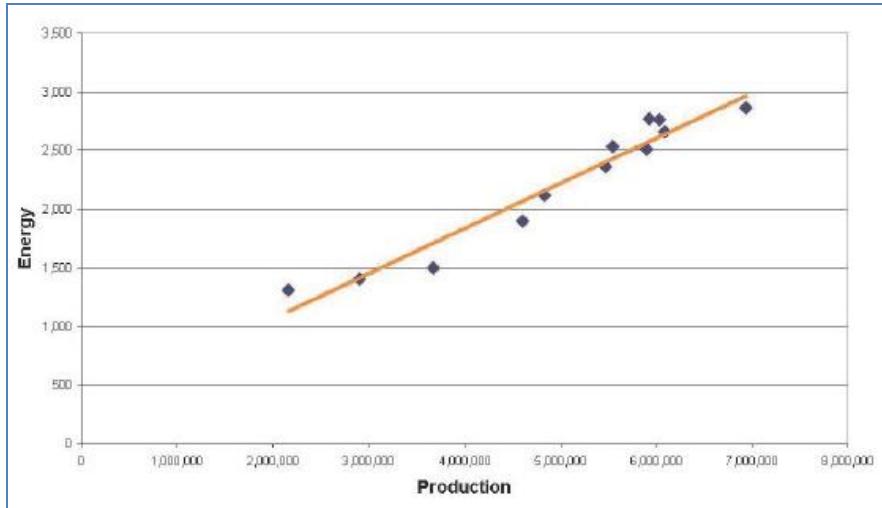


Figure 15 : Energy vs Production

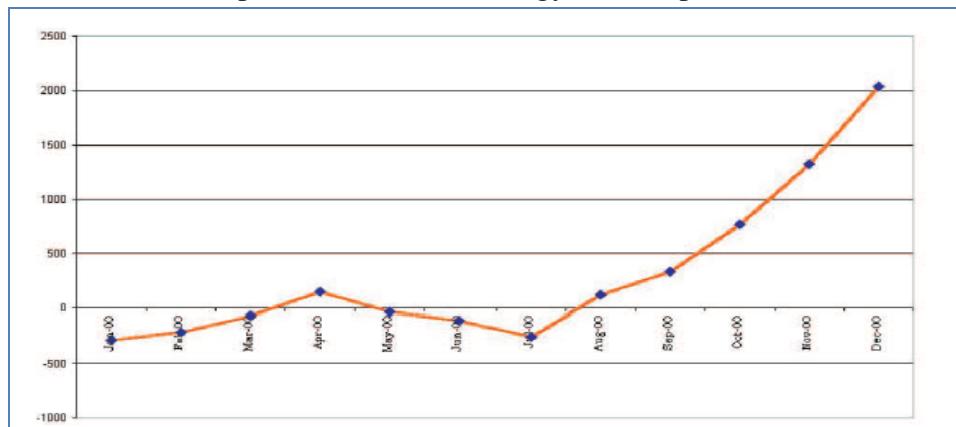
- We can use it to derive a "standard" for the up-coming year's consumption. This chart shows a low degree of scatter indicative of a good fit. We need not worry if our data fit is not good.
- If data fit is poor, but we know there should be a relationship, it indicates a poor level of control and hence a potential for energy savings.
- In producing the production/energy relationship chart we have also obtained a relationship relating production and energy consumption.

Energy consumed for the period = C + M x Production for same period

- Where M is the energy consumption directly related to production (variable) and C is the "fixed" energy consumption (i.e. energy consumed for lighting, heating/cooling and general ancillary services that are not affected by production levels).
- Using this, we can calculate the expected or "standard" energy consumption for any level of production within the range of the data set.
- We now have the basis for implementing a factory level M&T system. We can predict standard consumption, and also set targets –
- For example, standard less 5%. A more sophisticated approach might be applying different reductions to the fixed and variable energy consumption. Although, the above approach is at factory level, the same can be extended to individual processes as well with sub metering.
- At a simplistic level we could use the chart above and plot each new month's point to see where it lies. Above the line is the regime of poor energy efficiency, and below the line is the regime of an improved one.

CUSUM: Cumulative Sum

- Cumulative Sum (CUSUM) represents the **difference between the base line (expected or standard consumption) and the actual consumption points over the base line period of time.**
- This useful technique not only provides a trend line, it also calculates savings/losses to date and shows when the performance changes.
- A typical CUSUM graph follows a trend and shows the random fluctuation of energy consumption and should oscillate around zero (standard or expected consumption).
- This trend will continue until something happens to alter the pattern of consumption such as the effect of an energy saving measure or, conversely, a worsening in energy efficiency (poor control, house- keeping or maintenance).
- CUSUM chart (see Figure .8) for a generic company is shown. The CUSUM chart shows what is really happening to the energy performance. The formula derived from the 1999 data was used to calculate the expected or standard energy consumption.



- From the chart, it can be seen that starting from year 2000, performance is better than standard. Performance then declined (line going up) until April, and then it started to improve until July. However, from July onwards, there is a marked, ongoing decline in performance - line going up.
- When looking at CUSUM chart, the changes in direction of the line indicate events that have relevance to the energy consumption pattern. Clearly, site knowledge is needed to interpret better what they are. For this sample company since we know that there were no planned changes in the energy system, the change in performance can be attributed to poor control, housekeeping or maintenance.

Case Study

The CUSUM Technique

- Energy consumption and production data were collected for a plant over a period of 18 months. During month 9, a heat recovery system was installed.
- Using the plant monthly data, estimate the savings made with the heat recovery system. The plant data is given in Table

TABLE-3 MONTH WISE PRODUCTION WITH ENERGY CONSUMPTION

Month	E_{act} - Monthly Energy Use (toe * / month)	P - Monthly Production (tonnes / month)
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	380	500

* toe = tonnes of oil equivalent.

Table 2 Energy Consumption

Steps for CUSUM analysis

1. Plot the Energy - Production graph for the first 9 months
2. Draw the best fit straight line
3. Derive the equation of the line
The above steps are completed in Figure, the equation derived is $E = 0.4 P + 180$
4. Calculate the expected energy consumption based on the equation
5. Calculate the difference between actual and calculated energy use
6. Compute CUSUM

TABLE .4 CUSUM

Month	E _{act}	P	E _{calc} (0.4 P + 180)	E _{act} – E _{calc}	CUSUM (Cumulative Sum)
1	340	380	332	+8	+8
2	340	440	356	-16	-8
3	380	460	364	+16	+8
4	380	520	388	-8	0
5	300	320	308	-8	-8
6	400	520	388	+2	-6
7	280	240	276	+4	-2
8	424	620	428	-4	-6
9	420	600	420	0	-6
10	400	560	404	4	-10
11	360	440	356	+4	-6
12	320	360	324	-4	-10
13	340	420	348	-8	-18
14	372	480	372	0	-18
15	380	540	396	-16	-34
16	280	280	292	-12	-46
17	280	260	284	-4	-50
18	380	500	380	0	-50

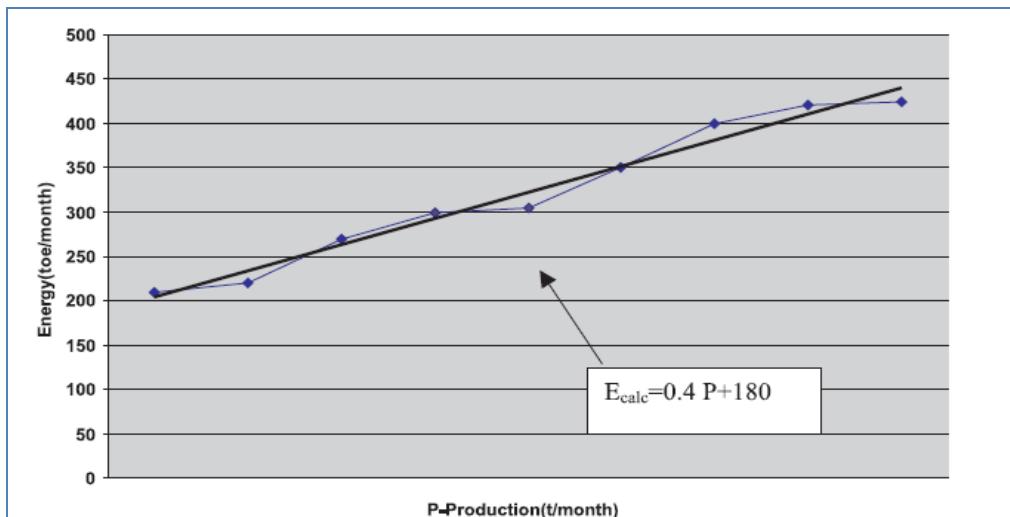
E_{act}- Actual Energy consumption E_{calc} - Calculated energy consumption These steps are shown in the Table .4.

7. Plot the CUSUM graph

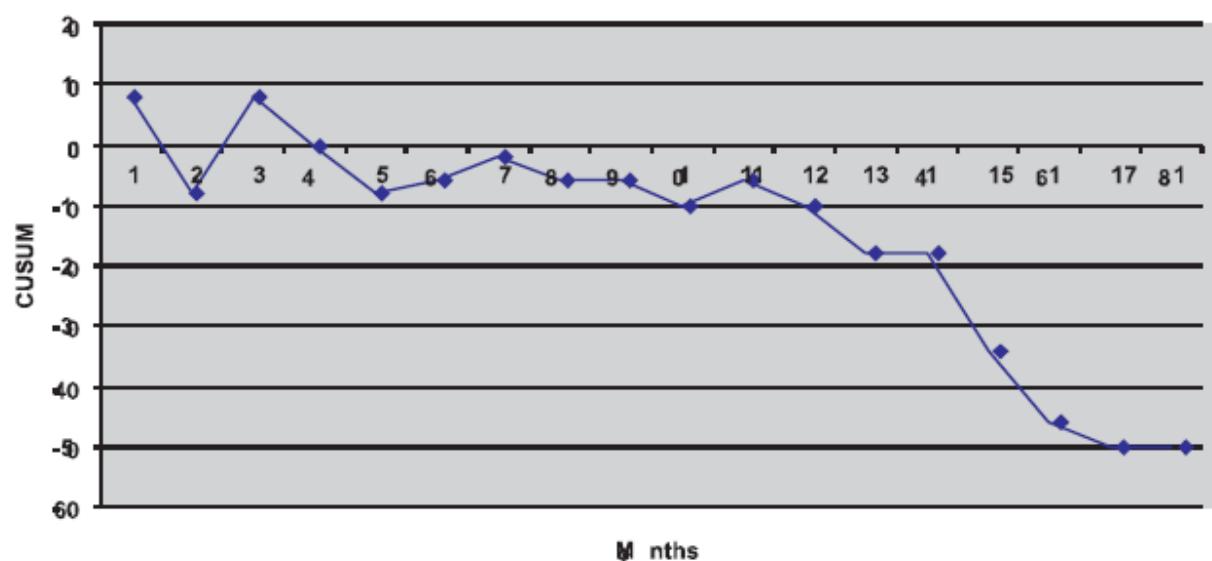
8. Estimate the savings accumulated from use of the heat recovery system.

From the Figure, it can be seen that the CUSUM graph oscillates around the zero line for several months and then drops sharply after month 11. This suggests that the heat recovery system took almost two months to commission and reach proper operating conditions, after which steady savings have been achieved. Based on the graph 8.10 (see Table 8.4), savings of 44 toe (50-6) have been accumulated in the last 7 months. This represents savings of almost 2% of energy consumption.

$$\frac{44}{2352^{\#}} \cdot 100 = 1.8\%$$



CUSUM chart for last 18 months is shown in Figure 10.

**Figure 10 Example CUSUM Graph**

- The CUSUM technique is a simple but remarkably powerful statistical method, which highlights small differences in energy efficiency performances.
- Regular use of the procedure allows the Energy Manager to follow plant performance and spot any trends early.

REFERENCES

1. Energy conservation – The Indian experience, Department of Power & NPC Publication
2. Energy Audit Reports of National Productivity Council
3. Cleaner Production – Energy Efficiency Manual prepared for GERIAP, UNEP, BANGKOK by National Productivity Council

4.3 ENERGY MANAGEMENT AND AUDIT

Definition

- An **energy audit** is an inspection, survey and analysis of energy flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s).
- Energy audit is the first step toward systematic efforts for conservation of energy. It involves collection and analysis of energy related data on regular basis and in a methodological manner.

Objectives of Energy Audit

The Energy Audit provides the vital information base for overall energy conservation program covering essentially energy utilization analysis and evaluation of energy conservation measures.

It aims at:-

- Identifying the quality and cost of various energy inputs.
- Assessing present pattern of energy consumption in different cost centers of operations.
- Relating energy inputs and production output.
- Identifying potential areas of thermal and electrical energy economy.
- Highlighting wastage's in major areas.
- Fixing of energy saving potential targets for individual cost centers.
- Implementation of measures for energy conservation & realization of savings.

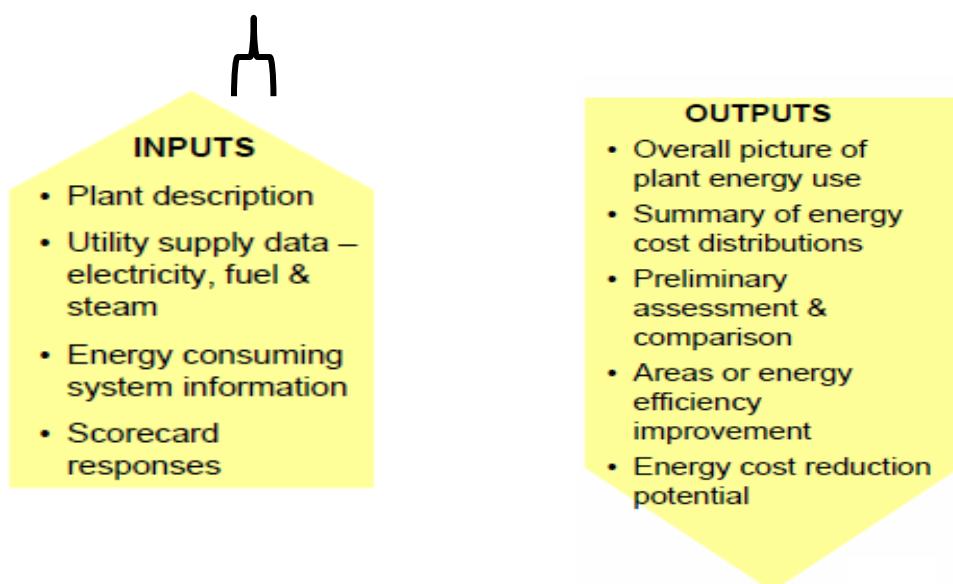
Need for Energy Audit

- In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials.
- If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction.
- Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists.
- The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities.
- Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.
- In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.
- The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs.

- Energy Audit provides a "bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.



Inputs and Outputs of Energy Audit



Type of Energy Audit

The type of Energy Audit to be performed depends on:

- Function and type of industry
- Depth to which final audit is needed, and
- Potential and magnitude of cost reduction desired

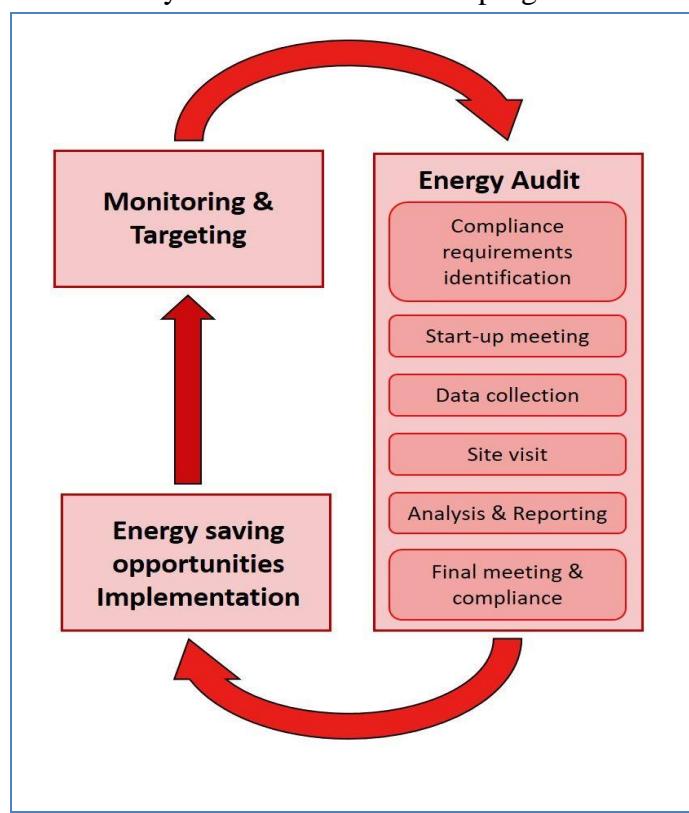
Thus Energy Audit can be classified into the following two types.

- i) Preliminary Audit
- ii) Detailed Audit

Walk-through or Preliminary Energy Audit (PEA)

- The preliminary audit (alternatively called a simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit.

- It involves minimal interviews with site-operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.
- Typically, only major problem areas will be covered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided.
- A list of energy conservation measures (ECMs, or energy conservation opportunities, ECOs) requiring further consideration is also provided. This level of detail, while not sufficient for reaching a final decision on implementing proposed measure, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit.
- Considerable savings are possible through small improvements in the “house keeping” practices, and the cumulative effect of many such small efficiency improvements could be quite significant.
- These can be identified by a short survey, observation and measurements. Many energy conscious industries have already achieved considerable progress in this area.



Approach to Preliminary Energy Audit (PEA)

- This essentially involves preliminary data collection and analyses. The PEA is based on collection of available data, analysis, observation and inference based on experience and judgment is carried out within a short time.
- The PEA is the first step in implementing an energy conservation programme, and consists of essentially collecting and analyzing data without the use of sophisticated instruments. The ability and experience on the part of Energy Auditor will influence the degree of its success.

- The PEA is essentially, as the name implies a preliminary data collection and its analysis process. Readily available data on the plant's energy systems and energy –using processes or equipment are obtained and studied.
- The operation and condition of equipment are observed by going around the plant. These provides basis to develop recommendations for immediate short term measures and to provide quick and rough estimates of savings that are possible and achievable.
- A preliminary study usually identifies and assesses obvious areas for energy savings such as stream leaks, compressed air leaks, poor or missing insulation, condensate recovery, idling equipment, deterioration and deficiencies in combustion and heat transfer equipment etc. and serves to identify specific areas for the detailed plant energy study.

Preliminary Energy Audit Methodology

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely (and the easiest areas for attention
- Identify immediate (especially no-/low-cost) improvements/ savings
- Set a 'reference point'
- Identify areas for more detailed study/measurement
- Preliminary energy audit uses existing, or easily obtained data

Detailed Energy Audit (DEA)

- This would be a comprehensive energy study using portable energy monitoring instruments. The essential part of this audit is carrying out various measurements and analyses covering individually every significant energy consuming plant item/processes, to determine their efficiencies and loss of energy at that point, and potential energy savings.
- The Detailed plant energy study is a comprehensive analyses and evaluation of all aspects of energy generation, distribution and utilization within plant.
- The analyses is based on consistent and detailed accounting of all energy inputs into a system and all energy outputs from a system which results in the development of energy and mass balance.
- At the plant level, the analyses require time series data on a daily, monthly, or yearly basis, on the quantities of all forms of primary energy flowing into the plant, e.g. coal, fuel, oil, electricity, etc. And production figures of major products, by-products and waste products, at the department or sectional level.
- Information is required on the quantity of energy forms consumed, and the production figures of intermediate products. At the equipment level, in addition to the quantities of energy forms and material products, process parameters such as temperature, pressure, flow rate, etc. are also required.
- Data generation and collection is an essential and critical element of a detailed energy audit study. Difficulties in getting data required generally arise due to unavailability of historical records. The acquisition of actual operating data through existing or new permanently installed instruments or portable test instruments cannot be overemphasized in this context.

- Measurements are critical in any serious effort to conserve energy. Apart from helping to quantify energy consumption, measurements also provide a means to monitor equipment performance and check equipment condition. Examples of measurements and instrument types are:
 - Flow/Velocity: Orifice plate, Pitot tube, Venturi tube, Turbine meter, Vortex shedding flow meter
 - Temperature: Thermometers - Bimetallic, Resistance etc., Thermocouple, Radiation pyrometer.
 - Pressure: Bourdon gauge Diaphragm gauge, Manometers
 - Stack Gas Analysis: Orsat apparatus, Oxygen analyzers, Carbon dioxide analyzers, Carbon monoxide analyzers.
 - Heat flow: Thermography equipment
 - Electrical: Multimeter, Ammeter, Wattmeter, Power Factor meter, Light meter

Detailed energy auditing is carried out in three phases: Phase I, II and III.

- Phase I - Pre Audit Phase
- Phase II - Audit Phase
- Phase III - Post Audit Phase

Phase I -Pre Audit Phase Activities

- A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

Initial Site Visit and Preparation Required for Detailed Auditing

- An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.
- During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -
 - Discuss with the site's senior management the aims of the energy audit.
 - Discuss economic guidelines associated with the recommendations of the audit.
 - Analyse the major energy consumption data with the relevant personnel.
 - Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.
 - Tour the site accompanied by engineering/production

The main aims of this visit are: -

- To finalise Energy Audit team
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/ additional metering required.
- To decide whether any meters will have to be installed prior to the audit eg. kWh, steam,oil or gas meters.
- To identify the instrumentation required for carrying out the audit.
- To plan with time frame
- To collect macro data on plant energy resources, major energy consuming centers
- To create awareness through meetings/ programme

Phase II- Detailed Energy Audit Activities

- Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete.
- Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out.
- Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.
- The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process.

Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed.

- The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

The information to be collected during the detailed audit includes: -

1. Energy consumption by type of energy, by department, by major items of process equipment, by end-use
 2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
 3. Energy cost and tariff data
 4. Process and material flow diagrams
 5. Generation and distribution of site services (eg.compressed air, steam).
 6. Sources of energy supply (e.g. electricity from the grid or self-generation)
 7. Potential for fuel substitution, process modifications, and the use of co-generation Systems (combined heat and power generation).
 8. Energy Management procedures and energy awareness training programs within the establishment.
- Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs.

The audit team should collect the following baseline data:

- Technology, processes used and equipment details
- Capacity utilization
- Amount & type of input materials used
- Water consumption
- Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated

- Percentage rejection / reprocessing
- Efficiencies / yield

Ten steps methodology for detailed energy audit

Step No.	Plan of Action	Purpose/ Result
Step:1	Phase I: Pre Audit Phase Plan and organise Walk through Audit Informal Interview with Energy Manager, Production / Plant Manager	Resource planning, Establish/organize a Energy audit team Organize Instruments & time frame Macro Data collection (suitable to type of industry.) Familiarisation of process/plant activities First hand observation & Assessment of current level operation and practices
Step:2	Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	Building up cooperation Issue questionnaire for each department Orientation, awareness creation
Step:3	Phase II –Audit Phase Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	Historic data analysis, Baseline data collection Prepare process flow charts All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. Design, operating data and schedule of operation Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step:4	Conduct survey and monitoring	Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.

Step:5	Conduct of detailed trials / experiments for selected energy guzzlers	Trials/Experiments: 24 hours power monitoring (MD, PF, kWh etc.). Load variations trends in pumps, fan compressors etc. Boiler/Efficiency trials for (4 – 8 hours) Furnace Efficiency trials Equipments Performance experiments etc
Step:6	Analysis of energy use	Energy and Material balance & energy loss/waste analysis
Step:7	Identification and development of Energy Conservation (ENCON) opportunities Use brainstorming and value analysis techniques	Identification & Consolidation ENCON measures Conceive, develop, and refine ideas Review the previous ideas suggested by unit personal Review the previous ideas suggested by energy audit if any Use brainstorming and value analysis techniques Contact vendors for new/efficient technology
Step:8	Cost benefit analysis	Assess technical feasibility, economic viability and prioritization of ENCON options for implementation Select the most promising projects Prioritise by low, medium, long term measures
Step:9	Reporting & Presentation to the Top Management	Documentation, Report Presentation to the top Management.
Step:10	Phase III –Post Audit phase Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance Action plan, Schedule for implementation Follow-up and periodic review

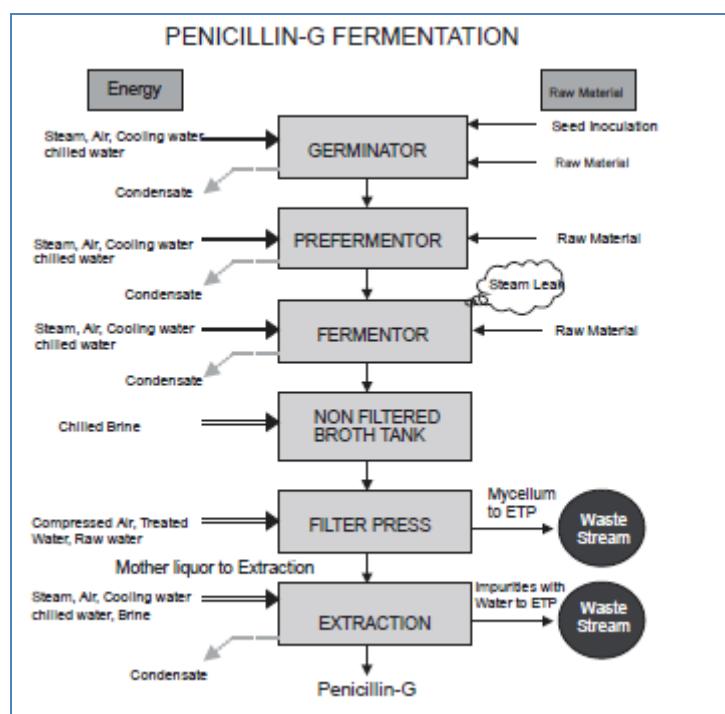
Detailed Process Flow Steps In Energy Management

Draw process flow diagram and list process steps; identify waste streams and obvious energy wastage

- An overview of unit operations, important process steps, areas of material and energy use and sources of waste generation should be gathered and should be represented in a flowchart as shown in the figure below.
- Existing drawings, records and shop floor walk through will help in making this flow chart. Simultaneously the team should identify the various inputs & output streams at each process step.

Example: A flowchart of Penicillin-G manufacturing is given in the figure3.1 below.

- Note that waste stream (Mycelium) and obvious energy wastes such as condensate drained and steam leakages have been identified in this flow chart
- The audit focus area depends on several issues like consumption of input resources, energy efficiency potential, impact of process step on entire process or intensity of waste generation / energy consumption. In the above process, the unit operations such as germinator, prefermentor, fermenter, and extraction are the major conservation potential areas identified.



Identification of Energy Conservation Opportunities

Fuel substitution: Identifying the appropriate fuel for efficient energy conversion

Energy generation :Identifying Efficiency opportunities in energy conversion equipment/utility such as captive power generation, steam generation in boilers, thermic fluid heating, optimal loading of DG sets, minimum excess air combustion with boilers/thermic fluid heating, optimising existing efficiencies, efficient energy conversion equipment, biomass gasifiers, Cogeneration, high efficiency DG sets, etc.

Energy distribution: Identifying Efficiency opportunities network such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, Etc.

Energy usage by processes: This is where the major opportunity for improvement and many of them are hidden. Process analysis is useful tool for process integration measures.

Technical and Economic feasibility

The technical feasibility should address the following issues

- Technology availability, space, skilled manpower, reliability, service etc
- The impact of energy efficiency measure on safety, quality, production or process.
- The maintenance requirements and spares availability

The Economic viability often becomes the key parameter for the management acceptance. The economic analysis can be conducted by using a variety of methods. Example: Pay back method, Internal Rate of Return method, Net Present Value method etc. For low investment short duration measures, which have attractive economic viability, simplest of the methods, payback is usually sufficient. A sample worksheet for assessing economic feasibility is provided below:

Sample worksheet for economic feasibility

Name of energy efficiency measure

Investment	Annual operating costs	Annual savings
Equipments	Cost of capital	Thermal Energy
Civil works	Maintenance	Electrical Energy
Instrumentation	Manpower	Raw material
Auxiliaries	Energy	Waste disposal
	Depreciation	

Classification of Energy Conservation Measures

Based on energy audit and analyses of the plant, a number of potential energy saving projects may be identified. These may be classified into three categories:

1. Low cost - high return;
 2. Medium cost - medium return;
 3. High cost - high return
- Normally the low cost - high return projects receive priority. Other projects have to be analyzed, engineered and budgeted for implementation in a phased manner.
 - Projects relating to energy cascading and process changes almost always involve high costs coupled with high returns, and may require careful scrutiny before funds can be committed.
 - These projects are generally complex and may require long lead times before they can be implemented. Refer Table for project priority guidelines.

Priority	Economical Feasibility	Technical Feasibility	Risk / Feasibility
A - Good	Well defined and attractive	Existing technology adequate	No Risk/ Highly feasible
B - May be	Well defined and only marginally acceptable	Existing technology may be updated, lack of confirmation	Minor operating risk/May be feasible
C - Held	Poorly defined and marginally unacceptable	Existing technology is inadequate	Doubtful
D - No	Clearly not attractive	Need major breakthrough	Not feasible

Energy Audit Reporting Format

- After successfully carried out energy audit energy manager/energy auditor should report to the top management for effective communication and implementation.
- A typical energy audit reporting contents and format are given below. The following format is applicable for most of the industries.
- However the format can be suitably modified for specific requirement applicable for a particular type of industry.

<p style="text-align: center;">Report on DETAILED ENERGY AUDIT TABLE OF CONTENTS Table of Contents</p>	
i. Acknowledgement ii. Executive Summary Energy Audit Options at a glance & Recommendations	
1.0 Introduction about the plant <ul style="list-style-type: none"> 1.1 General Plant details and descriptions 1.2 Energy Audit Team 1.3 Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others) 1.4 Major Energy use and Areas 	
2.0 Production Process Description <ul style="list-style-type: none"> 2.1 Brief description of manufacturing process 2.2 Process flow diagram and Major Unit operations 2.3 Major Raw material Inputs, Quantity and Costs 	
3.0 Energy and Utility System Description <ul style="list-style-type: none"> 3.1 List of Utilities 3.2 Brief Description of each utility <ul style="list-style-type: none"> 3.2.1 Electricity 3.2.2 Steam 3.2.3 Water 3.2.4 Compressed air 3.2.5 Chilled water 3.2.6 Cooling water 	

The following Worksheets (refer Table 3.2 & Table 3.3) can be used as guidance for energy audit assessment and reporting.

TABLE 5 . SUMMARY OF ENERGY SAVING RECOMMENDATIONS					
S.No.	Energy Saving Recommendations	Annual Energy Savings (Fuel & Electricity) (kWh/MT or kl/MT)	Annual Savings Rs.Lakhs	Capital Investment (Rs.Lakhs)	Simple Payback period
1					
2					
3					
4					
Total					

TABLE 6 TYPES AND PRIORITY OF ENERGY SAVING MEASURES

	Type of Energy Saving Options	Annual Electricity /Fuel savings	Annual Savings	Priority
		KWh/MT or kl/MT	(Rs Lakhs)	
A	No Investment (Immediate) <ul style="list-style-type: none"> - Operational Improvement - Housekeeping 			
B	Low Investment (Short to Medium Term) <ul style="list-style-type: none"> - Controls - Equipment Modification - Process change 			
C	High Investment (Long Term) <ul style="list-style-type: none"> - Energy efficient Devices - Product modification - Technology Change 			

Reporting Format for Energy Conservation Recommendations

A: Title of Recommendation	:	
B: Description of Existing System and its operation	:	
C: Description of Proposed system and its operation	:	

D: Energy Saving Calculations		
Capacity of main cooling tower	=	5000 m ³ / hr
Temp across cooling tower (design)	=	8 °C
Present capacity	=	3000 m ³ /hr
Temperature across cooling tower(operating)	=	4 °C
% loading of main cooling tower	=	(3000 x 4)/(5000 x 8) = 30%
Capacity of DG Set cooling tower	=	240 m ³ /hr
Temp across the tower	=	5°C
Heat Load (240x1000 x 1x 5)	=	1200,000 K.Cal/hr
Power drawn by the DG set cooling tower		
No of pumps and its rating	=	2 nos x 7.5 kW
No of fans and its rating	=	2 Nos x 22 kW
Power consumption@ 80% load	=	(22 x2 +7.5 x2) x.80 = 47 kW
Additional power required for main cooling tower for additional water flow of 240m ³ /h (66.67 l/s) with 6 kg/cm ²	=	(66.67 x 6) / (102 x 0.55) = 7 kW
Net Energy savings	=	- 7

Understanding Energy Costs

- Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful.
- The annual company balance sheet is the other sources where fuel cost and power are given with production related information.

Energy invoices can be used for the following purposes:

- They provide a record of energy purchased in a given year, which gives a base-line for future
- Energy invoices may indicate the potential for savings when related to production requirements or to air conditioning requirements/space heating etc.
- When electricity is purchased on the basis of maximum demand tariff
- They can suggest where savings are most likely to be made.
- In later years invoices can be used to quantify the energy and cost savings made through energy conservation measures

Fuel Costs

A wide variety of fuels are available for thermal energy supply. Few are listed below:

- Fuel oil Low Sulphur Heavy Stock (LSHS)
- Light Diesel Oil (LDO)
- Liquefied Petroleum Gas (LPG)
- COAL, LIGNITE, WOOD ETC.

while purchasing. The following factors should be taken into account during procurement of fuels for energy efficiency and economics.

- Price at source, transport charge, type of transport
- Quality of fuel (contaminations, moisture etc)
- Energy content (calorific value)

Power Costs

Electricity price in India not only varies from State to State, but also city to city and consumer to consumer though it does the same work everywhere. Many factors are involved in deciding final cost of purchased electricity such as:

- Maximum demand charges, kVA
(i.e. How fast the electricity is used?)
- Energy Charges, kWh
- TOD Charges, Peak/Non-peak period (i.e. When electricity is utilized ?)
- Power factor Charge, P.F
(i.e., Real power use versus Apparent power use factor)
- Other incentives and penalties applied from time to time
- High tension tariff and low tension tariff rate changes
- Slab rate cost and its variation
- Type of tariff clause and rate for various categories such as commercial, residential, industrial, Government, agricultural, etc.
- Tariff rate for developed and underdeveloped area/States
- Tax holiday for new projects

Example: Purchased energy Bill

A typical summary of energy purchased in an industry based on the invoices

TABLE -7			
Type of energy	Original units	Unit Cost	Monthly Bill Rs.
Electricity	5,00,000 kWh	Rs.4.00/kWh	20,00,000
Fuel oil	200 kL	Rs.10,000/ kL	20,00,000
Coal	1000 tons	Rs.2,000/ton	20,00,000
Total			60,00,000

Figure .2 Annual Energy Bill

Unfortunately the different forms of energy are sold in different units e.g. kWh of electricity, liters of fuel oil, tonne of coal. To allow comparison of energy quantities these must be converted to a common unit of energy such as kWh, Giga joules, kCals etc.

$$\text{Electricity (1 kWh)} = 860 \text{ kCal/kWh (0.0036 GJ)}$$

$$\text{Heavy fuel oil (Gross calorific value, GCV)} = 10000 \text{ kCal/litre (0.0411}$$

$$\text{GJ/litre) Coal (Gross calorific value, GCV)} = 4000 \text{ kCal/kg (28 GJ/ton)}$$

Benchmarking and Energy Performance

- Benchmarking of energy consumption internally (historical / trend analysis) and externally (across similar industries) are two powerful tools for performance assessment and logical evolution of avenues for improvement.
- Historical data well documented helps to bring out energy consumption and cost trends

month-wise / day-wise. Trend analysis of energy consumption, cost, relevant production features, specific energy consumption, help to understand effects of capacity utilization on energy use efficiency and costs on a broader scale.

- Few comparative factors, which need to be looked into while benchmarking externally are:
- Scale of operation
- Vintage of technology
- Raw material specifications and quality
- Product specifications and quality

Benchmarking energy performance permits

- Quantification of fixed and variable energy consumption trends vis-à-vis production levels
- Comparison of the industry energy performance with respect to various production levels (capacity utilization)
- Identification of best practices (based on the external benchmarking data)
- Scope and margin available for energy consumption and cost reduction
- Basis for monitoring and target setting exercises.

The benchmark parameters can be:

- Gross production related
 - e.g. kWh/MT clinker or cement produced (cement plant), e.g. kWh/kg yarn produced (Textile unit)
 - e.g. kWh/MT, kCal/kg, paper produced (Paper plant), e.g. kCal/kWh Power produced (Heat rate of a power plant), e.g. Million kilocalcs/MT Urea or Ammonia (Fertilizer plant)
 - e.g. kWh/MT of liquid metal output (in a foundry)
- Equipment / utility related
 - e.g. kW/ton of refrigeration (on Air conditioning plant)
 - e.g. % thermal efficiency of a boiler plant
 - e.g. % cooling tower effectiveness in a cooling tower
 - e.g. kWh/NM³ of compressed air generated
 - e.g. kWh /litre in a diesel power generation plant.

While such benchmarks are referred to, related crucial process parameters need mentioning for meaningful comparison among peers. For instance, in the above case:

- For a cement plant - type of cement, blaine number (fineness) i.e. Portland and process used (wet/dry) are to be reported alongside kWh/MT figure.
- For a textile unit - average count, type of yarn i.e. polyester/cotton, is to be reported along side kWh/square meter.
- For a paper plant - paper type, raw material (recycling extent), GSM quality is some important factors to be reported along with kWh/MT, kCal/Kg figures.
- For a power plant / cogeneration plant - plant % loading, condenser vacuum, inlet cooling water temperature, would be important factors to be mentioned alongside heat rate (kCal/kWh).
- For a fertilizer plant - capacity utilization(%) and on-stream factor are two inputs worth comparing while mentioning specific energy consumption
- For a foundry unit - melt output, furnace type, composition (mild steel, high carbon steel/cast iron etc.) raw material mix, number of power trips could be some useful oper

ating parameters to be reported while mentioning specific energy consumption data.

- For an Air conditioning (A/c) plant - Chilled water temperature level and refrigeration load (TR) are crucial for comparing kW/TR.
- For a boiler plant - fuel quality, type, steam pressure, temperature, flow, are useful comparators alongside thermal efficiency and more importantly, whether thermal efficiency is on gross calorific value basis or net calorific value basis or whether the computation is by direct method or indirect heat loss method, may mean a lot in benchmarking exercise for meaningful comparison.
- Cooling tower effectiveness - ambient air wet/dry bulb temperature, relative humidity, air and circulating water flows are required to be reported to make meaningful sense.
- Compressed air specific power consumption - is to be compared at similar inlet air temperature and pressure of generation.
- Diesel power plant performance - is to be compared at similar loading %, steady run condition etc.

Plant Energy Performance

- Plant energy performance (PEP) is the measure of whether a plant is now using more or less energy to manufacture its products than it did in the past: a measure of how well the energy management programme is doing.
- It compares the change in energy consumption from one year to the other considering production output. Plant energy performance monitoring compares plant energy use at a reference year with the subsequent years to determine the improvement that has been made.
- However, a plant production output may vary from year to year and the output has a significant bearing on plant energy use.
- For a meaningful comparison, it is necessary to determine the energy that would have been required to produce this year production output, if the plant had operated in the same way as it did during the reference year.
- This calculated value can then be compared with the actual value to determine the improvement or deterioration that has taken place since the reference year.

Production factor

- Production factor is used to determine the energy that would have been required to produce this year's production output if the plant had operated in the same way as it did in the reference year. It is the ratio of production in the current year to that in the reference year.

Reference Year Equivalent Energy Use

- The reference year's energy use that would have been used to produce the current year's production output may be called the "reference year energy use equivalent" or "reference year equivalent" for short.
- The reference year equivalent is obtained by multiplying the reference year energy use by the production factor (obtained above)
- Reference year equivalent = Reference year energy use x Production factor
- The improvement or deterioration from the reference year is called "energy performance" and is a measure of the plant's energy management progress. It is the reduction or increase in the current year's energy use over the reference, and is calculated

by subtracting the current year's energy use from the reference years equivalent.

- The result is divided by the reference year equivalent and multiplied by 100 to obtain a percentage.
- The energy performance is the percentage of energy saved at the current rate of use compared to the reference year rate of use. The greater the improvement, the higher the number will be.

Matching Energy Usage to Requirement

- Mismatch between equipment capacity and user requirement often leads to inefficiencies due to part load operations, wastages etc. Worst case design, is a designer's characteristic, while optimization is the energy manager's mandate and many situations present themselves towards an exercise involving graceful matching of energy equipment capacity to end-use needs. Some examples being:
 - Eliminate throttling of a pump by impeller trimming, resizing pump, installing variable speed drives
 - Eliminate damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for better efficiency.
 - Moderation of chilled water temperature for process chilling needs
 - Recovery of energy lost in control valve pressure drops by back pressure/turbine adoption
 - Adoption of task lighting in place of less effective area lighting

Maximizing System Efficiency

Once the energy usage and sources are matched properly, the next step is to operate the equipment efficiently through best practices in operation and maintenance as well as judicious technology adoption. Some illustrations in this context are:

- Eliminate steam leakages by trap improvements
- Maximise condensate recovery
- Adopt combustion controls for maximizing combustion efficiency
- Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy consuming equipment, wherever significant energy efficiency margins exist.

Optimising the Input Energy Requirements

Consequent upon fine-tuning the energy use practices, attention is accorded to considerations for minimizing energy input requirements. The range of measures could include:

- Shuffling of compressors to match needs.
- Periodic review of insulation thickness
- Identify potential for heat exchanger networking and process integration.
- Optimisation of transformer operation with respect to load.

Fuel and Energy Substitution

Fuel substitution:

- Substituting existing fossil fuel with more efficient and less cost/less polluting fuel such as natural gas, biogas and locally available agro-residues.
- Energy is an important input in the production. There are two ways to reduce energy dependency; energy conservation and substitution.

- Fuel substitution has taken place in all the major sectors of the Indian economy. Kerosene and Liquefied Petroleum Gas (LPG) have substituted soft coke in residential use.

Few examples of fuel substitution

- Natural gas is increasingly the fuel of choice as fuel and feedstock in the fertilizer, petro chemicals, power and sponge iron industries.
- Replacement of coal by coconut shells, rice husk etc.
- Replacement of LDO by LSHS

Few examples of energy substitution

- ✓ Replacement of electric heaters by steam heaters
- ✓ Replacement of steam based hotwater by solar systems

Case Study : Example on Fuel Substitution

A textile process industry replaced old fuel oil fired thermic fluid heater with agro fuel fired heater. The economics of the project are given below:

A: Title of Recommendation : Use of Agro Fuel (coconut chips) in place of Furnace oil in a Boiler

B: Description of Existing System and its operation

: A thermic fluid heater with furnace oil currently.

In the same plant a coconut chip fired boiler is operating continuously with good performance.

C: Description of Proposed system and its operation

: It was suggested to replace the oil fired thermic fluid heater with coconut chip fired boiler as the company has the facilities for handling coconut chip fired system.

D: Energy Saving

Calculations Old System

Type of fuel Firing

: Furnace Oil fired heater

GCV

: 10,200 kCal/kg

Avg. Thermal Efficiency

: 82%

Heat Duty

: 15 lakh kCal / hour

Operating Hours

: 25 days x 12 month x 24 hours = 7,200 hrs.

Annual Fuel Cost

: Rs.130 lakh (7200 x 1800 Rs./hr.)

Modified System

Type of fuel saving

= Coconut chips fired Heater

GCV

= 4200 kCal/kg

Average Thermal Efficiency

= 72 %

Heat Duty

= 15 lakh kCal / hour

Annual Operating Cost

= 7200 x 700 Rs./hr = 50 lakh

Annual Savings

= 130 - 50 = Rs.80

lakh . Additional Auxiliary Power +

= Rs. 10 lakh

Net Annual Saving	= Rs.
70 lakh Investment for New Coconut Fired heater	=
Rs. 35 lakh	

Simple pay back period = **6 months**

Energy Audit Instruments

- The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. The parameters generally monitored during energy audit may include the following:
- Basic Electrical Parameters in AC &DC systems - Voltage (V), Current (I), Power factor, Active power (kW), apparent power (demand) (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc.
- Parameters of importance other than electrical such as temperature & heat flow, radiation, air and gas flow, liquid flow, revolutions per minute (RPM), air velocity, noise and vibration, dust concentration, Total Dissolved Solids (TDS), pH, moisture content, relative humidity, flue gas analysis - CO₂, O₂, CO, SO_x, NO_x, combustion efficiency etc.

Key instruments for energy audit are listed below.

- To obtain the best information for a successful energy cost control program, the auditor must make some measurements during the audit visit. The amount of equipment needed depends on the type of energy-consuming equipment used at the facility.

Tape Measures

- The most basic measuring device needed is the tape measure. A 25-foot tape measure 1" wide and a 100- foot tape measure are used to check the dimensions of walls, ceilings, windows, etc.

Light meter

- One simple and useful instrument is the light meter which is used to measure illumination levels in facilities. A light meter that reads in foot candles allows direct analysis of lighting systems and comparison with recommended light levels specified by the Illuminating Engineering Society.

Thermometers

- Several thermometers are generally needed to measure temperatures in offices and other worker areas, and to measure the temperature of operating equipment. Knowing process temperatures allows the auditor to determine process equipment efficiencies, and also to identify waste heat sources for potential heat recovery programs.

Voltmeter

- An inexpensive voltmeter is useful for determining operating voltages on electrical equipment and especially useful when the nameplate has worn off of a piece of equipment or is otherwise unreadable or missing.

Wattmeter/Power Factor Meter

- A portable hand-held wattmeter and power factor meter is very handy for determining the power consumption and power factor of individual motors and other inductive devices.

Combustion Analyzer

- Combustion analyzers are portable devices capable of estimating the combustion efficiency of furnaces, boilers, or other fossil fuel burning machines.

Safety Equipment

- The use of safety equipment is a vital precaution for any energy auditor. A good pair of safety glasses is an absolute necessity for almost any audit visit. Hearing protectors may also be required on audit visits to noisy plants or areas with high horsepower motors driving fans and pumps.
- Electrical insulated gloves should be used if electrical measurements will be taken, and asbestos gloves should be used for working around boilers and heaters. Breathing masks may also be needed when hazardous fumes are present from processes or materials used.
- The operating instructions for all instruments must be understood and staff should familiarize themselves with the instruments and their operation prior to actual audit use.

1 Electrical Measuring Instruments:
These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.
2 Combustion analyzer:
This instrument has in-built chemical cells which measure various gases such as O ₂ , CO, NO _x and SO _x .
3 Fuel Efficiency Monitor:
This measures oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.
4 Fyrite:
A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separate fyrite can be used for O ₂ and CO ₂ measurement.
5 Contact thermometer:
These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.
6 Infrared Thermometer:
This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.

7	Pitot Tube and manometer: Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.
8	Water flow meter: This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.
9	Speed Measurements: In any audit exercise speed measurements are critical as they may change with frequency, belt slip and loading. A simple tachometer is a contact type instrument which can be used where direct access is possible. More sophisticated and safer ones are non contact instruments such as stroboscopes.
10	Leak Detectors: Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.
11	Lux meters: Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.

REFERENCES

1. NPC energy audit manual and reports
2. Energy management handbook, John Wiley and Sons - Wayne C. Turner
3. Guide to Energy Management, Cape Hart, Turner and Kennedy
4. Cleaner Production – Energy Efficiency Manual for GERIAP, UNEP, Bangkok prepared by National Productivity Council

References-

1. <https://www.beeindia.gov.in/content/standard-labeling>
2. www.beestarlabel.com/
3. <https://beeindia.gov.in/sites/default/files/1Ch8.pdf>
4. <https://beeindia.gov.in/sites/default/files/1Ch3.pdf>

Unit 5: Agriculture Equipment and Post Harvest Technology

A brief history of farm mechanization

Agriculture in India is unique in its characteristics, where over 250 different crops are cultivated in its varied agro-climatic regions, unlike 25 to 30 crops grown in many of the developed nations of the world. Moreover, the use of various sources of power from the humble arm of the farmer to the mightiest of tractors is ubiquitous. India is the largest producer of tractors in the world. The quantum of research outlay for the farming sector is a meager 0.86 % of the GDP as against 2-3 % in the developed world. In spite of this disparity, India has emerged as a net exporter of food grains and continues to forge ahead in the adoption and indigenization of many of the advanced technologies developed elsewhere in the world. In 1951, when the country was in its formative years after centuries of colonial rule, there were only 8635 tractors in use and all of them were imported. Production of tractors commenced during 1961-62, turning out 880 of them. This figure has peaked to over 262,000 in 1999-2000. The sale of tractors in 2003-2004 was 172,000. The quantum of power available for the farming sector rose from 45.29 million kW in 1971-1972 to over 170 million kW in 2000-2001. Correspondingly, power intensity on the Indian farm increased from 0.2 kW/hectare (symbol: ha) to 1.30 kW/ha on the basis of net-cropped area. The state of Punjab has the highest average farm-power intensity of 3.5 kW/hectare and also has the highest productivity levels. During the same period, contribution of animate power reduced from 60% of the total farm power to less than 17% and mechanical and electrical power sources increased from 40% to over 83%. It is also seen that the adoption of mechanical and electrical power was higher for stationary applications than for traction required for field operations. Power for traction (tractors and power tillers) increased from 8.46% to 32.85%, indicating that more and more power-operated equipment were coming into use. Human power continues to be a significant component for digging, clod breaking, sowing, intercultural, harvesting, threshing, cleaning, and grading for which traditional tools and implements have evolved over time in different parts of the country. The small and marginal farmers rely on draught animals for field operations, transport and agro-processing.

The extent of area under the command of draught animals is about 57%. The need to achieve timeliness of field operations and effective utilization of inputs has resulted in the development of appropriate machinery, which also reduce drudgery. Traditional tools and implements such as bullock-operated country plough, and bakhar for tillage, dufan or tifan, enatigoru and funnel and tube-attachment on country ploughs as sowing devices; sickles, khurpi, spades and a/pad thresher for harvesting, digging and threshing; and swing basket, Persian wheel (rahat) and cradle pump for irrigation, etc. have been very popular in India. Use of electric or diesel engine-operated irrigation pumps, animal and tractor-operated cultivator and disc harrow for seed-bed preparation; seed drill or seedcum-fertilizer drill and planter for line sowing with fertilizer application; and mechanical power thresher and combine harvesters has also increased.

Farmers have also adopted sprinkler-and drip-irrigation systems in commercial crops. Sun drying, winnowing, paddy hulling, pulse milling, oil expelling, wheat milling, pickle making,

guy and khandsari, ghee and khoa making etc. are the major processing activities undertaken by the farmers.

The traditional processing equipment used by the farmers include supa, chalni, chakiya, fanta, silbatta, okhli, mathani, puffing pan, mini oil ghanis/kolhus, rice hullers and flour chakkis etc. High capacity modern machines introduced in urban and suburban areas for processing of agricultural produce have helped in increasing the income of the processors. Uses of wind and solar energy for winnowing and drying have been in vogue from times immemorial. India receives about 5×10^{15} kWh/year solar energy, which can profitably be utilised for over 200 days in a year. The availability of solar photovoltaic devices has encouraged their use for water pumping and lighting. Several designs of cookers and water heaters are also available.

Cooking needs of the villages are mostly met by the burning of biomass. Anaerobic fermentation of animal excreta for the generation of methane has attained considerable attention and several designs of biogas plants are in use. Biomass can also be gasified to obtain a combustible gas mixture mainly consisting of carbon monoxide and hydrogen in specially designed apparatus. This gas can be utilised for thermal applications and also for running engines.

Cellulose based waste and non-edible oils of plant origin can be converted by bio-chemical processes to alcohol and esters for use in internal combustion engines to provide motive power and reduce the dependence on fossil fuels. The manufacture of agricultural machinery in the country is carried out by village artisans, tiny units, small-scale industries and the State Agro-Industrial Development Corporations. Production of tractors, motors, engines and process equipment is the domain of the organised sector.

The traditional artisans and small-scale industries rely upon own experience; user's feedback and government owned research and development institutions for technological support and operate from their backyards or on road side establishments without regular utility services. Medium and large-scale industries operate in their own premises with sound infrastructure, usually forming a part of an industrial estate, well-established manufacturing and marketing facilities and employ skilled manpower. Diesel engines, electric motors, irrigation pumps, sprayers and dusters, land development machinery, tractors, spare parts, power tillers, post harvest and processing machinery and dairy equipment are produced in this sector.

They have professional marketing network of dealers and provide effective after sales service. They also have in-house research and development facilities or have joint ventures with advanced countries for technology up gradation. India is recognized, the world over, as a leader in the manufacture of agricultural equipment and machinery such as combine harvesters, plant protection equipment, drip irrigation and micro-sprinkler. Sizeable quantities of farm implements are exported to Africa, Middle East, Asia, South America and other countries.

Need of farm mechanization

- The agriculture and allied sector continues to be significant for the inclusive and sustainable growth of the Indian economy. Indian Agriculture Sector not only ensures food security but also provides employment for substantial volume of population, directly & indirectly. Though agriculture contributed only 17.4% to the country's Gross Value Added for

the year 2016-17 (at current prices), still it is a driver for demand creation. Growth of agriculture sector has been fluctuating. It increased from -0.2% in 2014-15 to 6.3% in 2016-17, and then declined to 2.9% in 2018-19. Farmers' income has not been able to keep pace, such as to cater to increasing costs of production including that of rising labour wages. Hence, there is a strong case for labour-substituting farm/agriculture machinery. Parallelly, it is also important to note, that several activities are highly time-bound and unless executed as per schedule, the farmer is likely to suffer loss.

Agriculture mechanization is an appropriate answer to such challenges. Farm mechanization, more appropriately agriculture mechanization will also let off the wage labour as also the farmer of the drudgery involved in manual operations, besides enhancing manpower productivity since skills are integral to machine based operations. Lack of access to farm power is one of the primary reasons for slow uptake of farm mechanization and hence non-intensification of farm productivity, particularly among small and marginal farmers.

There is a direct correlation between having access to farm implements and impact on efficiency, timeliness of the farm operations. It proves to be completely unviable for a small or marginal farmer to purchase farm equipment and without its usage the farmer can never sustain positive returns from agricultural output. Effective use of agriculture machinery helps to increase productivity & production of output, undertake timely farm operations and enable the farmers to quickly rotate crops on the same land. By raising a second crop or multi-crops from the same land, there is improvement in the cropping intensity and making agricultural land commercially more viable.

Mechanization also helps in animal husbandry, dairying and fisheries. Farm mechanization not only provides optimal utilization of resources e.g., land, labour, water but helps farmers to save valuable time and also reduces drudgery. This judicious use of time, labour and resources facilitates sustainable intensification (multicropping) and timely planting of crops, leading to an increase in productivity. Though, the level of farm mechanization in India stands at about 40-45% with states such as UP, Haryana and Punjab having very high mechanization levels, but north-eastern states having negligible mechanization. This level of farm mechanization is still low as compared to the countries such as the U. S. (95 %), Brazil (75%) and China (57%). While the level of mechanization lags behind other developed countries, it has seen an average agriculture growth rate of 3.56 % through the last decade.

According to Economic Survey, Farm mechanization and crop productivity has a direct correlation as farm mechanization saves time and labor, reduces drudgery, cut down production cost in the long run, reduces postharvest losses and boosts crop output and farm income.

Use of improved implements has potential to increase productivity up to 30 per cent and reduce the cost of cultivation up to 20 per cent. At present, Indian farmers are adopting farm mechanization at a faster rate in comparison to recent past.

Although, the sale of tractors in India cannot be taken as the only measure of farm mechanization but to a great extent it reflects the level of mechanization.

Indian tractor industries have emerged as the largest in the world and account for about one third of total global tractor production.

According to the World Bank estimates, half of the Indian population would be urban by the year 2050. It is estimated that percentage of agricultural workers in total work force

would drop to 25.7% by 2050 from 58.2% in 2001. Thus, there is a need to enhance the level of farm mechanization in the country. Due to intensive involvement of labour in different farm operations, the cost of production of many crops is quite high.

Human power availability in agriculture also increased from about 0.043KW/ ha in 1960-61 to about 0.077 KW/ ha in 2014- 15. However, as compared to tractor growth, increase in human power in agriculture is quite slow. Over the year, the shift has been towards the use of mechanical and electrical sources of power. In 1960-61, about 93% farm power was coming from animate sources, which has reduced to about 10% in 2014-15.

On the other hand, mechanical and electrical sources of power have increased from 7% to about 90% during the same period. As there is predominance of small operational holding in Indian Agriculture, it is, therefore, necessary to consolidate the land holdings to reap the benefits of agricultural mechanization.

There is a need to innovate custom hiring service or a rental model by institutionalization for high cost farm machinery such as combine harvester, Sugarcane harvester, potato combine, paddy transplanter, laser guided land leveler, rotavator etc. to reduce the cost of operation and it can be adopted by private players or State or Central Organization in major production hubs.

Share of farm mechanization in farming operations

The penetration of powered machines in various farm activities is assessed in the range of 40 to 45 per cent. Share of mechanization of field activities in 2016-17 is represented in the following Table 1.

Table 5.1

Type of Operation	Percentage of operations mechanised
Soil working & seed bed preparation	40
Seeding and planting	29
Plant protection	34
Irrigation	37
Harvesting and Threshing	60-70 % for wheat and rice and <5 % for others

Status of availability of Agricultural Equipment in India.

Table 1:

Introduction to farm mechanization

Most grain and seed crops are now harvested with combined harvester-threshers, commonly known as combines.

- Except for the differences in the feeding arrangement and the addition of a straw stacker, stationary threshers employ the same principles and include the same basic components as combines.
- Although the greatest application of combines is in harvesting the small grains, corn and soybeans, these machines are also used for a wide variety of small-acreage or specialty crops.

Thus, although most emphasis in the following discussion will be placed upon grain harvesting, occasionally consideration will be given to other seed crops.

Present status of farm Mechanism

Present status of farm mechanisation in India can be viewed under the following general categories

- Improved manual tools.
- Improved animal drawn implements.
- Tractor operated implements. Custom hiring units on the farm.
- Other stationary equipments like threshers, irrigation pumps, sprayers, dusters, etc.
- Unit power available for crop production is about 0.54 hp / ha whereas desirable level is about 1 hp / hectare

Improved manual tools

- Improved manual tool plays important role in minimising the physical strain on the worker.
- It increases the output of work per unit time.
- This category includes sickles, khurpi, pruning, knives, wheel hand hoe, long handle hoes, manually operated seed drills and many such items.
- The manual tools vary in their size and design to some extent according to local conditions.

Animal drawn improved implements

- More than 80% farmers depend upon animal drawn implements. Improved implement increases the output and quality of work.
- This includes improved steel ploughs, cultivators, harrows, seed drills, seed-cum-fertilizer drills, multipurpose tool bar, bakhar, puddlers, levellers, improved carts, scrapers and many other implements.
- At present a large number of animal drawn implements are manufactured by local firms.

Tractors and matching implements

- Tractor is an important machine used for farm mechanisation.
- About 10% area of the country are covered by tractor operated implements.
- Tractor population has increased from 9000 to about 1.04 million during last 40 years.
- The production of indigenous tractors started in India in 1961. M/s. Eicher Ltd. is the first tractor manufacturer in India.
- 39 models of tractor are being produced in India in different hp ranges. There are 3 models of tractor of less than 20 hp, 9 models of tractor of 20-29 hp, 11 models of tractor of 30-39 hp, 8 models of tractor of 40-49 hp and 8 models of more than 50 hp.
- The list of manufacturers of tractors and power tillers are given in Appendix C and D.
- The technical details of tractors are given in Appendix E.

Facilities for training and testing

There are three major farm machinery training and testing institutes in India, besides minor centres

1. Central Region Farm Machinery Training & Testing Institute, Budni (M.P.).
 2. Northern Region Farm Machinery Training & Testing Institute, Hissar (Haryana).
 3. Southern Region Farm Machinery Training & Testing Institute, Anantpur (A.P.).
- These centres perform the testing of tractors, power tillers and farm machines on extensive basis.

- Training facilities are also there for engineers, technicians, operators, mechanics and user in connection with repair, maintenance and operation of farm machines and tractors.

Custom hiring

- The farmers who do not have their own tractors, try to hire the tractors with matching implements for their cultivation work on payment of custom hiring charges.
- The custom hiring work is being done by state agro industries corporation, government agencies, co-operative societies and private tractor owners.
- These tractors are utilised for hot weather ploughing, seed bed preparation, ridge making, leveling, land reclamation and tractor mounted combine.
- Custom hiring is also done for stationary equipments like threshers, irrigation pumps, sprayers and dusters.

Limiting factors in farm mechanization:

The followings are the limiting factors in farm mechanization in India.

- Small land holdings.
- Less investing capacity of farmers.
 - Agricultural labour is easily available.
- Adequate draught animals are available in the country.
- Lack of suitable farm machines for different operations.
- Lack of repair and servicing facilities for machines.
- Lack of trained man power.
- Lack of co-ordination between research organisations and manufacturers.
- High cost of machines.
- Inadequate quality control of machines.

Suggestions for farm mechanization:

- To develop a national policy on farm mechanisation.
- To establish an apex body to implement the national policy on farm mechanisation. This may provide basis of industries to plan their capacities, sale and servicing of equipments.
- To open adequate training centres for imparting training to engineers, mechanics, technicians, operators and users on farm power and machinery regarding proper selection, operation, maintenance and repair of machines.
- To start testing and evaluating centres for farm power and machinery on regional basis.
- To establish adequate centres for repairs and spare parts of machines.
- To reinforce tractor testing stations on the lines of International testing stations.
- To improve the industrial policy for maintaining better quality of implements and machines.
- Agricultural Engineering Extension Education wing is required to be established on sound footing to keep the farmers up-to-date on various aspects of application of engineering to agriculture.
- The landless workers need financial assistance to own hand tools to improve their earnings.
- Post harvest technology deserves special attention.
- Custom hiring system is required to be encouraged in rural area.

Future trend of farm machinery and implements

- History indicates that the process of mechanization is dynamic with no ultimate goal in sight
 - Each manufacturers must continually improved his products And developed new ones in order to maintain a profitable position
 - Safety, comfort, and convenience for the operator will continue the great deal of attention
 - Concentrate automatic control for complex machines become increasingly important
 - As longer and larger tractors are introduced, tillage tools must be designed for higher speeds are to efficiently utilize
 - Mechanical harvest of fruits and vegetables are difficult because varied characteristics of the different plants, fruits and vegetables
 - The economic adaptation of certain types of machines to small farmers is a problem that needs more attention before our agriculture, can become completely mechanized
- Simplification of the more complex machines which is in direct contrast to present development trends is needed and is a real challenge to agricultural engineers

5.1 Farming Equipments-

a. Farm tractor

Tractor is a self-propelled power unit having wheels or tracks for operating agricultural implements and machines including trailers. Tractor engine is used as a prime mover for active tools and stationary farm machinery through power take-off shaft (PTO) or belt pulley.

Classification of tractors

Tractors can be classified into three classes on the basis of structural-design:

- (i) **Wheel tractor:** Tractors, having three or four pneumatic wheels are called wheel tractors. Four- wheel tractors are most popular everywhere.
- (ii) **Crawler tractor:** This is also called track type tractor or chain type tractor. In such tractors, there is endless chain or track in place of pneumatic wheels.
- (iii) **Walking tractor (Power tiller):** Power tiller is a walking type tractor. This tractor is usually fitted with two wheels only. The direction of travel and its controls for field operation is performed by the operator, walking behind the tractor.

On the basis of purpose, wheeled tractor is classified into three groups:

- (a) **General purpose tractor:** It is used for major farm operations; such as ploughing, harrowing, sowing, harvesting and transporting work. Such tractors have (i) low ground clearance (ii) increased engine power (iii) good adhesion and (iv) wide tyres.
- (b) **Row crop tractor:** It is used for crop cultivation. Such tractor is provided with replaceable driving wheels of different tread widths. It has high ground clearance to save damage of crops. Wide wheel track can be adjusted to suit inter row distance.
- (c) **Special purpose tractor:** It is used for definite jobs like cotton fields, marshy land, hillsides, garden etc. Special designs are there for special purpose tractor.

Tractor components

A tractor is made of following main components:

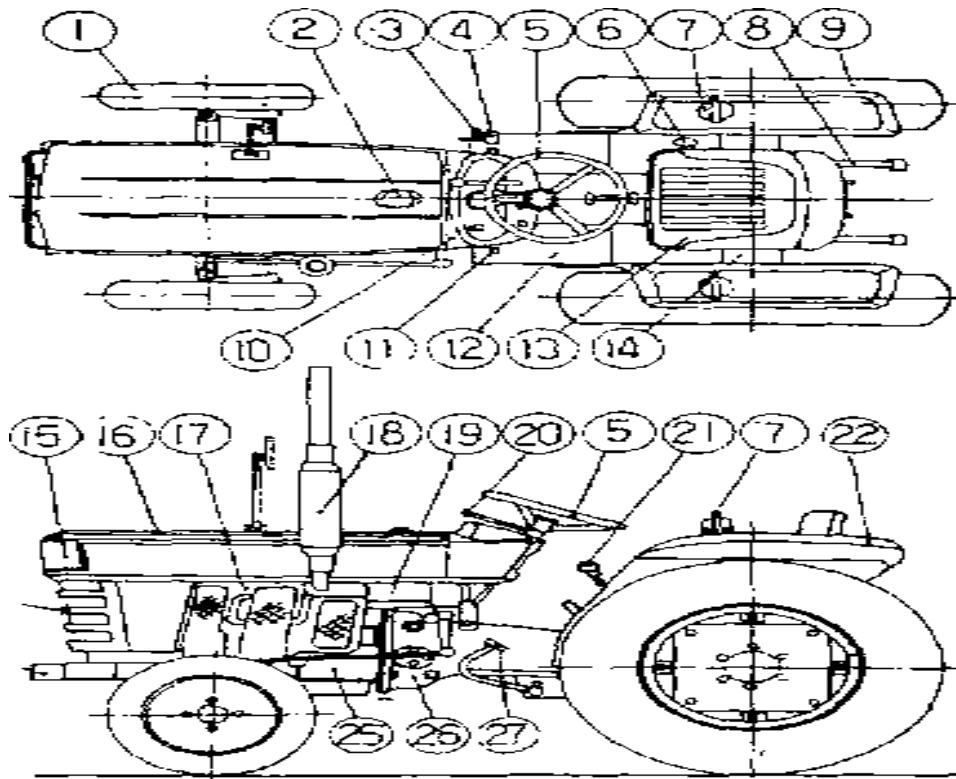
- (1) I. C. engine, (2) Clutch (3) Transmission gears (4) Differential unit (5) Final drive (6) Rear wheels (7) Front wheels (8) Steering mechanism (9) Hydraulic control and hitch

system (10) Brakes (11) Power take-off unit (12) Tractor pulley and (13) Control panel. Every tractor is fitted with an I. C. engine, the engine may be carburetor type or diesel type but nowadays almost all the tractors are diesel tractors.

Selection of tractor

Selection of tractor depends upon following factors:

- (1) **Land holding:** Under a single cropping pattern, it is normally recommended to consider 1 hp for every 1 hectares of land, In other words, one tractor of 20-25 hp is suitable for 20 hectares farm.
- (2) **Cropping pattern:** Generally less than 1.0 hectare/hp have been recommended where adequate irrigation facilities are available and more than one crop is taken. So a 30-35 hp tractor is suitable for 25 hectares farm.
- (3) **Soil condition:** A tractor with less wheel base, higher ground clearance and low overall weight may work successfully in lighter soil but it will not be able to give sufficient depth in black cotton soil.
- (4) **Climatic condition:** For very hot zone and desert area, air cooled engines are preferred over water-cooled engines. Similarly for higher altitude, air cooled engines are preferred because water is liable to be frozen at higher altitude.
- (5) **Repairing facilities:** It should be ensured that the tractor to be purchased has a dealer at near by place with all the technical skills for repair and maintenance of machine.
- (6) **Running cost:** Tractors with less specific fuel consumption should be preferred over others so that running cost may be less.
- (7) **Initial cost and resale value:** While keeping the resale value in mind, the initial cost should not be very high; otherwise higher amount of interest will have to be paid.
- (8) **Test report:** Test report of tractors released from farm machinery testing stations should be consulted for guidance.



1. Front wheel 2.Fuel tank cap 3. Accelerator pedal 4. Brake pedal 5.Steering wheel 6. Hydraulic control lever 7. Turn signal lamp 8 Lift arm 9. Rear tire 10 Instrument panel
 11.Clutch pedal 12.Step 13 Seat 14.Rear axle housing 15 Side clearance 16 Engine hood 17. Fan cover 18.Muffler 19. Fuel tank 20.Throttle lever 21.Main speed change lever 22.Fender

Fig. 1 Components of tractor

Hitching system of Tractor Drawn Implements

Tractor drawn implements possess higher working capacity and are operated at higher speeds. These implements need more technical knowledge for operations and maintenance work. Tractor drawn implements may be a) Trailed type b) Semi-mounted type and c) Mounted type.

a) **Trailed type implement:** It is one that is pulled and guided from single hitch point but its weight is not supported by the tractor.

Semi-mounted type implement: This type of implement is one which is attached to the tractor along a hinge axis and not at a single hitch point. It is controlled directly by tractor steering unit but its weight is partly supported by the tractor.

b) **Mounted type implement:** A mounted implement is one which is attached to the tractor, such that it can be controlled directly by the tractor steering unit. The implement is carried fully by the tractor when out of work.

b. Power tiller

It is a prime mover in which the direction of travel and its control for field operation is performed by the operator walking behind it. It is also known as hand tractor or walking type tractor. The concept of power tiller came in the world in the year 1920. Japan is the first country to use power tiller on large scale. In Japan, the first successful model of power tiller was designed in the year 1947. Production of power tiller rapidly increased during the year 1950 to 1965. Power tiller was first introduced in India in the year 1963. Power tiller is a walking type tractor. The operator walks behind the power tiller, holding the two handles of power tiller in his own hands. Power tiller may be called a single axle walking type tractor, though a riding seat is provided in certain designs. Average size of holding in India is about 2.5



Fig.2 power tiller

hectares. There are 89% of total land holdings of less than six hectares. Under such conditions, power tiller may be useful as a power unit.

Components of power tiller: A power tiller consists of the following main parts:

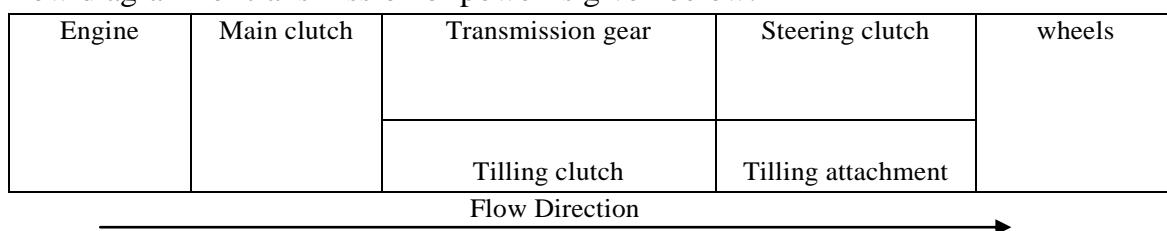
(1) Engine (2) Transmission gears (3) Clutch (4) Brakes (5) Rotary unit.

All the power tillers are fitted with an I. C. engine. At present, most of the power tillers are fitted with diesel engine. The makes like Kubota, Mitsubishi, and Sarachi have used diesel engine in India.

Operation: The main clutch is a lever on the handle. The lever can be shifted to on or off position while operating in the field. When the lever is shifted to on position, the power from the engine is transmitted through the main clutch to the various parts of the power tiller. When the lever is shifted to off position the power from the engine is cut-off from the rest of the transmission

Power transmission in power tiller: For operation of power tiller, the power is obtained from the IC Engine, fitted on the power tiller. The engine power goes to the main clutch with the help of belt or chain. From main clutch, the power is divided in two routes, one goes to transmission gears, steering clutch and then to the wheel. The other component goes to the tilling clutch and then to the tilling attachment.

The flow diagram for transmission of power is given below:



V - belt is usually used to transmit power from the engine to the main clutch, because V-belt has very high efficiency and it works as a shock absorber also.

c. Tillage

It is a mechanical manipulation of soil to provide favorable condition for crop production. Soil tillage consists of breaking the compact surface of earth to a certain depth and to loosen the soil mass, so as to enable the roots of the crops to penetrate and spread into the soil.

Objectives of Tillage

- To obtain deep seed bed, suitable for different type of crops.
- To add more humus and fertility to soil by covering the vegetation.
- To destroy and prevent weeds.
- To aerate the soil for proper growth of crops.
- To increase water-absorbing capacity of the soil.
- To destroy the insects, pests and their breeding places and
- To reduce the soil erosion.

Classification of Tillage

Primary tillage

It constitutes the initial major soil working operation. It is normally designed to reduce soil strength ,cover plant materials and rearrange aggregates. The operations performed to open up

any cultivable land with a view to prepare a seed bed for growing crops is known as primary tillage. Animal drawn implements mostly include indigenous plough and mould-board plough. Tractor drawn implements include mould-board plough, disc plough, subsoil plough, chisel plough and other similar implements.

Secondary tillage

Tillage operations following primary tillage those are performed to create proper soil tilt for seeding and planting are secondary tillage. These are lighter and finer operations, performed on the soil after primary tillage operations. Secondary tillage consists of conditioning the soil to meet the different tillage objectives of the farm. The implements include different types of harrow, cultivators, levelers, clod crushers etc.

Types of Tillage

Minimum Tillage - It is the minimum soil manipulation necessary to meet tillage requirements for crop production.

Strip Tillage - It is a tillage system in which only isolated bands of soil are tilled.

Rotary Tillage -It is the tillage operations employing rotary action to cut, break and mix the soil.

Mulch Tillage -It is the preparations of soil in such a way that plant residues or other mulching materials are specially left on or near the surface.

Combined Tillage -Operations simultaneously utilizing two or more different types of tillage tools or implements to simplify, control or reduce the number of operations over a field are called combined tillage.

Difference between tools/ Implements/Machines

Tool - It is an individual working element such as disc or shovel.

Implement - It is equipment generally having no driven moving parts, such as harrow or having only simple mechanism such as plough.

Machine -It is a combination of rigid or resistant bodies having definite motions and capable of performing useful work.

implements for Primary Tillage

- **Plough** - Ploughing is the primary tillage operations, which are performed to cut, break and invert the soil partially or completely. Ploughing essentially means opening the upper crust of the soil, breaking the clods and making the soil suitable for sowing seeds.

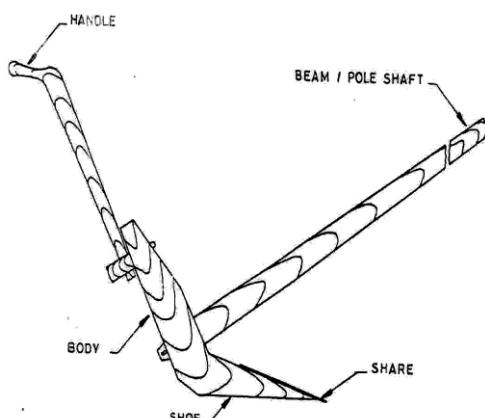


Figure 3 Country plough

Country or Indigenous plough:

It penetrates into the soil and breaks it open. The functional components include share, body, shoe, handle and beam. It can be used for dry land, garden land and wetland ploughing operations.

Share - It is the working part of the plough attached to the shoe with which it penetrates into the soil and breaks it open.

Shoe - It supports and stabilizes the plough at the required depth.

Body - It is main part of the plough to which the shoe, beam and handle are generally attached. In country plough body and shoe are integral part.

Beam - It is generally a long wooden piece, which connects the main body of the plough to the yoke.

Handle - A wooden piece vertically attached to the body to enable the operator to control the plough.

Operational adjustments

a. Lowering or raising the beam with respect to the plough body, resulting in a change in the angle of the share with the horizontal plane to increase or decrease the depth of operation.

Changing the length of the beam (body to yoke on the beam) to increase or decrease the depth of operation.

a. The size of the plough is represented by the width of the body.

Mold board plough:

Function: 1) cutting the furrow slice 2) lifting the soil 3) turning the furrow slice and 4) pulverizing the soil.

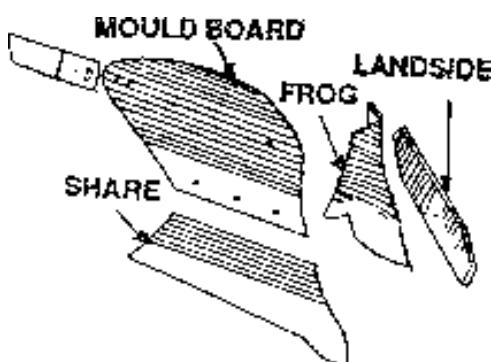


Figure 4 . Components of Mold Board plough

Components

M.B. plough consists of (Fig.4) Share, Mould board, Land side, Frog and Tail piece.

Share - It penetrates into the soil and makes a horizontal cut below the soil surface. It is a sharp, well polished and pointed component. The shares are made of chilled cast iron or steel. The steel mainly contains about 0.70 to 0.80% carbon and about 0.50 to 0.80% manganese besides other minor elements.

Moldboards - The mouldboard is that part of the plough which receives the furrow slice from the share. If lifts, turns and breaks the furrow slice. To suit different soil conditions and crop requirements, mouldboard has been designed in different shapes. The mouldboard is of following types: a) General purpose b) Stubble c) Sod or Breaker and d) Slat.

- i) **General purpose** - It is a mouldboard having medium curvature lying between stubble and sod. The sloping of the surface is gradual. It turns the well defined furrow slice and pulverises the soil thoroughly. It has a fairly long mouldboard with a gradual twist, the surface being slightly convex.
- ii) **Stubble type** -It is short but broader mouldboard with a relatively abrupt curvature which lifts breaks and turns the furrow slice used in stubble soils. Its curvature is not gradual but it is abrupt along the top edge. This causes the furrow slice to be thrown off quickly, pulverizing it much better than other types of mouldboard. This is best suited to work in stubble soil that is under cultivation for years together. Stubble soil is that soil in which stubble of the plants from the previous crop is still left on the land at the time of ploughing.
- iii) **Sod or Breaker type** - It is a long moldboard with gentle curvature which lifts and inverts the unbroken furrow slice. It is used in tough soil of grasses. It turns over thickly covered soil. This is very useful where complete inversion of soil is required by the farmer.
- iv) **Slat type** - It is a mouldboard whose surface is made of slats placed along the length of the mouldboard, so that there are gaps between the slats. This type of mouldboard is often used, where the soil is sticky, because the solid mouldboard does not scour well in sticky soils.

Plough accessories

There are a few accessories necessary for plough such as (i) Jointer (ii) Coulter (iii) Gauge wheel (iv) Land wheel and (v) Furrow wheel.

Jointer - It is a small irregular piece of metal having a shape similar to an ordinary plough bottom. It looks like a miniature plough. Its purpose is to turn over a small ribbon like furrow slice directly in front of the main plough bottom. This small furrow slice is cut from the left and upper side of the main furrow slice and is inverted so that all trashes on the top of the soil are completely turned down and buried under the right hand corner of the furrow.

Coulter- It is a device used to cut the furrow slice vertically from the land ahead of the plough bottom. It cuts the furrow slice from the land and leaves a clear wall. It also cuts trashes which are covered under the soil by the plough. The coulter may be (a) Rolling type disc coulter or (b) Sliding type knife coulter.

Gauge wheel- It is an auxiliary wheel of an implement to maintain uniform depth of working. Gauge wheel helps to maintain uniformity in respect of depth of ploughing in different soil conditions. It is usually placed in hanging position.

Land wheel - It is the wheel of the plough, which runs on the ploughed land.

Front furrow wheel - It is the front wheel of the plough, which runs in the furrow. **Rear furrow wheel** - It is the rear wheel of the plough, which runs in the furrow.

- d. **Disc Plough:** It is a plough, which cuts, turns and in some cases breaks furrow slices by means of separately mounted large steel discs. A disc plough is designed with a view of reduce friction by making a rolling plough bottom instead of sliding plough bottom. A disc plough works well in the conditions where mould board plough does not work satisfactorily.

Advantages of disc plough

- ◆ A disc plough can be forced to penetrate into the soil which is too hard and dry for working with a mould board plough.
- ◆ It works well in sticky soil in which a mould board plough does not scour.
- ◆ It is more useful for deep ploughing.
- ◆ It can be used safely in stony and stumpy soil without much danger of breakage.
- ◆ A disc plough works well even after a considerable part of the disc is worn off in abrasive soil.
- ◆ It works in loose soil also (such as peat) without much clogging.

Disadvantages of disc plough

- ◆ It is not suitable for covering surface trash and weeds as effectively as mouldboard plough does.
- ◆ Comparatively, the disc plough leaves the soil in rough and more cloddy condition than that of mouldboard plough.

Types of Disc Plough

Disc ploughs are of two types (i) Standard disc plough and (ii) Vertical disc plough.

(i) Standard disc plough

It consists of steel disc of 60 to 90 cm diameter, set at a certain angle to the direction of travel. Each disc revolves on a stub axle in a thrust bearing, carried at the lower end of a strong stand which is bolted to the plough beam. The angle of the disc to the vertical and to the furrow wall is adjustable. In action, the disc cuts the soil, breaks it and pushes it sideways. There is little inversion of furrow slice as well as little burying of weeds and trashes. The disc plough may be mounted type or trailed type. In mounted disc plough, the side thrust is taken by the wheels of the tractor. Disc is made of heat treated steel of 5 mm to 10 mm thickness. The amount of concavity varies with the diameter of the disc. The approximate values being 8 cm for 60 cm diameter disc and 16 cm for 95 cm diameter. A few important terms connected with disc plough is explained below

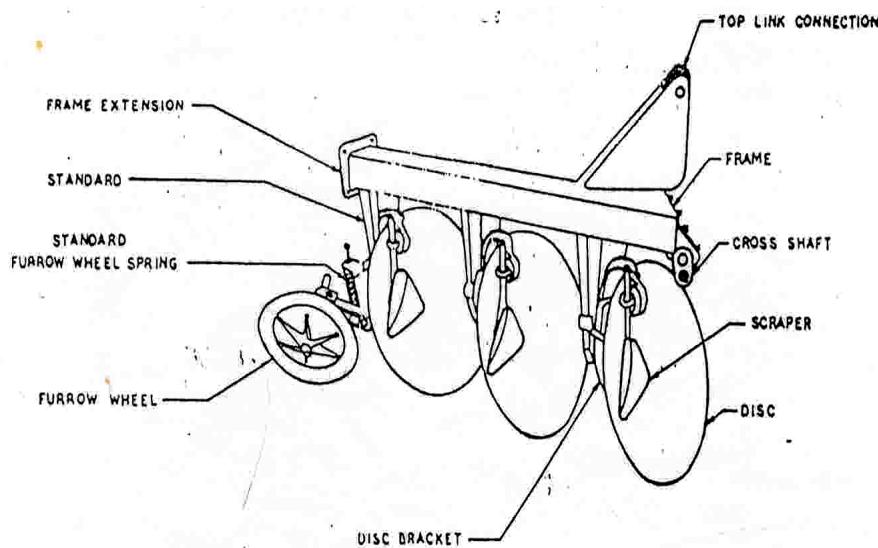


Figure 5 Standard disc plough

Disc - It is a circular, concave revolving steel plate used for cutting and inverting the soil.

Disc angle - It is the angle at which the plane of the cutting edge of the disc is inclined to the direction of travel. Usually the disc angle of good plough varies between 42° to 45° .

Tilt angle - It is the angle at which the plane of the cutting edge of the disc is inclined to a vertical line. The tilt angle varies from 15° to 25° for a good plough.

Scraper - It is a device to remove soil that tends to stick to the working surface of a disc.

Concavity - It is the depth measured at the centre of the disc by placing its concave side on a flat surface.

(ii) **Vertical Disc Plough**

It is the plough which combines the principle of regular disc plough and disc harrow and is used for shallow working in the soil.

D. Rotary tiller

The rotary cultivator is widely considered to be the most important tool as it provides fine degree of pulverization enabling the necessary rapid and intimate mixing of soil besides reduction in traction demanded by the tractor driving wheels due to the ability of the soil working blades to provide some forward thrust to the cultivating outfit. Rotary tiller is directly mounted to the tractor with the help of three point linkage. The power is transmitted from the tractor PTO (Power Take Off) shaft to a bevel gear box mounted on the top of the unit, through telescopic shaft and universal joint. From the bevel gear box the drive is further transmitted to a power shaft, chain and sprocket transmission system to the rotor. The tynes are fixed to the rotor and the rotor with tynes revolves in the same direction as the tractor wheels. The number of tynes varies from 28 - 54. A levelling board is attached to the rear side of the unit for levelling the tilled soil. A depth control lever with depth wheel provided on either side of the unit ensures proper depth control. The following types of blades are used with the rotor.

- i. **'L' type blade** - Works well in trashy conditions, they are more effective in cutting weeds and they do not pulverize the soil much.
- ii. **Twisted blade** - Suitable for deep tillage in relatively clean ground, but clogging and wrapping of trashes on the tynes and shafts.
- iii. **Straight blade** - Employed on mulchers designed mainly for secondary tillage.

e. **Chisel plough**

Chisel ploughs are used to break through and shatter compacted or otherwise impermeable soil layers. Deep tillage shatters compacted sub soil layers and aids in better infiltration and storage of rainwater in the crop root zone. The improved soil structure also results in better development of root system and the yield of crops and their drought tolerance is also improved. The functional component of the unit include reversible share, tyne (chisel), beam, cross shaft and top link connection.

Sub-Soil plough

The function of the sub-soiler is to penetrate deeper than the conventional cultivation machinery and break up the layers of the soil, which have become compacted due to the movement of heavy machinery or as a result of continuous ploughing at a constant depth. These compacted areas prevent the natural drainage of the soil and also inhibit the passage of air and nutrients through the soil structure. The sub-soiler consists of heavier tynes than the chisel plough to break through impervious layer shattering the sub-soil to a

depth of 45 to 75 cm and requires 60 to 100 hp to operate it. The advantages are same as that of chisel plough.

Ploughing System

Normal Ploughing: It is the ploughing up to a depth of about 15 cm.

Contour Ploughing: It is the method of ploughing in which the soil broken and turned along the contours.

Secondary tillage

Tillage operations following primary tillage which are performed to create proper soil tilth for seeding and planting are secondary tillage. These are lighter and finer operations, performed on the soil after primary tillage operations. Secondary tillage consists of conditioning the soil to meet the different tillage objectives of the farm. These operations consume less power per unit area compared to primary tillage operations. Secondary tillage implements may be tractor drawn or bullock drawn implements.

1. Harrow

Harrow is a secondary tillage implement that cuts the soil to a shallow depth for smoothening and pulverizing the soil as well as to cut the weeds and to mix the materials with the soil. There are several types of harrow used in India such as disc harrow, spike tooth harrow, spring tooth harrow, acme harrow, patela, triangular harrow, bade harrow, guntaka and reciprocating power harrow.

1.1. Disc harrow

It is a harrow, which performs the harrowing operation by means of a set, or a number of sets of rotating slat discs, each set being mounted on a common shaft. Disc harrow is found very suitable for hard ground, full of stalks and grasses. It cuts the lumps of soil, clods and roots. Discs are mounted on one, two or more axles which may be set at a variable angle to the line of motion. As the harrow is pulled ahead, the discs rotate on the ground. Depending upon the disc arrangements, disc harrows are divided into two classes a) Single action and b) Double action.

Single action disc harrow

It is a harrow with two gangs placed end to end, which throw the soil in opposite directions. The discs are arranged in such a way that right side gang throws the soil towards right, and left side gang throws the soil towards left (Fig.).

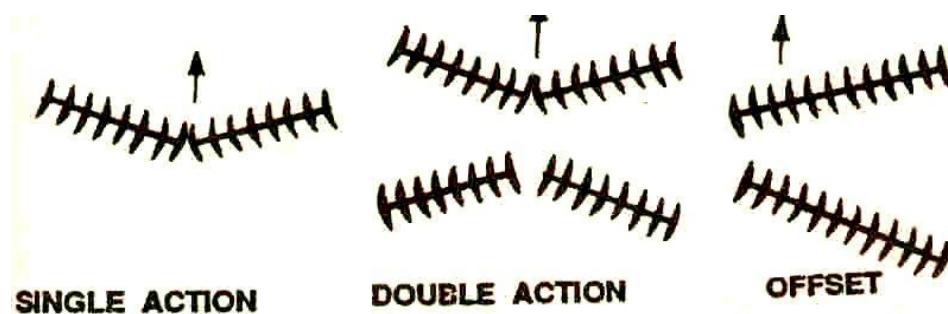


Figure 6 Types of disc harrow

Double action disc harrow

A disc harrow consisting of two or more gangs, in which a set of one or two gangs follow behind the set of the other one or two, arranged in such a way that the front and back gangs throw the soil in opposite directions. (Fig.). Thus the entire field is worked twice in each trip. It may be of two types a) Tandem and b) Off-set.

a) **Tandem disc harrow** - It is a disc harrow comprising of four gangs in which each gang can be angled in opposite direction (Fig.).

b) **Off-set disc harrow**- It is a disc harrow with two gangs in tandem, capable of being off-set to either side of the centre line of pull. Two gangs are fitted one behind the other. the soil is thrown in both directions because discs of both gangs face in opposite directions. (Fig.).

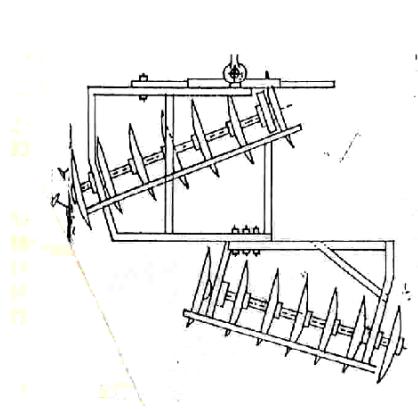


Figure 7 Tandem disc harrow

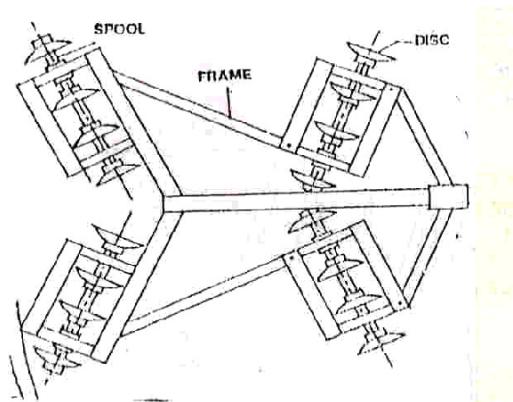


Figure 8 Offset disc harrow

A disc harrow mainly consists of disc, gang, gang bolt, gang central lever, spool or arbor bolt or spacer, bearings, transport wheels, scraper and weight box.

- i. **Disc:** It is a circular concave revolving steel plate used for cutting and inverting the soil. Disc is made of high grade heat-treated hardened steel. Tractor drawn disc harrows have concave discs of size varying from 35-70 cm diameter. Concavity of the disc affects penetration and pulverization of soil. Usually two types of disc are used in disc harrows, plain disc and cut away disc.
- ii. **Gang:** Each set of discs that are mounted on a common shaft is called the gang.
- iii. **Gang bolt or arbor bolt:** It is a long heavy square headed bolt from the other end, a set of discs are mounted on the gang bolt. The spacing between the discs on the gang bolt ranges from 15 to 25 cm for light duty and 25 to 30 cm for heavy-duty harrows.
- iv. **Gang control lever:** A lever, which operates the gang mechanisms of the disc harrow, is called the gang control lever.
- v. **SPOOL or spacer:** The flanged tube, mounted on the gang bolt between every two discs to prevent the lateral movement of the disc on the shaft is called the "spool" or 'spacer'.
- vi. **Bearing:** Bearing is essential to counteract the end thrust of the gang due to soil thrust. The harrow bearings are subjected to heavy radial and thrust loads chilled cast iron bearings are used to heavy radial and thrust loads and they are also used due to their durability.

vii. Transport wheel: In trailing type disc harrow, the transport wheels are provided for transport work on roads and for preventing the edges of the discs from damage. Mounted type disc harrows do not require wheels for transport work.

viii. Scraper: It prevents disc from clogging. It removes the soil that may stick to the concave side of the disc.

ix. Weight box: A box like frame is provided on the main frame of the harrow for putting additional weight on the implement. Additional weight helps in increasing the penetration of the disc in the soil.

A sharp edged disc has more effective penetration compared to blunt edged disc. It is observed that penetration is better in low speed than in high speed. The following are a few adjustments for obtaining higher penetration

- i. By increasing the disc angle
- ii. By adding additional weight in harrow
- iii. By lowering the hitch point
- iv. By using the sharp edged discs of small diameter and losses concavity
- v. By regulating the optimum speed.

1.2. Spike tooth harrow

It is a harrow with peg shaped teeth of diamond cross section to a rectangular frame. It is used to break the clod, stir the soil, uproot the weeds, level the ground, break the soil and cover the seeds. Its principle is to smoothen and level the soil directly after ploughing. Spike tooth harrows may be of rigid type and flexible type. Tractor drawn harrows are usually flexible type. It has got the advantage of being turned up for transporting purpose (Fig.9.) This harrow mainly consists of teeth, tooth bar frame, clamps, guard, braces, levers and hooks.

1.3 Spring tooth harrow

It is a harrow with tough flexible teeth, suitable to work in hard and stony soils. Spring tooth harrow is fitted with springs having loops of elliptical shape. It gives a spring action in working condition. It is used in the soil when obstruction like stone, roots and weeds are hidden below the ground surface. This type pulverizes the soil and helps in killing weeds. The levers are provided for setting the teeth for varying the depth of harrowing (Fig.10). For light harrowing, the adjustment is done in slanting position. Draft hooks on each corner of every section for hitching purpose.

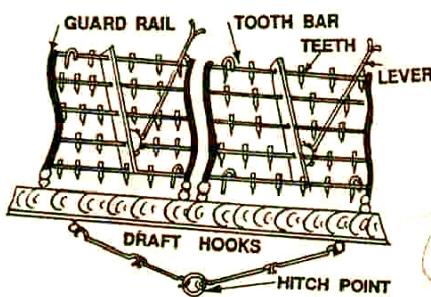


Fig.9. Spike tooth harrow

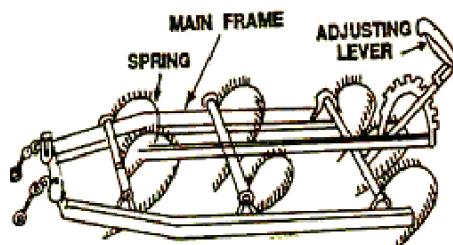


Fig.10. Spring tooth harrow

1.4. Acme harrow

It is a special type of harrow having curved knives. It is also called as knife harrow. The front part of the knife breaks the soil and crushes the clods (Fig.11). This harrow obtains a good pulverization. It is good for mulching also.

1.5. Patela

It is a wooden plank used for smoothening the soil and crushing the weeds. It is also used for breaking clods, packing and levelling the ploughed soil and to remove the weeds. It is made of a wooden plank with a number of curved steel hooks bolted to a steel angle section, which are fixed or hinged to the rear side of the plank (Fig.12). The cutting edge levels and packs the soil and the curved hooks uproot and collect the weeds.

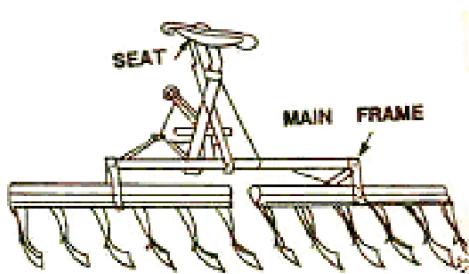


Fig.11. Acme harrow

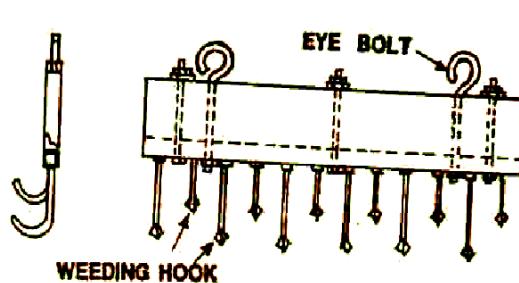


Fig.12. Patela

1.6. Triangular harrow

It is a spike tooth harrow with triangular frame (Fig.13). The frame is made of wood and pointed spikes are fitted in the frame. The teeth of the spikes are fixed and not adjustable.

1.7. Blade harrow (Bakhar)

It is an implement, which consists of one or more blades attached to the beam or frame, used for shallow working of the soil (Fig.14) with minimum soil inversion. It is used to prepare seedbeds mostly in clayey soils. It works like a sweep, which moves into top surface of the soil without inverting the soil.

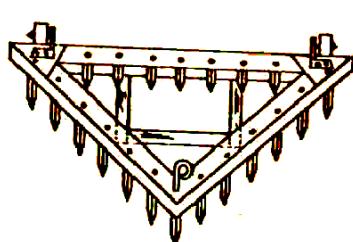


Fig. 13. Tri angular harrow

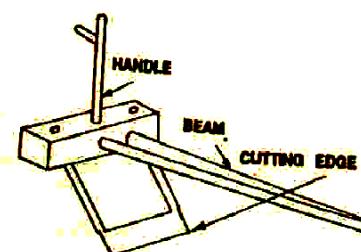


Fig.14. Blade harrow

1.8. Guntaka

It is an important type of blade harrow. It is an implement, which consists of one or more blades attached to a frame or beam. It is used for shallow working of the soil with minimum soil inversion. It is mainly used to prepare the seed bed mostly in clay soils. The function of Bakhar the same as that of the guntaka.

1.9. Reciprocating power harrow

It is a harrow fitted with rigid tynes driven by the power takes off in a reciprocating, transverse or rotary motion as the machine moves forward. The power tiller harrow is a rear mounted reciprocatory comb type (fig.15). It has two horizontal oscillating arms having staggered pegs in two rows at 200 mm spacing. Two sets of slider crank mechanisms provide power from power tiller PTO through universal joint and bevel gear reduction box to the arms. An eccentric embedded flywheel actuates the pitman. The two arms move in opposite directions and hence the implement is dynamically balanced. The amplitude of vibration is 200 mm and the frequency of operation is 400 cycles per minute. A transport wheel provided in the rear of the unit ensures depth control. The unit is attached to the power tiller through the hitch point provided in front portion of the unit. The oscillating pegs breaks the clod, pulverizes the soil to a fine tilth.

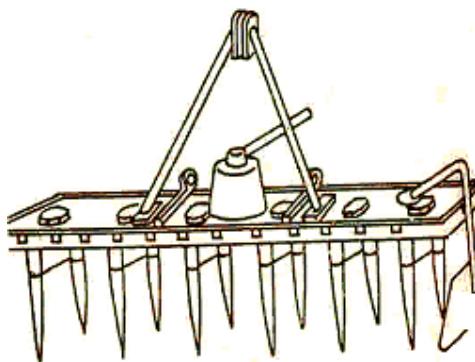


Fig.15. Reciprocating Harrow

2. Bund former

It is used for making bunds or ridges by collecting the soil. Bunds are required to hold water in the soil, thereby one can conserve moisture and prevent run-off. The size of the bund former is determined by measuring the maximum horizontal distance between the two rear ends of the farming boards. Bund former consists of forming board, beam and handle (Fig.16).

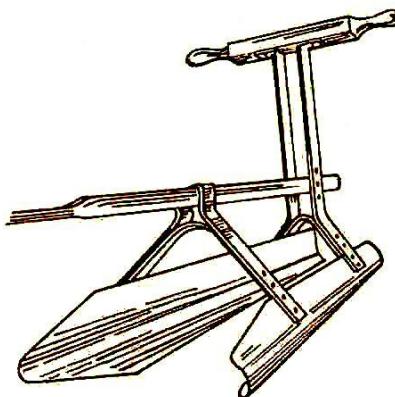


Fig. 16. Bund former

3. Ridger

It is an implement importantly used to form ridges required for sowing row crop seeds and plants in well-tilled soil. The ridger is also used for forming field or channels, earthing up and similar other operations. Ridger is also known as ridging plough and double mould board plough. The

ridger generally has 'V' shaped or wedge shaped share fitted to the frog. The nose or tip of share penetrates into the soil and breaks the earth. The mould boards lift, invert and also cast aside the soil, forming deep channels and ridges of the required size. A ridger consists of beam, clevis, frog, handle, mould boards, share and sliding share.

4. Puddler

Puddler is an implement for churning the soil with water. It is used to prepare paddyfields with standing water after initial ploughing with country plough. It breaks up the clods and churns the soil. The main purpose of puddling is to reduce leaching of water or decrease percolation of water, to kill the weeds by decomposition and to facilitate transplantation of paddy seedlings by making the soil softer. Puddling is done in standing water of 5-10 cm depth. A common puddler has puddling units each having four straight blades or paddles or fan type blades or squirrel type blade mounted on an axle. The axle with the puddling units is fully mounted on two bearings fitted on a frame made of metal or wood. The weight of the puddler is 30-40 kg. A puddler consists of a frame, puddling unit, axle, metal cross beam and handle.

5. Leveller

Land levelling is expected to bring permanent improvement in the value of land. Levelling work is carried out to modify the existing contours of land so as to achieve certain objectives desired for efficient agricultural production system. These objectives include

- (i) efficient application of irrigation water,
- (ii) improved surface drainage,
- (iii) minimum soil erosion
- (iv) increased conservation of rain water specially on dry lands and
- (v) provision of an adequate field size and even topography for efficient mechanisation.

6. Cultivators

It is an implement for inter cultivation with laterally adjustable tines or discs to work between crop rows. The cultivator stirs the soil, and breaks the clods. The tines fitted on the frame of the cultivator comb the soil deeply in the field. A cultivator performs functions intermediate between those of plough and the harrow. Destruction of weeds is the primary function of a cultivator. The following are a few important functions performed by a cultivator.

1. Interculture the fields.
2. Destroy the weeds in the field.
3. Aerate the soil for proper growth of crops.
4. Conserve moisture by preparing mulch on the surface.
5. To sow seeds when it is provided with sowing attachments.
6. To prevent surface evaporation and encourage rapid infiltration of rain water into the soil.

The cultivator can be 1) Disc cultivator, 2) Rotary cultivator, 3) Tine cultivator.

- **Disc cultivator :** It is a cultivator fitted with discs.
- **Rotary cultivator :** It is a cultivator with tines or blades mounted on a power driven horizontal shaft.
- **Tine cultivator :** It is a cultivator fitted with tines having shovels.
- **Tractor Drawn Cultivator**
- **Trailed type cultivator**

It consists of a main frame which carries a number of cross members to which tines are fitted. At the forward end of the cultivator, there is a hitch arrangement for hitching purpose. A pair of wheels are provided in the cultivator. The height of the hitch is adjusted so that main frame remains horizontal over a range of depth setting. The tines in each row are spaced widely to allow free passage of the soil and trash around them. The tines in subsequent rows are staggered so that the implement can cover the entire width nicely.

Mounted Cultivator

Tractors fitted with hydraulic lift operate the mounted type cultivators. A rectangular frame of angle iron is mounted on three point hydraulic linkage of the tractor. The cross members carry the tines in two staggered lines. Depending upon the type of soil and crop, shovels are chosen for use on the cultivators. Usually tractor drawn cultivators are of two types, depending upon the flexibility and rigidity of tines (i) Cultivator with spring loaded tines (ii) Cultivator with rigid tynes.

Cultivator with spring loaded tines

A tine hinged to the frame and loaded with a spring so that it swings back when an obstacle is encountered, is called spring loaded line. Each of the tine of this type of cultivator is provided with two heavy coil springs (Fig. 17), pre-tensioned to ensure minimum movement except when an obstacle is encountered. The springs operate, when the points strike roots or large stones by allowing the tines to ride over the obstruction, thus preventing damage. On passing over the obstruction, the tines are automatically reset and work continues without interruption. The tines are made of high carbon steel and are held in proper alignment on the main frame members. This type of cultivator is particularly recommended for soils which are embedded with stones or stumps.

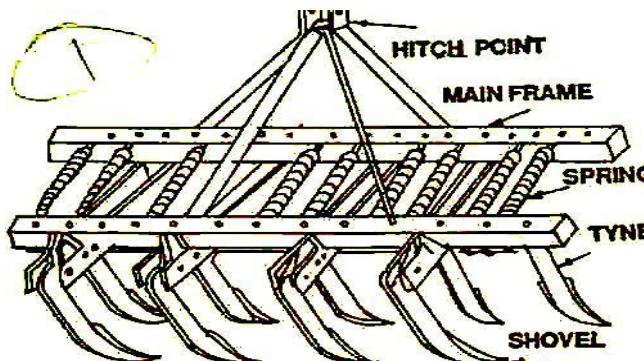


Fig.17 . Tractor drawn cultivator

Cultivator with rigid tines

Rigid tines of the cultivators are those tines which do not deflect during the work in the field. The tynes are bolted between angle braces, fastened to the main bars by sturdy clamps and bolts. Spacing of the tines is changed simply by slackening the bolts and sliding the braces to the desired position. Since rigid tines are mounted on the front and rear tool bars, the spacing between the tynes can be easily adjusted without getting the tines choked with stubbles of the previous crop or weed growth. A pair of gauge wheel is used for controlling the depth of operation.

Sowing & its equipment

Seeding or sowing is an art of placing seeds in the soil to have good germination in the field. A perfect seeding gives

- a. Correct amount of seed per unit area.

- b. Correct depth at which seed is placed in the soil.
- c. Correct spacing between row-to-row and plant-to-plant.

Sowing methods

(i) Broadcasting

Broadcasting is the process of random scattering of seed on the surface of seedbeds. It can be done manually or mechanically both. When broadcasting is done manually, uniformity of seed depends upon skill of the man. Soon after broadcasting the seeds are covered by planking or some other devices. Usually higher seed rate is obtained in this system. Mechanical broadcasters are used for large-scale work. This machine scatters the seeds on the surface of the seedbed at controlled rates.

(ii) Dibbling

Dibbling is the process of placing seeds in holes made in seedbed and covering them. In this method, seeds are placed in holes made at definite depth at fixed spacing. The equipment used for dibbling is called dibbler. It is a conical instrument used to make proper holes in the field. Small hand dibblers are made with several conical projections made in a frame. This is very time consuming process, so it is not suitable for small seeds. Mostly vegetables are sown in this way.

(iii) Drilling

Drilling consists of dropping the seeds in furrow lines in a continuous flow and covering them with soil. Seed metering may be done either manually or mechanically. The number of rows planted may be one or more. This method is very helpful in achieving proper depth, proper spacing and proper amount of seed to be sown in the field. Drilling can be done by (1) Sowing behind the plough (2) Bullock drawn seed drills (3) Tractor drawn seed drills.

(iv) Seed dropping behind the plough

It is very common method used in villages. It is used for seed like maize, gram, peas, wheat and barley. A man drops seeds in the furrow behind the plough. Sowing behind the plough can be done by a device known as malobansa. It consists of a bamboo tube provided with a funnel shaped mouth. One man drops the seeds through the funnel and other man handles the plough and the bullocks. This is a slow and laborious method.

(v) Transplanting

Transplanting consists of preparing seedlings in nursery and then planting these seedlings in the prepared field. It is commonly done for paddy, vegetable and flowers. It is very time consuming operation. Equipment for placing plants in the soil is called transplanter.

(vi) Hill dropping

In this method, seeds are dropped at fixed spacing and not in a continuous stream. Thus the spacing between plant to plant in a row is constant. In case of drills, the seeds are dropped in continuous stream and the spacing between plant to plant in a row is not constant.

(vii) Check row planting

It is a method of planting, in which row-to-row and plant-to-plant distance is uniform. In this method, seeds are planted precisely along straight parallel furrows. The rows are always in two perpendicular directions. A machine used for check row planting is called check row planter.

Seed drill

Seed drill is a machine for placing the seeds in a continuous flow in furrows at uniform rate and at controlled depth with or without the arrangement of covering them with soil.

Function of seed drill: Seed drill performs the following functions

- i) To carry the seeds.
- ii) To open furrow to an uniform depth
- iii) To meter the seeds
- iv) To place the seed in furrows in an acceptable pattern
- v) To cover the seeds and compact the soil around the seed.

Seed cum fertilizer drill

Seed drills, fitted with fertilizer dropping attachment, distribute the fertilizer uniformly on the ground. It is called seed cum fertilizer drill. Such a drill has a large seed box which is divided lengthwise into two compartments, one for seed and another for fertilizers. Seed drill may be classified as (i) Bullock drawn (ii) Tractor drawn.

Components of seed drill

A seed drill with mechanical seed metering device mainly consists of : (i) Frame (ii) Seed box (iii) Seed metering mechanism (iv) Furrow openers (iv) Covering device (vi) Transport wheels.

Frame: The frame is usually made of angle iron with suitable braces and brackets. The frame is strong enough to withstand all types of loads in working condition.

Seed box :It may be made of mild steel sheet or galvanized iron with a suitable cover. A small agitator is sometimes provided to prevent clogging of seeds.

Covering device: It is a device to refill a furrow after the seed has been placed in it. Covering the seeds are usually done by patta, chains, drags, packers, rollers or press wheels, designed in various sizes and shapes.

Transport wheel: There are two wheels fitted on the main axle. Some seed drills have got pneumatic wheels also. The wheels have suitable attachments to transmit power to operate seed dropping mechanism.

Seed metering mechanism

The mechanism of a seed drill or fertilizer distributor which delivers seeds or fertilizers from the hopper at selected rates is called *seed metering mechanism*. Seed metering mechanism may be of several types:

(a) Fluted feed type (b) Internal double run type (c) Cup feed type (d) Cell feed mechanism (e) Brush feed mechanism (f) Auger feed mechanism (g) Picker wheel mechanism (h) Star wheel mechanism.

(a) Fluted feed type- It is a seed metering device with adjustable fluted roller to collect and deliver the seeds into the seed tube. Fluted feed type mechanism consists of a fluted wheel, feed roller, feed cut-off and adjustable gate for different sizes of grains. (Fig.18). The feed roller and the feed cut-off device are mounted a shaft, running through the feed cups. The roller carries grooves throughout its periphery. It rotates with the axle over which it is mounted throws the grains out on the adjustable gate from where it falls into the seed tube. The fluted rollers which are mounted at the bottom of the seed box, receive seeds into longitudinal grooves and pass on to the seed tube through the holes provided for this purpose. By shifting the fluted wheel side ways, the length of the grooves exposed

to the seed can be increased or decreased and hence the amount of seed is controlled.

(b) **Internal double run type-** It is a seed metering device in which the feed wheel is provided with fine and coarse ribbed flanges. It consists of discs, mounted on a spindle and housed in a casing fitted below the seed box (Fig. 19). It has double faced wheel. Internal double-run type roller one face has a larger opening for larger seeds and the other face has smaller opening for smaller seeds. A gate is provided in the bottom-of the box to cover the opening not in use. The rate of seeding is varied by adjusting the speed of the spindle which carries the discs.

(c) **Cup feed mechanism-** It is a mechanism consisting of cups or spoons on the periphery of a vertical rotating disc which picks up the seeds from the hopper and delivers them into the seed tubes. It consists of a seed hopper which has two parts. The upper one is called grain box and the lower one is called feed box. The seed delivery mechanism consists of a spindle, carrying a number of discs with a ring of cups attached to the periphery of each disc (Fig. 20). The spindle with its frame and attachment is called seed barrel. When the spindle rotates, one disc with its set of cups rotates and picks up few seeds and drops them into small hoppers. The cups have two faces, one for larger seeds and the rate at which the seed barrel revolves. This type of mechanism is common on British seed drills.

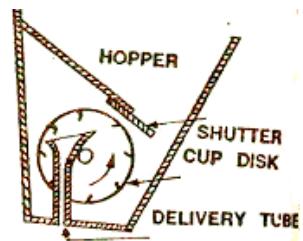
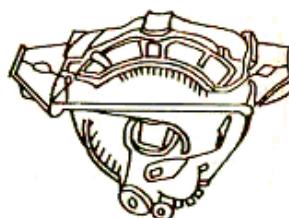
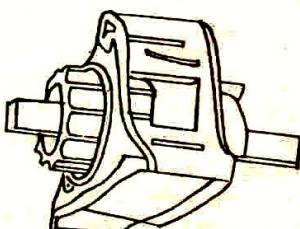


Fig.18. Fluted roller type mechanism

Fig.19. Internal double run

Fig20 . Cup feed

Interculture tools and implements

Weeds can compete with productive crops or pasture, or convert productive land into unusable scrub. Weeds are also often poisonous, distasteful, produce burrs, thorns or other damaging body parts or otherwise interfere with the use and management of desirable plants by contaminating harvests or excluding livestock. They provide competition for space, nutrients, water and light.

Dry land weeder

Dry land weeders with long handles are suitable for weeding in row crops in rain fed

and garden lands. The long handle eliminates the back strain and provides comfort to the operator for continuous operation in standing posture. This is a long handled tool and consists of 25 mm dia. 1200 mm long conduit pipe over which 520 mm long handle is fitted

Peg tooth type Star wheel type Dry land weeder (Fig 21.). To the bottom of the vertical pipe frame, two arms made of 250 x 25 x 3 mm of MS plates are fitted. At the extreme end of the

arm 120 mm dia star wheel is fixed.

The cutting blade is fitted to the bottom portion of the arm, and 200 mm to the back of the star

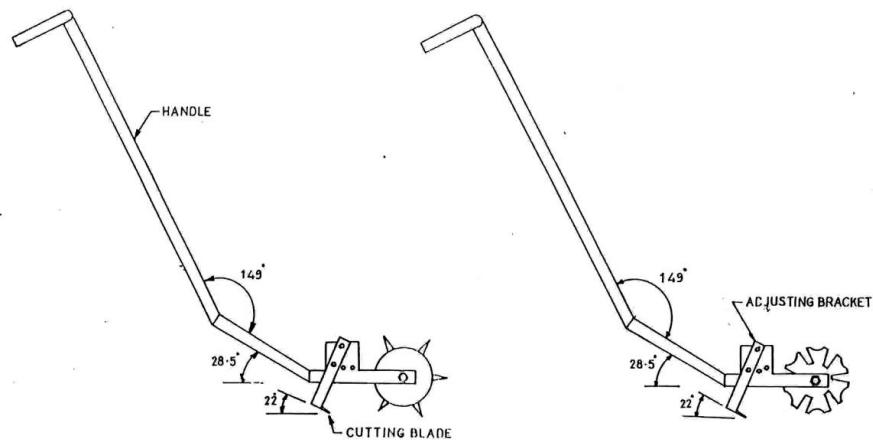


Figure 21 Dry land weeder

wheel. The star wheel facilitates easy movement of the tool. The cutting blade cuts the weeds. The operating width of the blade is 120 mm. The star type is suitable for operation in loamy and sandy soil. In the peg type the star wheel is replaced by pegs facilitating easier operation in clay soil. The coverage of the weeder is 0.05 ha/day.

2. Cono weeder for paddy

It is useful for uprooting and burying weeds in between standing rows of rice crop in wetlands. It disturbs the topsoil and increases the aeration. The unit consists of a long handle made of mild steel tube. Two truncated rollers one behind other are fitted at the bottom of the long handle (Fig.22). The conical rollers have serrated projections on the periphery. A float provided in the front portion prevents the unit from sinking into, the puddled soil. The cono weeder can also be used for trampling the green manure crop in addition to weeding operation. They are more efficient than manual pulling of weeds.

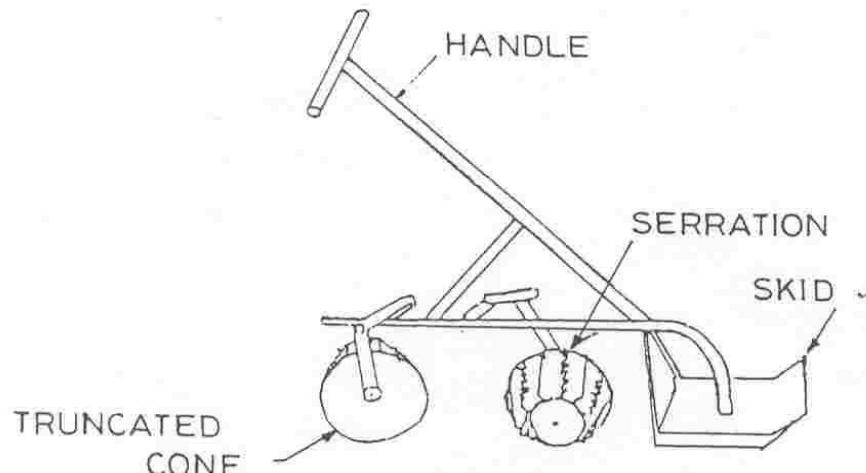


Fig.22 Cono weeder

3. Engine operated weeder

A 3-hp petrol start kerosene run engine operates the weeder. The engine power is transmitted to ground wheels through V belt-pulley and sprocket - chain mechanism. At the back of the machine a replaceable sweep blade is fixed (Fig.23). Sweep blades of different width can be fitted to the machine depending on the row to row spacing of the crop. A tail wheel is provided at the rear to maintain the operating depth. The sweep blade can be raised or lowered so as to have the desired operating depth. The cost of the unit is Rs. 50,000/- and the field capacity is 0.75 ha per day. The salient features of the unit are:

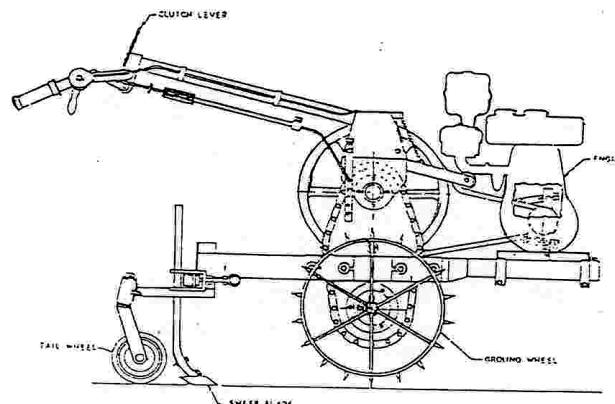


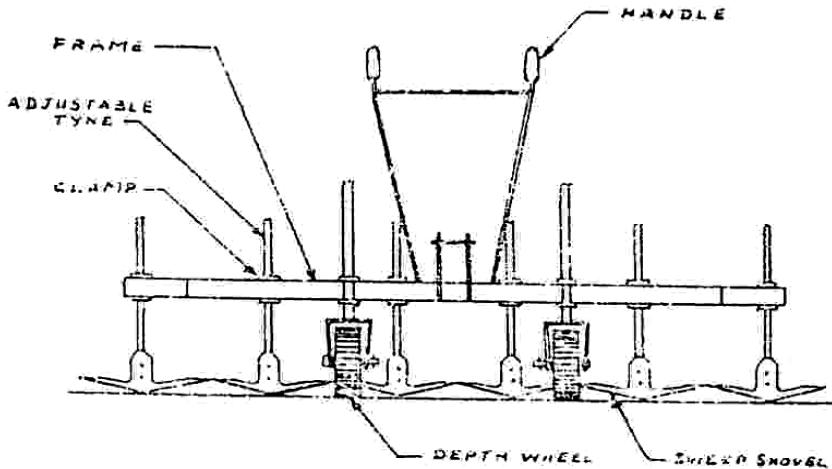
Fig 23 Engine operated weeder

- Useful for weeding between rows of crops like tapioca, cotton, sugarcane, maize, tomato and pulses whose rows spacing is more than 45 cm
- Can also be used for weeding and intercultural operations in orchards, coconut and areca nut plantations.

4. Sweep

It is an intercultural implement for removing shallow rooted weeds in between rows. The sweep consists of V shaped shovels with bevel edged wings. The shovels are held by the tynes fixed to a frame by means of counter sunk bolts and nuts. When the sweep is used for secondary tillage, five or six tynes may be clamped with the shovels in line having no gap in between them (Fig.24). By just skimming under the soil at a shallow depth of 2 to 3 cm, the sweep breaks the capillary in the soil pores and provides soil mulch. When the sweep is used for intercultural operations, the space between the shovels is adjusted to suit the row spacing of the crop and with different sizes of blades. The coverage is 1.75 to 2.5 ha/day. The salient features of the unit are:

- * Suitable for all row crops and soils; provides soil mulch and conserves soil moisture
- * Suitable for inter cultural operations.

**Fig. 24. Sweep**

5. Junior hoe

It is an interculture equipment used primarily for weeding in between the rows of standing crops. It consists of reversible shovels with curved tynes attached to framework with hinge arrangement. A handle and beam are fixed to the framework for guiding and attaching the unit to the yoke. The spacing between the shovel can be adjusted according to the row spacing of the crop. The coverage is 1.5 ha per day.

Plant protection equipment

Sprayers

Sprayer is a machine to apply fluids in the form of droplets. Sprayer is used for the following purpose.

- * Application of herbicides to remove weeds.
- * Application of fungicides to minimize fungus diseases.
- * Application of insecticides to control insect pests.
- * Application of micro nutrients on the plants. The main function of sprayer are
- * To break the liquid droplets of effective size.
- * To distribute them uniformly over the plants.
- * To regulate the amount of liquid to avoid excessive application.

Basic components of sprayer

Components of a sprayer are as follows

- | | | |
|--------------------|------------------|------------------------|
| (1) Nozzle body | (2) Swirl plate | (3) Filter |
| (4) Over-flow pipe | (5) Relief valve | (6) Pressure regulator |
| (7) Cut-off valve | (8) Spray boom | (9) Drop legs |
| (10) Nozzle boss | (11) Nozzle disc | (12) Nozzle cap |
| (13) Nozzle tip | (14) Spray lance | (15) Spray gun. |

**Fig.25. Sprayer components**

- **Nozzle body** - It is the main component on which other component of a nozzle fit (Fig. 25a).
- **Swirl plate** - It is the part of a cone nozzle which imparts rotation to the liquid passing through it (Fig. 25b).
- **Spray gun** - It is a lance from which spray is readily adjustable during the operation.
- **Spray boom** - It is a spray lance with spray nozzles fitted to a head, mounted at right angles to the lance (Fig. 25d).
- **Filter** - It is a component to remove suspended matter larger than a predetermined size from fluid.
- **Over-flow pipe** - It is a conduit through which excess fluid from a pump is by-passed by the action of a relief valve or pressure regulator.
- **Relief valve** - It is an automatic device to control the pressure of fluid or gas within range a predetermined value.
- **Pressure regulator** - It is an automatic device to control the pressure of fluid or gas within a range of settings.
- **Cut-off valve** - It is a mechanism between the pump and the nozzle to control the flow of liquid from the sprayer. This is operated by hand.
- **Nozzle disc** - It is component containing the final orifice of a nozzle usually a cone nozzle. **Nozzle boss** - It is a lug on spray boom or spray lance to which a nozzle body or cap is screwed.
- **Nozzle tip** - It is component containing the final orifice of a nozzle usually a fan nozzle. **Spray lance** - A hand-held pipe through which the liquid reaches the nozzle mounted at the free end.

Type of spray

- (1) High volume spray (more than 400 litres spray/hectare)
- (2) Low volume spray (5 to 400 litres, per hectare)
- (3) Ultra low volume (ULV) spray (less than 5 litres spray/hectare).

High volume spray

The dilute liquids are applied by hydraulic machines. It consumes more time and labour.

Low volume spray

It uses air steam from a fan as a pesticide carrier with small quantities of liquid. There is saving of material spraying.

Ultra low volume sprayer

The sprayer has a motor powered by 6 to 12 volt battery and is attached with a spinning disc, having grooves or teeth and rotates at a very high revolution per minute (4000- 9000). The spinning disc receives the concentrated chemical from a plastic container having a capacity of 1 litre (approx). Average droplet size varies between 35-100 micron. It is used for application of weedicide and for spraying small trees and crops.

Types of nozzle

The three common types of nozzle

- (a) Hollow cone nozzle (b) Solid cone nozzle (c) Fan type nozzle.

(a) Hollow cone nozzle

This liquid is fed into a whirl chamber through a tangential entry or through a fixed spiral passage to give a rotating motion. The liquid comes out in the form of a narrow conical sheet which then breaks up into small drops.

(b) Solid cone nozzle

This nozzle covers the entire area at small range. The construction is similar to hollow cone

nozzle with the addition of an internal jet which strikes the rotating liquid just within the orifice of discharge. The breaking of drop is mainly due to impact.

(c) Fan nozzle

It is a nozzle which forms narrow elliptical spray pattern. In this type the liquid is forced to come out as a flat fan shaped sheet which is then broken into droplets. This nozzles is mostly used for low pressure spraying.

Hand atomizer

This sprayer has a container of 0.5 to 3.5 litres capacity. The container has in side a built in pump. While in other cases, the air pump is mounted externally. In both the cases, the air pump outlet pipe is suspended in the container. The outer end of the pipe terminates in a nozzle with 0.6 – 1.6 mm diameter orifice. The container is filled to approximately three-

fourth of its capacity and air is compressed on the remaining space by means of the pump. Before use, the plunger type pump is worked to develop an air pressure of 0.15 – 0.35 kg/cm². The spray comes out from the nozzle usually via. a suitable trigger control valve. The application rate ranges from 18 to 45 litres per acre.

Hand compression sprayer: These sprayers are similar to the hand atomizer but are adopted for spraying large quantities of liquids. They are more easily operated than the knapsack sprayer. The typical hand compression sprayer comprises a tank for holding spray material and compressed air, vertical air pump with a handle, filling port, spray lance with nozzle and release and shut-off devices. Besides, it has a metal or plastic skirt which protects the bottom of the tank of the sprayer against wear and makes the sprayer stable when placed on the ground. It also serves as a base for the back- rest. In addition, it has adjustable straps. These should be made of cotton belt, leather or plastic. As the spraying proceeds, the pumping is required to maintain the normal pressure of 2.0 – 3.5 kg/cm².

Knapsack hand compression sprayer

It has a flat or bean-shaped tank designed to fit comfortably on the back of the operator. The capacity of the tank is 10-20 litres. It is generally, made of galvanized, iron, brass or stainless steel. Recently, plastic material has also been used for the construction of the spray tank. It is more expensive than the bucket pump, but is similar to its in principle. In some cases, it is provided with a built-in double barrel spray pump of piston or diaphragm type with a lever for operating. In other cases, the tank is provided with a single pump and pressure having a plunger pump and mechanical agitator. Higher outputs are provided by the plunger type pumps, than by the diaphragm pumps. However, the later type of pumps requires comparatively less energy for operation and also less maintenance.

The pressure developed in these sprayers depends on the pump and varies from 3 to 12 kg/cm² which is more than that developed in a hand compression sprayer. However, a pressure of 3-4 kg/cm² can be maintained in most cases without much effort. The sprayer can be used for spraying row crops, vegetables and nursery stocks and shrubs and trees 2-2.5m high. The coverage is 0.5-1.0 ha/day.

Rocker sprayer

This sprayer consists of pump assembly, platform with frame and fork, operating lever, pressure chamber, suction hose with strainer, delivery hose, extension rod with spray

nozzles, etc. The rocking movement of the handle helps in building pressure in the pressure chamber. There is no built in tank and separate spray tank is necessary. The sprayer builds up a high pressure of $14\text{-}18 \text{ kg/cm}^2$. In some it may be as much as 36 kg/cm^2 . It can therefore be used for spraying the field crops. The sprayer is popular in some of the coconut and arecanut areas. Long hose connections up to 30 m are made to one or two outlets.

Foot or pedal sprayer

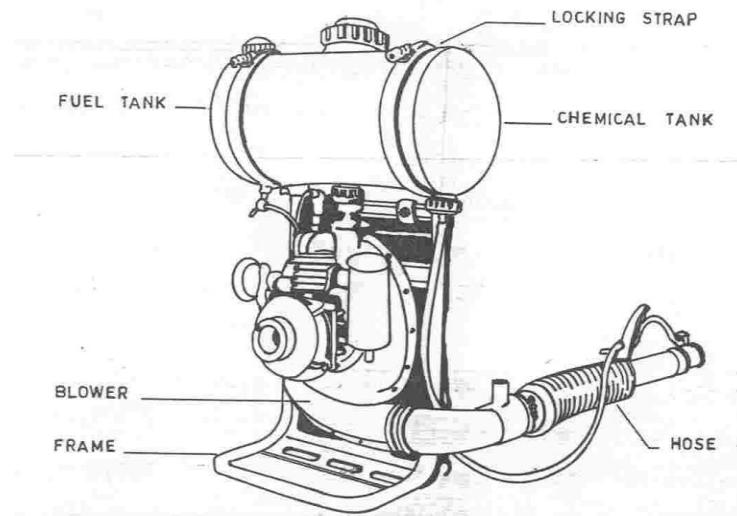
The foot or pedal sprayers, as they are commonly called, consist of plunger assembly, stand, suction hose, delivery hose, extension rod with a spray nozzle etc . One end of the suction hose is fitted with strainer and the other with a flexible coupling. Similarly, the delivery hose has one end fitted with a sheet off pistol and the other with a flexible coupling. Foot instead of hand operates it, but the principle is the same as in case of the rocker sprayer. The pump is fitted on iron stand and a pedal attached to the plunger rod operates the sprayer by its upward and downward movement. This sprayer also does not have a built-in tank. Constant pedalling is required for continuous spray. It develops a pressure of $17\text{-}21 \text{ kg/cm}^2$. It is easy to operate and can be used for spraying tall crops as well as fruit trees.

Power sprayer

Motorized knapsack sprayer:

Knapsack motorized sprayer are the versatile and simple power operated machines. The spray liquid is flown out by means of an air current generated in the machine. They deliver 6.8 to 42.5 m^3 (240 to 1500 ft^3) of air per minute at a velocity of $200\text{-}420 \text{ km}$ ($125\text{-}260 \text{ miles}$) per hour at the nozzle. The tank, which has a capacity of $10\text{-}12 \text{ lit}$, is mostly made of high density polyethylene (Fig26.). Another small tank of $10\text{-}15 \text{ lit}$ capacity is provided for the fuel. They are light, weighing $12\text{-}20 \text{ kg}$ including accessories. Generally, they are powered by $1.2\text{-}3.0 \text{ hp}$ petrol engines and the frame is provided with shock-proof cushion which comfortably fix on the back of the operator to eliminate vibrations of the engine. The delivery hoses are very small.

Some manufacturers also provide diffuser and deflector accessories with the delivery hose for adjusting the swath according to requirements. It is advisable not to load the tank to its full capacity. About half a litre space should be left to provide for air cushion. A part of the air generated by the blower is directed into the tank to form air cushion over the liquid within the tank. Liquid from the tank passed through a tube to the nozzle on the spray lance by gravity, partly helped by the air pressure exerted over the liquid within the tank. The machine, when fitted with a rotary pump and high tree lance can spray trees about 8 m high. The discharge rate can be adjusted differently and varies in different makes taking 0.4 to 3.0 minutes to discharge one litre. Effective width is $7\text{-}8 \text{ m}$ horizontally and $5\text{-}6 \text{ m}$ vertically. A power sprayer essentially consists of : (i) Prime mover (ii) Tank (iii) Agitator (iv) Air-chamber (v) Pressure gauge (vi) Pressure regulator (vii) Strainer (viii) Boom (ix) Nozzles.

**Fig.26. Motorized Knapsack sprayer**

- (i) **Prime mover** - Prime mover is needed to supply power to the power sprayer. It is usually combustion engine. The power generally varies from 1 to 5 HP.
- (ii) **Tank** - Steel tank is widely used to prevent corrosion. Plastic tanks are also getting popular due to freedom from corrosion and ease of moulding into smooth shapes. A covered opening, fitted with a removable strainer is provided for easy filling, inspection and cleaning. A drain plug is there at the bottom of the tank for draining the liquid.
- (iii) **Agitator** - Agitator are needed to agitate the liquid of the tank. Propeller or paddle type mechanical agitators are provided for agitating the liquid. Horizontal shaft may be used with flat blades rotating at about 100 to 120 rev/min. paddle tip seeds in excess of 2.5 m/sec may cause foaming.
- (iv) **Air chamber** - An air chamber is provided on the discharge line of the pump to level out the pulsations of the pump thereby providing a constant nozzle pressure.
- (v) **Pressure gauge** - The pressure gauge is provided on the discharge line to guide the operator regarding spray pressure. The spray pressure should be under specified limit.
- (vi) **Pressure regulator** - It is meant for adjusting the pressure of the sprayer according to the requirement of the crops in the field.
- (vii) **Strainer** - A strainer is included in the suction line between the tank and the pump to remove dust, dirt and other foreign materials.
- (viii) **Boom** - Field sprayer to be driven by a tractor has a long boom in a horizontal place on which nozzles are fixed at specified spacing. The boom can be adjusted vertically to suit the height of plants in different fields.
- (ix) **Nozzle** - It is used to break the liquid into the desired spray and deliver it to plants. A nozzle consists of: (a) body (b) screw cap (c) disc (d) washer (e) vortex plate (f) strainer. Usually the flow rate for a particular nozzle is proportional to the square root the pressure and the discharge rate is proportional to the orifice area. Nozzles have smaller angles. Operating pressure below 1.5 kg/cm^2 is undesirable because the nozzle does not work satisfactory.

Hand Rotary Duster

This consists basically of a blower completely with a gearbox and a hopper. It is operated by rotating the crank. The cranking motion is transmitted through the gearbox to the blower. A drive is taken from the dust agitator located in the hopper. The rotary duster may be hand carried type or shoulder mounted or hand carried type. The feeder is controlled by a feed control lever, which operate a slide to control the aperture at the bottom of the hopper.

Motorized knapsack duster

Knapsack dusters are common in India. The capacity of the hopper is about 9 kg. The discharge of the dust can be controlled by rotating the plated hose on the blower elbow, which carries the discharge hose. In the spraying cum dusting unit, the conversion of sprayers to duster is very simple and effected by replacing the liquid feed tubes by appropriate dust feeds. Agitation is provided by directing a part of air from the discharge. The dust tank may be the same as for the spray unit except that all the liquid feeds are removed. In some cases, there is a separate unit for replacing the spray lance. Part required for conversion of a sprayer into duster can be purchased at nominal cost from the suppliers of knapsack sprayers cum dusters.

Battery operated sprayer

The battery operated sprayer developed consists of a 10 lit capacity plastic tank and a 6 Volt rechargeable battery both fixed in a frame which is carried on the back of the operator. A plastic spinning disc along with a micro motor is fitted at the end of an aluminium handle. Chemical is taken from the tank to the spinning disc through a plastic hose. A cut off valve is provided in the hose line to stop of flow of spray fluid when desired. The salient features of the unit are light in weight, less water requirement & low cost.

Harvesting & threshing equipment

Harvesting

It is the operation of cutting, picking, plucking and digging or a combination of these operations for removing the crop from under the ground or above the ground or removing the useful part or fruits from plants.

Harvesting action can be done by four ways:

- 1) Slicing action with a sharp tool.
- 2) Tearing action with a rough serrated edge
- 3) High velocity single element impact with sharp or dull edge.
- 4) Two elements scissors type action.

Manual harvesting involves slicing and tearing action. Harvesting can be done by: (i) Manually operated tool (ii) Animal drawn machine (iii) Mechanically operated machine. There are a few related terms in connection with harvesting, which are as below:

Mower: It is a machine to cut herbage crops and leave them in swath.

Reaper: It is a machine to cut grain crops.

Reaper binder: It is a reaper, which cuts the crops and ties them into neat and uniform sheaves.

Swath: It is the material as left by the harvesting machine.

Sickle: It is a curved steel blade having a handgrip and used for harvesting by manually.

Windrow: It is a row of material formed by combining two or more swaths.

Windrower: It is a machine to cut crops and deliver them in a uniform manner in a row.

Sickle:

Sickle is a simple harvesting tool. It is used for harvesting crops and cutting other vegetations. It essentially consists of a metallic blade and a wooden handle. Sickles are classified into two classes: (i) Plain and (ii) Serrated. Blade is the main metallic part of the sickle. It is desirable to make the blade made of carbon steel. The blade is made in a curved shape. The teeth of serrated sickle are made sharp for efficient working in the field. The handle of the sickle is made of well-seasoned wood. The forged end of the blade for fixing the handle is called tang. The plain or serrated edge in the inner side of the blade is called cutting edge. Protective metallic bush fitted at the junction of the blade and the handle to keep the tang tight in the handle is called ferrule. Harvesting by sickle is a very slow and labour consuming device.

Sickle

Mower:

Mower is a machine to cut herbage crops and leave them in swath.

There are different types of mower used in different ways such as: (i) Cylinder mower (ii) Reciprocating mower (iii) Horizontal rotary mower (iv) Gang mower and (v) Flail mower.

Cylinder mower: It has rotating helical blades arranged in horizontal cylindrical form. With the rotation of blades, forage or grasses are cut continuously.

Reciprocating mower: It is a mower with a knife having sections that reciprocate against stationary fingers. It is most common type of mower used everywhere.

Horizontal rotary mower: It is a mower with high speed knife rotating in the horizontal plane. Due to rotation of knife, the grasses and forage are cut in uniform way.

Gang mower: It is an assembly of two or more ground driven cylinder mowers.

Flail mower: It is a mower with high speed swinging knives, operating either in a horizontal plane or around a horizontal cylinder.

Conventional Type of Mower

The conventional mower mainly consists of : (i) Frame (ii) Power transmitting unit (iii) Cutting bar (iv) Shoes (v) Ledger plate (vi) Wearing plate (vii) Knife (viii) Grass board and (ix) Pitman.

Frame

The frame provides space for gears, clutch and bearings. The lever for lifting the cutting bar is attached to the frame. A flywheel is used to store energy to provide steady speed to the cutting mechanism.

Power transmitting unit

The power-transmitting unit consists of axle, gears, crank wheel, crankshaft and pitman. Tractor drawn semi-mounted or mounted type mowers are operated by P.T.O. shaft. In this case, the cutting mechanism is driven independently of the forward speed of the mower. A shaft is connected with the P.T.O. shaft which drives a pulley with the help of an universal joint. This V pulley rotates another smaller pulley on the crankshaft of the machine and reciprocating motion is transmitted to the cutter bar.

Cutter bar

It is an assembly comprising of fingers, knife guides, on wearing plates and shoes. It is used for cutting grasses and forage. It is made of high grade steel. It works like a knife. The knife is a metal bar, on which triangular sections are mounted. The knife section makes reciprocating motion and cuts the plants. There are knife guards, provided on the cutter bar. The knife stops at the centre of the guard on each stroke. There are ledger plates provided with the knife guard, on which the knife moves. Knife clips hold the sections down against the ledger plates. Knife clips are placed with wearing plates spaced 20 to 30 cm apart.

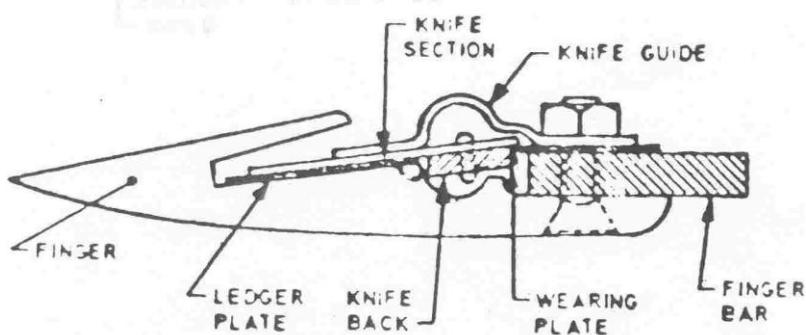


Figure 28 Cutter bar

Shoe - A shoe on each end of the cutter bar is always provided to regulate the height of cut above the ground. The inner shoe is larger in section and is placed at the inner end of the cutter bar. The outer shoe is placed at the outer end and is smaller in section.

Ledger plate - It is a hardened metal inserted in a guard (finger) over which knife sections move to give a scissor like cutting action.

Wearing plate - It is a hardened steel plate attached to the finger bar to form a bearing surface for the back of the knife.

Knife - It is the reciprocating part of the cutter bar, comprising of knife head, knife back and knife sections.

Knife section - It is a flat steel plate (triangular shape) with two cutting edges.

Knife head - It is the portion of the knife which is connected to the pitman.

Knife back - It is the strip of steel to which knife sections are riveted and the knife head is attached

Grass board - Grass board is provided at the cutter end of the mower which causes the cut plants to fall towards the cut material. Shoes are provided for easy and smooth sliding of the cutter bar.

Pitman - Pitman is a type of connecting rod which is pinned to the crankshaft with the help of a pin. It transmits reciprocating motion to a knife head. Wooden pitman is commonly used for the mowers.

Breaking of knives - Breaking of knives is a common trouble in operation of a mower. It is caused due to play in bearings and worn knife head holders. Non-alignment is an important cause for breaking the knife because when the mower is out of alignment, it works on a certain angle which is always harmful.

Alignment of mower

Under working condition of the mower, the standing crops exert pressure on the cutter bar tending to push it backward. In correct operating position, the crankpin, knife head and the outer end of the knife should be in a straight line. This line should be at right angle to the direction of travel of the mower. For achieving this object, the cutter bar is set at about 88° to the direction of motion i.e. inward lead of 2° is given to it in order to overcome the back pushing action of the crops. When the cutter bar is properly aligned, the knife and the pitman run in a straight line. This gives better cutting in the field. Generally 2cm lead per meter length of cutter bar is recommended.

Registration of mower

A mower knife is said to be in proper *registration* when the knife section stops in the centre of its guard on every stroke i.e. the centre of the knife section is at the centre of the guard, when it is in operating condition. Adjustment is commonly made by moving the entire cutter bar in or out with respect to the pitman. If mower is not well registered, there is unbalanced load, uneven harvesting and excessive clogging of crops on the knife.

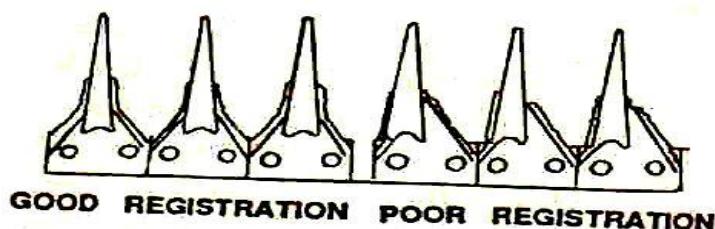


Figure 29 Registration of mower

Vertical conveyer reaper (Self operated/Tractor mounted): It is mostly used for harvesting paddy and wheat. The reaper is front mounted at the tractor, which can be lowered and raised by the hydraulic control. It is powered by the PTO of the tractor. Crop is guided by the star wheel to the cutter bar and held in vertical position by the springs. The crop is conveyed to the side by the conveyer belt. Its capacity may be 0.4-0.6 ha/h.

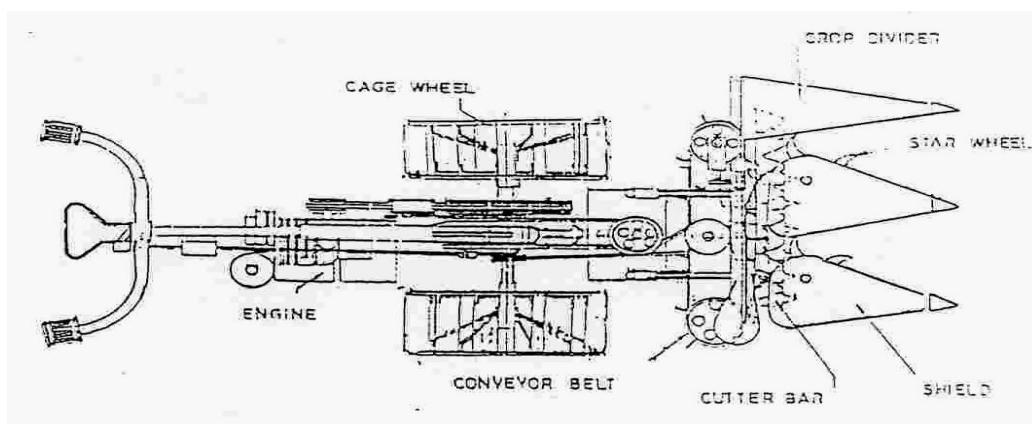


Figure 30 Self operated VCR

Vertical conveyer reaper (Power tiller operated): It can be used for harvesting wheat and paddy. The reaper is front mounted on the power tiller. Power is transmitted from the engine fly wheel to the reaper either through V belt or by providing gear box and propeller shafts. Crop is guided by the star wheels to the cutter bar and held in vertical position by the springs. The crop is conveyed to the side by the conveyor belt. Cutter bar length may be 100-160 cm. The capacity may be 0.25-0.35 ha/h.

Reaper binder: It cuts and binds the crop simultaneously. It cuts the crop at the height of about 10 cm from the ground level. The harvesting capacity is 0.25-0.35 ha/h.

Groundnut digger shaker: It is used for digging of groundnut crop. It is a tractor mounted PTO operated machine, suited for harvesting of both erect and spreading varieties of groundnut crop, grown in all types of soil. It consists of digging blade and a spike tooth conveyor.

Potato digger elevator: It is used for digging and windrowing the potatoes. The equipment is a PTO operated single row machine. The machine consists of cutting blade and elevator roller chain of iron bars. The potatoes are dug by the blade and lifted to a conveyor which is under periodic shaking. The potatoes are delivered at the rear of machine and collected manually. It is a tractor rear mounted PTO driven machine. Its capacity may be 0.15-0.2 ha/h. It can be operated by a 20-25 hp tractor. The groundnut vines are loosened by the blade and whole crop is lifted and Shaken by conveyor chain to remove all the soils. Thereafter the vines free of soil are dropped and windrowed behind the machine. The vines are collected manually.

Threshing

Thresher is a machine to separate grains from the harvested crop and provide clean grain without much loss and damage. During threshing, grain loss in terms of broken grain, un-threshed grain, blown grain, spilled grain etc. should be minimum. Bureau of Indian Standards has specified that the total grain loss should not be more than 5 per cent, in which broken grain should be less than 2 per cent. Clean un-bruised grain fetch good price in the market as well as it has long storage life.

Traditional threshing methods

Trampling of paddy under feet, beating shelves of rice or wheat crop on hard slant surface, beating crop with a flail, treading a layer of 15 to 20 cm thick harvested crop by a team of animals are traditional methods followed by farmers depending upon capacity, lot size and situation. Tractor in many places is now used in place of animals for treading. Introduction of animal drawn olpad thresher reduced the drudgery of the operator and gave comparatively higher output per unit time. In all above methods the threshed materials are subjected to winnowing either in natural wind flow or blast from winnowing fan for separation of grain from straw. Threshing wheat by traditional method involves drudgery and takes more time to obtain required quality of bhusa. Due to these, mechanical threshers are widely accepted by the farmers.

Different parts of a thresher and their functions

A mechanical thresher consists of the following parts i. Feeding device (chute/tray/trough/hopper /conveyor) ii. Threshing cylinder (hammers/spikes/rasp-bars/wire-loops/syndicator) iii. Concave (woven-wire mesh/punched sheet/welded square bars) iv. Blower/aspirator v. Sieve-shaker-straw-walker.

Working principle of a thresher

During operation, the crop material is slightly pushed into the threshing cylinder through the feeding chute, which gets into the working slit created between the circumference of the revolving drum having attached spikes and the upper casing. The speed of the spikes is greater than the plant mass due to which they strike the latter which results in part of the grain being separated from straw. Simultaneously, the drum pulls the mass through the gap between the spikes and the upper casing with a varying speed. The angle iron ribs on the other hand, restrain the speed of the travelling of stalks clamped by the spikes. Due to this the spikes move in the working slit with a varying speed in relation to the shifting mass of material, which is simultaneously shifted, with a varying speed with respect to the upper casing. As a result, the material layer is struck several times by the spikes against the ribs, causing threshing of the major amount of grains and breaking stalks into pieces.

As the material layer shifts towards the progressively converging slit of lower concave, its size reduces. The vibration amplitudes, therefore, decrease where as the speed of the layer increases. This causes mutual rubbing of the ear stalks, as well as rubbing of the ears against the m is closed, the thicker stalk, which cannot be sieved through the concave, again joins the fresh stalk and edges of the concave bars and causes breaking of stalks depending on the concave clearance. Since the systeth same process is repeated until the stalk size is reduced to the extent that it can pass through the concave apertures. Thus fine bruised straw is produced. The effective threshing process means that the loss of un-threshed kernels ejected with the straw through the concave and the loss of grain damage should be low and the amount of the material passed through the concave should be high.

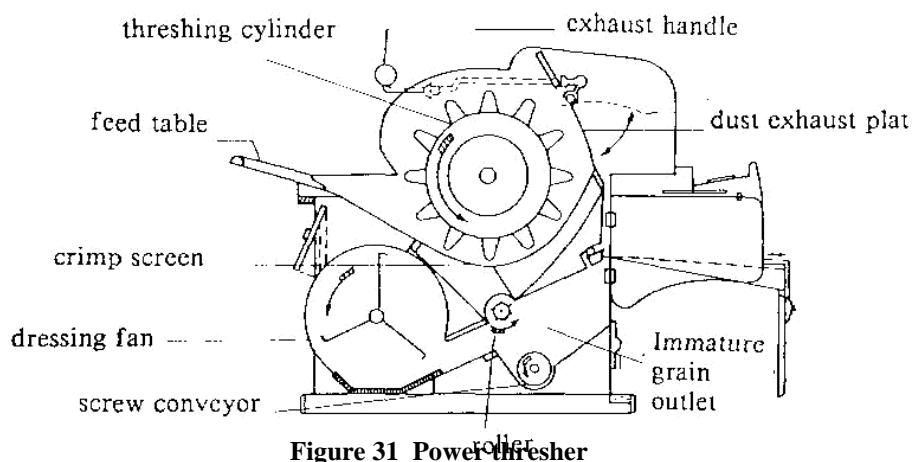


Figure 31 Power thresher

Adjustments

Various adjustments are required before starting threshing operation. The machine is to be installed on clean level ground and is to be set according to crop and crop conditions. The adjustments necessary to get best performance from the machine are (i) concave clearance, (ii) sieve clearance, (iii) sieve slope, (iv) stroke length and (v) blower suction opening. Besides these, cylinder concave grate, top sieve hole size and cylinder speeds for threshing different crops are important for a multi-crop thresher.

Different type of thresher and their suitability for crops

The type of thresher is generally designed according to the type of threshing cylinder fitted with the machine. The major type of threshers commercially available is as follows:

i. Dummy type

It consists of beaters mounted on a shaft which rotates inside a closed casing and concave.

ii. Hammer mill type

It is similar to dummy type but it is provided with aspirator type blower and sieve shaker assembly for cleaning grains.

iii. Spike-tooth type

Spikes are mounted on the periphery of a cylinder that rotates inside a closed casing and concave. It is provided with cleaning sieves and aspirator type blower.

iv. Raspbar type

Corrugated bars are mounted axially on the periphery of the cylinder. It is fitted with an upper casing and an open type concave at the bottom of the cylinder. The cleaning system is provided with blower fan and straw walker.

v. Wire-loop type

Wire-loops are fitted on the periphery of a closed type cylinder and woven wire mesh type concave is provided at the bottom.

vi. Axial flow type

It consists of spike tooth cylinder, woven-wire mesh concave and upper casing provided with helical louvers.

vii. Syndicator type

The cylinder consists of a flywheel with corrugation on its periphery and sides, which rotates inside a closed easing and concave. The rims of the flywheel are fitted with chopping blades.

Factors affecting thresher performance

The factors which affect the quality and efficiency of threshing are broadly classified in three groups:

i. Crop factors: Variety of crop, Moisture in crop material.

ii. Machine factors: Feeding chute angle, Cylinder type, Cylinder diameter, Spike shape, size, number Concave size, shape and clearance

iii. Operational factors: Cylinder speed, Feed rate, method of feeding, Machine adjustments.

Combine

It is a machine designed for harvesting, threshing, separating, cleaning and collecting grains while moving through standing crops. Bagging arrangement may be provided with a pick up attachment. The main functions of a combine are:

(i) Cutting the standing crops (ii) Feeding the cut crops to threshing unit (iii) Threshing the crops (iv) Cleaning the grains from straw (v) collecting the grains in a container.

2. Header (2) Reel (3) Cutter bar (4) Elevator canvas (5) Feeder canvas (6) Feeding drum (7) Threshing drum (8) Concave unit (9) Fan (10) Chauffer sieve (11) Grain sieve (12) Grain auger (13) Tailing auger (14) Tail board (15) Straw spreader (16) Return conveyor (17) Shaker (18) Grain elevator (19) Grain container.

Header is used to cut and gather the grain and deliver it to the threshing cylinder. The straw is pushed back on the platform by the reel. Small combines use *scoop type* headers, while large combines use T type headers with auger tables.

Harvesting is done by a cutting unit, which uses a cutter bar similar to that of a mower. The knife has got serrated edge to prevent the straw from slipping while in operation. There is suitable cutting platform which is provided with a reel and a canvas. The reel is made of wooden slats which help in feeding the crops to the cutting platform. The reel gets power through suitable gears and shafts. The reel revolves in front of the cutter bar, while working in the field. The reel pushes the standing crops towards the cutting unit. The reels are adjustable up and down as in or out. The cutter bar of the combine operates like a cutter bar of a mower. It cuts the standing crops and pushes them towards the conveyor. The conveyor feeds the crop to the cylinder and concave unit. The grain is swept underneath the augers and conveyed behind them. The threshing takes place between the cylinder and concave unit of the combine. The basic components of the threshing unit of the combine are similar to a power thresher. As soon as the crops are threshed, the threshed materials move to a straw rake. These rakes keep on oscillating and separating the grains. The cleaning unit consists of a number of sieves and a fan. The cleaning takes place on these sieves with the help of the fan. The un-threshed grains pass through tailing augur and go for re-threshing. The clean grains pass through grain elevator and finally go to packing unit. Grains are collected in a hopper provided at suitable place. The fan is adjusted such that the chaff etc is blown off to the rear side of the machine. The size of the combine is indicated by the width of cut, it covers in the field.

A combine may be (i) Self propelled type and (ii) P T O driven type.

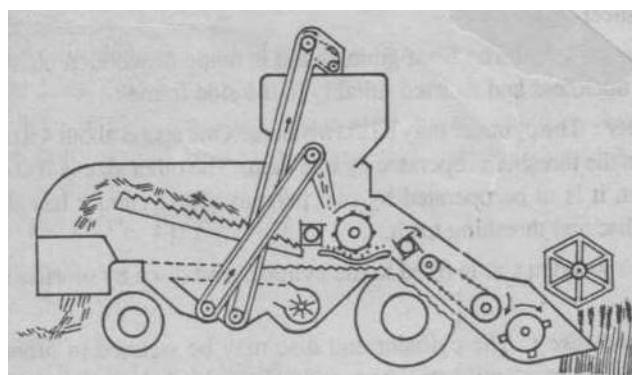


FIG.32 Combine

Post harvest Technology

Post harvest technology is inter-disciplinary "Science and Technique" applied to agricultural produce after harvest for its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of the people in relation to their needs. It has to develop in consonance with the needs of each society to stimulate agricultural production; prevent post-harvest losses, improve nutrition and add value to the products. In this process, it must be able to generate employment, reduce poverty and stimulate growth of other related economic sectors. The process of developing of post harvest technology and its purposeful use needs an inter-disciplinary and multi-dimensional approach, which must include, scientific creativity, technological innovations, commercial

entrepreneurship and institutions capable of inter-disciplinary research and development all of which must respond in an integrated manner to the developmental needs.

Post Harvest Technology- Importance and Role

Post harvest loss reduction technology encompasses the usage of optimum harvest factors, reduction of losses in handling, packaging, transportation and storage with modern infrastructure machinery, processing into a wide variety of products, home scale preservation with low cost technology. Use of thermal processing, low temperature, drying, chemical and biological reactions coupled with other preservation techniques are applied to enhance the storability. Containers and packaging materials confer portability as well as extend the shelf-life. Adoption of these techniques could make available a large quantity of food by avoiding losses and provide better quality food and nutrition, more raw materials for processing, thus ensuring better returns to the farmers.

Importance of Post-harvest technology lies in the fact that it has the capability to meet food requirement of growing population by eliminating losses making more nutritive food items from raw commodities by proper processing and fortification.

Post-harvest technology has potential to create rural industries. India, where 80 percent people live in the villages and 70 percent of them depend on agriculture has experienced that the process of industrialization has shifted the food, feed and fibre industries to urban areas. This process has resulted in capital drain from rural to urban areas, decreased employment opportunities in the rural areas balance trade in favour of urban sector and mismatched growth in economy and standard of living between rural and urban people. It is possible to evolve appropriate technologies which can establish agricultural based rural industries. The farmer whose role has been reduced to producer can be transformed into producer cum processor and thus getting more dividends for hard labour, input, kind of risk taken and generating resource for socio-economic advancement keeping pace with the modern times.

Status of food processing Industry

Important sectors in agro processing industries are: fruit and vegetable processing, grain processing, fish processing, milk processing, meat and poultry processing, packaged/convenience foods, alcoholic beverages and soft drinks etc.

Agricultural processing may be defined as an activity, which is performed to maintain or improve the quality or to change the form or characteristics of the agricultural product. Processing operations are undertaken to add value to agricultural materials after their production. The main purpose of agricultural processing is to minimize the qualitative and quantitative deterioration of the material after harvest.

Primary processing: Purification of raw materials by removing foreign matter, immature grain and then making the raw material eligible for processing by grading in different lots or conversion of raw material into the form suitable for secondary processing.

Secondary processing: Processing of primary processed raw material into product which is suitable for food uses or consumption after cooking, roasting, frying etc.

Tertiary processing: Conversion of secondary processed material into ready to eat form.

Food items are marketed in different forms as raw, primary processed, secondary processed and tertiary processed. The farmers in general prefer to sell their agricultural produce immediately after harvest leaving a part for own consumption and seed purposes. It has estimated that the farmers retain 44 per cent of the total wheat and 48 per cent of the paddy.

Mandies and grain traders procure the balance for processing and / or for marketing.

The food processing sector in India has gained importance due to consumers preferences for ready to cook (RTC) and ready to eat (RTE) foods, besides increased demand for snack foods and beverages. As much as 42 per cent of the food industry is in the organized sector and 33 per cent in the small scale, tiny and cottage sectors.

Sector wise food processing

Fruits and vegetable processing

India is the world's second largest producer of fruits and vegetables. It has potential to grow all types of temperate, sub - tropical and tropical fruits and vegetables because of varied agro - climatic diversity. The total production of fruits and vegetable is over 45 million tones and 85 million tonnes respectively. The losses are estimated to the extent of 20 -30 per cent due to lack of proper harvesting, processing and storage facilities, which is valued at Rs. 230 billion. The processed products from fruits and vegetables are beverages, jams, jellies, candies, preserves, canned fruits and vegetables, dehydrated fruits and vegetables, pickles, soup mixes, sauces and ketchups. Products that have growing demand, especially in the Middle East countries include pickles, chutneys, fruit pulps, canned fruits and vegetables, concentrated pulps and juices, dehydrated vegetables and frozen fruits and vegetables.

People generally prefer fresh fruits and vegetables in India due to abundance of seasonal fruits throughout the year available at low price. The production of pickles and chutneys has traditionally been rural level cottage industrial activity. However, in the recent years, processed foods in the form of canned fruits such as pineapple, mango slices and pulps, grapes, apple, peaches etc have increased considerably. The uses of fruits in the form of concentrated juice, dry powder, jam and jelly have also increased. The percentage production of processed fruits and vegetables are fruit juice and fruit pulp - 27, jams and jellies - 10, pickles -12, ready to serve beverages -13, synthetic syrups - 8, squashes - 4, tomato products - 4, canned vegetables- 4 and others -18.

The main fruits that enter the export market are mangoes, grapes, apples, citrus but other fruits identified for export are bananas, sapota, litchis etc. The main destinations for export of fruits being Middle East, U.K., Europe and to some extent Singapore, Malaysia etc. The important vegetables exported are potatoes (28.0%), onions (7.1%), cauliflower and cabbage (4.0 % each), okra (3.0%), peas (3.0%) and others (50.0 %).The exports are limited to Middle East, Europe, U.K and Singapore etc. At rural level solar assisted dehydrators could be promoted for preparation of ethnic food products like raisins, onion flakes and powder, chips, vegetables etc.

Food grain sector

Grains could emerge as a major export earner for India in coming years. India's food grains include rice, jowar, bajra, maize, wheat, gram and pulses.

Rice milling: Conventional rice hullers with a population of 91287 are very popular for milling of rice in rural areas. In conventional rice hullers, bran and husk are produced together and cannot be separated. The by - product is generally burnt. The modern rice mills have separate processing mechanism for dehusking and polishing of the paddy. The husk can be utilized for energy and for industrial products like furfural and the bran for extraction of edible and non edible grades oil. These mills also have better recovery and lower energy consumption compared to conventional hullers.

Wheat milling: Wheat production in the country has increased to more than 73.53 million tonnes. Burr mills (chakkis) are very common for milling of wheat in rural and urban areas. Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Bihar, West Bengal, Punjab, Haryana, Madhya Pradesh, Assam, Gujarat, Kerala have the largest number of roller flour mills. At present flours made by the roller mills are sold to institutional buyers like defence, hotels etc., and the household purchase is limited to only 1.0 per cent due to absence of open policy for sale of wheat flour through public distribution system. Sale of soy blended and branded wheat flour is likely to increase due to better quality flour and thus scope of organized wheat milling will increase in future.

Pulse milling: Pulses are the major sources for protein for the vegetarians in India. In a total world production of 60 million tonnes of pulses, India, China, Brazil, Turkey and Mexico account for 2 / 3 rd of the output. The pulses are made into dhal by dehusking and dehulling.

Oil extraction: The Technology Mission on oilseeds has helped in increasing the oilseeds production to 24.5 million tonnes. Oil extraction has been a cottage level activity in the country through Kolhus and Oil Ghanis. The introduction of high capacity mechanical expellers and solvent extraction technology has brought in modernization. Small capacity oil expellers have been developed which could be installed in rural areas for promoting agri - business and that might provide more employment. Soybean is not only a good source of oil but also rich in protein. India is now the fifth largest producer of soybean at a global level with production of more than 5.2 million tones. Soymilk analogues, nuggets and soy - blends are being marketed.

Processing of commercial crops

Sugarcane, tea and coffee are major commercial crops grown in India. Tea emerged as major foreign exchange earner. India is the largest producer and exporter of black tea. India exports between 150 -170 million kilograms of tea per annum. Of course, the scope of foreign investment in this sector is good and the multinational tea companies would either be trying for marketing joint ventures with the Indian producers or acquire stakes in Indian tea companies. The production of sugarcane has increased to more than 299 million tones. About 50 per cent sugarcane is estimated to be processed by sugar mills and the balance by small scale Gur and Khandsari units. Although, the efficiency of Gur and Khandsari sector is low compared to sugar mills, but these units provide more employment opportunities to rural work force and therefore, cannot be ignored and requires special attention. Improved sugarcane crushers and furnaces have been developed for producing hygienic gur for domestic and export market.

Packed and convenience food

Modern packed and convenience foods such as bread, biscuit, confectionery, chocolates, ready to eat foods like noodles, cereal flakes, etc have become popular in recent years especially in urban areas although traditional foods have been used in the country in the form of roasted, puffed, sweet meat and baked products. The extruded foods are largely produced in the unorganized sector. The traditional ethnic ready to eat foods prepared in hygienic conditions and marketed with better packaging has plenty of domestic and exports market.

Fishing and Fish Processing

One of the catchy investment sectors is fisheries. The marine fish include prawns, shrimps, tuna, cuttlefish, squids, octopus, red snappers, ribbon fish, mackerel, lobsters, cat fish etc. There is growing canned and processed fishes from India.

Meat and Poultry Processing

India ranks first in world cattle population, 50 per cent of buffalo population and one - sixth of total goat population of the world. There is vast scope to set up modern slaughter facilities and cold store chains in meat and poultry processing sector. Compared with meat, poultry industry has registered significant growth. India ranks fifth in the world and both poultry and egg processing units have come in a very big way in the country. India is exporting egg powder, frozen egg yolk and albumin powder to Europe, Japan and other countries. Poultry exports are mostly to Maldives and Oman. Indian poultry meat products have good markets in Japan, Malaysia, Indonesia and Singapore. Presently there are only five egg powder plants in India which is considered insufficient in view of growing export demand for different kind of powder - whole egg, yolk and albumin.

There is a large potential for setting up of modern slaughter facilities and development of cold chains in meat and poultry processing sector. The market has not been tapped for ready to eat and semi processed meat products in the domestic market as well as for exports to neighboring countries especially to the Middle East. Buffalo meat is surplus in the country and has good export potential.

Milk and Milk products

The total milk production is now around 100 million tones and the demand for milk is estimated at even higher level. Manufacture of casein and lactose, largely being imported presently, has good scope.

5.2 Elements of Cold chain

The Task Force on cold-chain development in India had suggested in its report to establish a **National Centre for Cold-chain Development (NCCD)** in India as an autonomous centre for excellence to be established as a registered society to work in close collaboration with industry and other stake holders to promote and develop integrated cold-chain in India for perishable F&V and other perishable allied agri – commodities to reduce wastages and improve the gains to farmers and consumers substantially. As recommended by the Task Force on cold-chain a National Centre for Cold-chain Development (NCCD) has been established to promote and develop integrated cold-chain in India for perishable agriculture and horticulture produce including perishable from allied sectors. The main objectives of the centre are to recommend standards and protocols for cold-chain infrastructure, suggest guidelines for human resource development and to recommend appropriate policy frame-work for development of cold-chain.

Objectives of Cold Chain-

- To recommend standards and protocols for cold chain infrastructure/building including post harvest management so as to harmonize with international standards and best practices and suggest mechanism for benchmarking and certification of infrastructure/building, process and services provided by cold chain industry.
- To suggest indicative guidelines for preparation of project reports for potential investors/entrepreneurs.

- To assess and develop appropriate IT-based management information system for the cold chain infrastructure
- To undertake and coordinate Research and Development (R&D) work required for development of cold chain industry in consultation with stakeholders.
- To undertake and coordinate the task of Human Resource Development (HRD) and capacity building. It may also conduct in-house training, short-term/long courses relevant for cold chain development.
- To launch publicity campaign to educate the stakeholders including awareness building about the benefits of integrated cold chain.
- To recommend appropriate policy framework relating to development of cold chain.
- To facilitate and foster the development of multi-modal transportation facilities for perishable agricultural, horticultural and allied commodities and establishment of National Green Grid Perishable Commodities

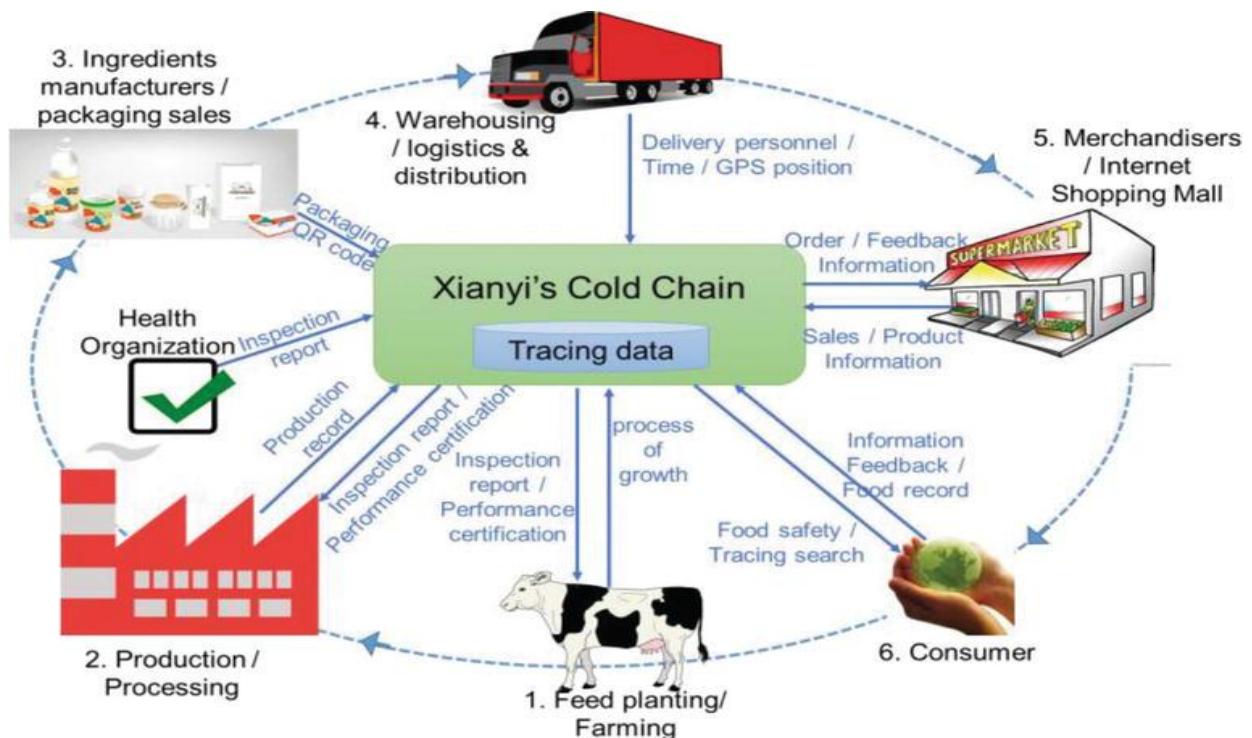


Figure 33 Xianyi's Cold Chain Model

In India, the cold-chain is applied successfully in the dairy supply chain, for frozen goods like ice cream and various meats. However, in case of the fresh fruits and vegetables, despite high level of demand as well as food loss, the cold-chain had not been advanced in a proper fashion. Cold-chain is not just a cold store, and is not about preservation; cold-chain is about facilitating the safe delivery of perishable products to markets, before expiry of its saleable life.

Components of well-designed cold-chain system Globally, the majority share of cold-chain is seen in fresh fruit and vegetable trade, whereas in India the situation is reversed and the cold-chain is seen to be integrated largely for dairy and frozen goods. The fruit &

vegetable cold-chain has to be designed to integrate the entire set of activities needed, to transfer the harvested value from source to consumer, while ensuring care for the value under its custody. Such a system would maintain the holding climate to manage the produce quality and extend marketable life, be efficient in minimising losses and comply with food safety standards. Barring a few produce types that require no specific handling procedure prior entering a cold store, or on its exit, the larger variety of perishables require preconditioning before entering the chain to market. The cold-chain, being nothing but a modern agri-logistics system ,must therefore at a minimum, incorporate the following infrastructure components:

- Modern pack-house at (or in proximity) to farm-gate
- Transport from pack-house to next stage in the supply chain.
- Cold storage (hub) in proximity to market
- Cold storage (bulk) when storing at farm-gate
- Ripening units
- Merchandising platforms (last mile retail units for select produce/products)
- Kitchen storage (domestic fridges, deep freezers – optional for select produce/products).The last two, are not equally imperative, given the near daily buying and consumption cycle of Indian consumers, in the case of fruits and vegetables.

A well-designed cold-chain system will balance the throughput capacity of each major infrastructure component. Throughput capacities (static inventory size, multiplied with number of inventory turns) is important to maintain the seamless integration across each function. The integration can be achieved through collaboration among individual asset owners or by owning the complete chain .Cold-chain safeguards value Cold-chain systems reduce food loss by ensuring that the perishable produce finds an avenue or physical access to consumption centres. Food loss occurs primarily because food perishes before being brought into consumption. This happens because access to market is beyond the normal lifespan or marketable holding life of the food item. Cold-chain applies technology to first extend the holding life of the produce, and secondly by providing a mode to transfer to market within this extended time period. In normal conditions, most of the fruits and vegetables have a limited life span, at times only a few days. Unless the selling cycle falls within this natural time span, cold-chain intervention is required. This is needed especially when the markets are concentrated over longer distance from farms. Being a logistics medium that merely extends marketable life for a predetermined duration the cold-chain must ensure that the produce must reach shelves or other destinations for end-use, well within this time restriction.

One of the end destinations can be food processing units, whose domain is preservation, wherein the farmers' harvest is converted into a new product, and a new value system is originated. In this case the harvested produce is used as feedstock for the processing facility. Processing technology usually outputs preserved products, such as dried snacks, carbonated drinks, pickles, jams, flour, aseptically packed items, etc., in which case cold-chain as a market link is no longer required.The cold-chain is a temperature controlled conduit, from source to consumer – originating at point of production such as farm or factory to destination point that is consumers. The cold-chain not only extends the marketable life span of whole fresh produce, it also brings organization and standardization to post-harvest food handling.

5.3 National Cooling Action Plan (NCAP)

The Government of India has taken main steps to create a National Cooling Action Plan (NCAP) – a vision document to meet the country's rapidly growing cooling needs in a climate-friendly manner in 2018. Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, is developing a National Cooling Action Plan (NCAP) that will provide a 20-year outlook on how cooling demand in India will evolve and grow, and outline strategies and actions that promote sustainable and smart ...The NCAP aims to develop comprehensive, sustainable and smart cooling strategies.

The objective to the NCAP is far-reaching and includes considerations ranging from thermal comfort, building design, and standards and labeling for appliances, while also considering energy poverty, energy access challenges and the impact of emissions from increased cooling.

References

- <http://www.hillagric.ac.in/edu/coa/agengg/lecture/243/agriengg-243.htm>
- <https://farmech.dac.gov.in/FarmerGuide/MH/index1.html>
- <https://www.ikisan.com/agri-machinery-introduction.html>
- <https://farmer.gov.in/dacdivision/Machinery1/intro.pdf>
- http://agritech.tnau.ac.in/postharvest/pht_intro.html