DON BOSCO COLLEGE
DEPARTMENT OF PHYSICS
STUDY MATERIAL

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BASIC OF ELECTRICITY AND APPLIANCES

UNIT I

Electrical charge – current – potential – units – Ohm's law – electrical energy – power – watt – kWh – consumption of electrical power –resistance – capacitance – inductance and its units – measuring meter Galvanometer, ammeter, voltmeter and multi meter.

UNIT II

Principles of transformers – constructional details – Core type, Shell type – classification of transformers – EMF equation – voltage ratio –current ratio – transformer on no load – auto transformer –applications.

UNIT III

AC and DC – single phase and three phase connections – three phase transformer – house wiring star-star, star-delta, delta –star connections – overloading – earthing – short circuiting – fuses –cooling of transformers – protective devices and accessories – losses intransformer.

UNIT IV

Electrical bulbs – fluorescent lamps – inverter – UPS – Stabilizer –principle and operations of fan – wet grinder – mixer – water heater –electric iron box – microwave oven – refrigerator.

UNIT V

Electric heating – resistance heating – induction heating – high frequency eddy current heating – Dielectric heating – resistance welding – electric arc welding – occupational hazards due to chemical reactions.

Books for study and also for reference :

1. A text book in electric power – P. L. Soni, P.V. Gupta and V.S. Bhatnagar.
2. Utilization of electrical energy – E.O. Taylor, Orient Longman.
3. Arts and Science of utilization of electrical energy – H. Partas, M/s. Dhanpat Raji & Sons, New Delhi.
4. A course in electrical power - J.B. Gupta, M/S. Jaataris & Sons.
5. A text book in electrical technology – B.L. Teraja, S. Chand & Co. , New Delhi.
6. A text book in electrical technology – A.K. Teraja, S. Chand & Co., New Delhi.
7. Alternating current machines – Philip Kermp
8. Performance and design of A.C. Machines – M.G. Say, ELBS Edn.
9. Theory of alternating current machinery – Alexander Langsdort.

UNIT I

ELECTRIC CHARGE

In physics, charge, also known as electric charge, electrical charge, or electrostatic charge and symbolized *q*, is a characteristic of a unit of matter that expresses the extent to which it has more or fewer electrons than protons. In atoms, the electron carries a negative elementary or unit charge; the proton carries a positive charge. The two types of charge are equal and opposite.

One of the basic properties of the elementary particles of matter giving rise to all electric and magnetic forces and interactions. The two kinds of charge are given negative and positive algebraic signs: measured in coulombs.

An object comprised of many atoms, the net charge is equal to the arithmetic sum, taking polarity into account, of the charges of all the atoms taken together. In a massive sample, this can amount to a considerable quantity of elementary charges. The unit of electrical charge in the **International System of Units** is the coulomb (symbolized C), where 1 C is equal to approximately 6.24×10^{18} elementary charges. It is not unusual for real-world objects to hold charges of many coulombs.

An electric field, also called an electrical field or an electrostatic field, surrounds any object that has charge. The electric field strength at any given distance from an object is directly proportional to the amount of charge on the object. Near any object having a fixed electric charge, the electric field strength diminishes in proportion to the square of the distance from the object (that is, it obeys the inverse square law).

When two objects having electric charge are brought into each other's vicinity, an electrostatic force is manifested between them. (This force is not to be confused with electromotive force, also known as voltage.) If the electric charges are of the same polarity, the electrostatic force is repulsive. If the electric charges are of opposite polarity, the electrostatic force is attractive. In free space (a vacuum), if the charges on the two nearby objects in coulombs are q_1 and q_2 and the centers of the objects are separated by a distance r in meters, the net force F between the objects, in newtons, is given by the following formula:

$F = (q_1 q_2) / (4\pi\varepsilon_o r^2)$

where ε_o is the permittivity of free space, a physical constant, and $\pi$is the ratio of a circle's circumference to its diameter, a dimensionless mathematical constant. A positive net force is repulsive, and a negative net force is attractive. This relation is known as Coulomb's law.

CURRENT

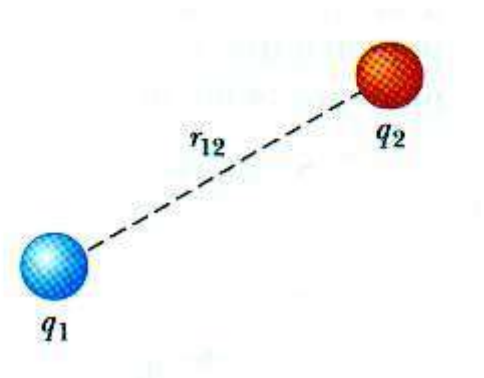
Current is a flow of electrical charge carriers, usually electrons or electron-deficient atoms. The common symbol for current is the uppercase letter I. **The standard unit is the** ampere, symbolized by A. One ampere of current represents one coulomb of electrical charge (6.24×10^{18} charge carriers) moving past a specific point in one second. Physicists consider current to flow from relatively positive points to relatively negative points; this is called conventional current or Franklin current. Electrons, the most common charge carriers, are negatively charged. They flow from relatively negative points to relatively positive points.

Electric current can be either direct or alternating. Direct current (DC) flows in the same direction at all points in time, although the instantaneous magnitude of the current might vary. In an alternating current (AC), the flow of charge carriers reverses direction periodically. The number of complete AC cycles per second is the frequency, which is measured in hertz. An example of pure DC is the current produced by an electrochemical cell. The output of a power-supply rectifier, prior to filtering, is an example of pulsating DC. The output of common utility outlets is AC.

Current per unit cross-sectional area is known as *current density*. An electric current always produces a magnetic field. The stronger the current, the more intense the magnetic field. A pulsating DC, or an AC, characteristically produces an electromagnetic field. This is the principle by which wireless signal propagation occurs.

ELECTRIC POTENTIAL

Electric potential, the amount of work needed to move a unit charge from a reference point to a specific point against an electric field. Typically, the reference point is the Earth, although any point beyond the influence of the electric field charge can be used.



The diagram shows the forces acting on a positive charge *q* located between two plates, A and B, of an electric field *E*. The electric force *F* exerted by the field on the positive charge is $F = qE$; to move the charge from plate A to plate B, an equal and opposite force ($F' = -qE$) must then be applied. The work *W* done in moving the positive charge through a distance *d* is $W = F'd = -qEd$.

The potential energy for a positive charge increases when it moves against an electric field and decreases when it moves with the electric field; the opposite is true for a negative charge. Unless the unit charge crosses a changing magnetic field, its potential at any given point does not depend on the path taken.

Although the concept of electric potential is useful in understanding electrical phenomena, only differences in potential energy are measurable. If an electric field is defined as the force per unit charge, then by analogy an electric potential can be thought of as the potential energy per unit charge. Therefore, the work done in moving a unit charge from one point to another (*e.g.,* within an electric circuit) is equal to the difference in potential energies at each point. In the **International System of Units (SI),** electric potential is expressed in units of joules per coulomb (*i.e.*, volts), and differences in potential energy are measured with a voltmeter

OHM'S LAW

1. **Ohm's Law** deals with the relationship between voltage and current in an ideal conductor. This relationship states that:

The potential difference (voltage) across an ideal conductor is proportional to the current through it.

The constant of proportionality is called the "resistance", **R**.

Ohm's Law is given by:

$$V = I R$$

Where V is the potential difference between two points which include a **resistance** R. I is the current flowing through the resistance. For biological work, it is often preferable to use the **conductance**, g = 1/R; In this form Ohm's Law is:

$$I = g V$$

2. Material that obeys Ohm's Law is called "**ohmic"** or "**linear"** because the potential difference across it varies linearly with the current.

3. Ohm's Law can be used to solve simple circuits. A complete circuit is one which is a closed loop. It contains at least one source of voltage (thus providing an increase of potential energy), and at least one potential drop i.e., a place where potential energy decreases. The sum of the voltages around a complete circuit is zero.

4. An increase of potential energy in a circuit causes a charge to move from a lower to a higher potential (ie. voltage). Note the difference between potential energy and potential.

Because of the electrostatic force, which tries to move a positive charge from a higher to a lower potential, there must be another 'force' to move charge from a lower potential to a higher inside the battery. This so-called force is called the **electromotive force**, or **emf**. The SI unit for the emf is a volt (and thus this is not really a force, despite its name). We will use a script E, the symbol V, E to represent the emf.

A decrease of potential energy can occur by various means. For example, heat lost in a circuit due to some electrical resistance could be one source of energy drop.

Because energy is conserved, the potential difference across an emf must be equal to the potential difference across the rest of the circuit. That is, Ohm's Law will be satisfied:

$$V = I R$$

ELECTRICAL ENERGY

Electrical energy is the **energy** carried by moving electrons in an **electric** conductor. It cannot be seen, but it is one of our most useful forms of **energy** because it is relatively easy to transmit and use. All matter consists of atoms, and every atom contains one or more electrons, which are always moving.

ELECTRIC POWER

In physics, **power** is the rate of doing work. It is equivalent to an amount of energy consumed per unit time. In the MKS system, the unit of power is the joule per second (J/s), known as the watt in honor of James Watt, the eighteenth-century developer of the steam engine.

The electric power in watts associated with a complete electric circuit or a circuit component represents the rate at which energy is converted from the electrical energy of the moving charges to some other form, e.g., heat, mechanical energy, or energy stored in electric fields or magnetic fields. For a resistor in a D C Circuit the power is given by the product of applied voltage and the electric current:

$P = VI$

Power = Voltage x Current

WATT

The SI unit of power, equivalent to one joule per second,corresponding to the rate of consumption of energy in an electric circuit where the potential difference is one volt and the current one ampere.

The watt (abbreviated W) is the International System of Units' (SI) standard unit of power (energy per unit time), the equivalent of one jouleper second. The watt is used to specify the rate at which electrical energy is dissipated, or the rate at which electromagnetic energy is radiated, absorbed, or dissipated.

In DC (direct-current) and low-frequency AC (alternating current) electrical circuits and systems, power is the product of the current and the voltage. Power is also proportional to the ratio of the square of the voltage to the resistance, and to the product of the resistance and the square of the current. Consider a circuit in which the current, voltage, and resistance are all constant. If the current in amperes is represented by I, the voltage (or potential difference) in volts is represented by E, and the resistance in ohms is represented by R, then the following equations hold for power in watts, represented by P.

KWH

The **kilowatt**-hour (symbolized **kWh**) is a unit of energy equivalent to one **kilowatt** (1 kW) of power expended for one hour. One watt is equal to 1 J/s. One **kilowatt**-hour is 3.6 mega joules, which is the amount of energy converted if work is done at an average rate of one thousand watts for one hour.

KILOWATT-HOUR DEFINITION

Kilowatt-hour is an energy unit (symbol kWh or kW·h).

One kilowatt-hour is defined as the energy consumed by power consumption of 1kW during 1 hour:

1 kWh = 1kW · 1h

One kilowatt-hour is equal to $3.6\cdot10^6$ joules:

1 kWh = $3.6\cdot10^6$ J

The energy E in kilowatt-hour (kWh) is equal to the power P in kilowatts (kW), times the time t in hours (h).

$E_{(kWh)} = P_{(kW)} \cdot t_{(h)}$.

ELECTRICAL RESISTANCE

Electrical resistance is the repulsion of a current within a circuit. It explains the relationship between voltage (amount of electrical pressure) and the current (flow of electricity). Resistance, discovered by Georg Simon Ohm in 1827, is the ratio between voltage and current.

Resistance is an electrical quantity that measures how the device or material reduces the electric current flow through it.The resistance is measured in units of ohms (Ω).

ELECTRICAL CAPACITANCE

Electrical conductance of a conductor is defined as the capacity to store charge in it. Whenever charge is applied to an insulator its potential is raised to some certain level. Charge on a conductor and its electric potential are both directly proportional to each other. So, as we increase the charge electric potential also increases.

$$V \propto Q$$

Some other units in which capacitance can be measured is: 1 Microfarad i.e. 1uuF=10^{-12}

1 Micro farad i.e. 1uF=10^{-6}

INDUCTANCE

A current generated in a conductor by a changing magnetic field is proportional to the rate of change of the magnetic field. This effect is called INDUCTANCE and is given the symbol L.

FACTORS AFFECTING INDUCTANCE.

The amount of inductance in an inductor is dependent on:

- a. The number of turns of wire in the inductor.
- b. The material of the core.
- c. The shape and size of the core.
- d. The shape, size and arrangement of the wire making up the coils.

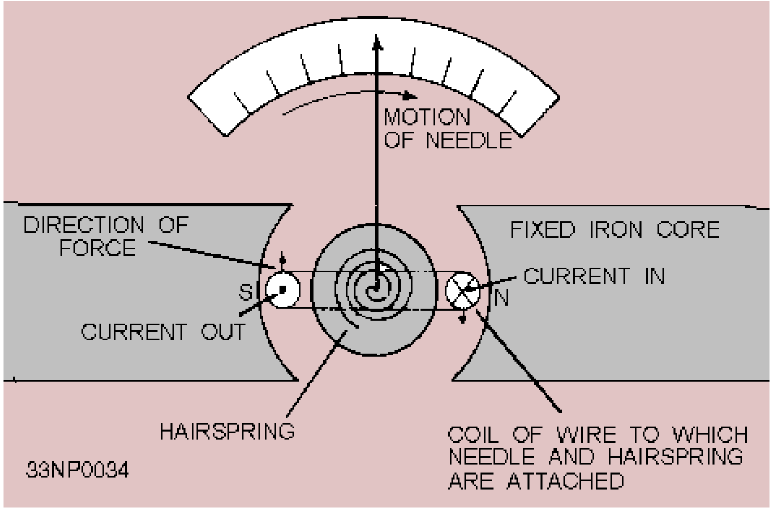
Inductance unit - a measure of the property of an electric circuit by which an electromotive force is induced in it

- electromagnetic unit, emu - any of various systems of units for measuring electricity and magnetism
- ab henry - a unit of inductance equal to one billionth of a henry
- milli henry - a unit of inductance equal to one thousandth of a henry
- henry, H - a unit of inductance in which an induced electromotive force of one volt is produced when the current is varied at the rate of one ampere per second.

MEASURING METER GALVANOMETER

The galvanometer is used to measure very low currents, such as those in bridge circuits. In modified form, the galvanometer has the highest sensitivity of any of the various types of meters in use today. A simplified diagram of a galvanometer is shown in figure 3-1. It is different from other instruments used for the same purpose because its movable coil is suspended by means of metal ribbons instead of a shaft and jewel-bearing arrangement often used in other instruments.

Figure 3-1. - Simplified galvanometer.



AMMETER

An **ammeter** is a **measuring** instrument used to **measure** the electric current in a circuit. Electric currents are **measured** in amperes (A).

DIGITAL MULTIMETER

Essential or key details of how a digital multimeter works - digital multimeter operation. The key process that occurs within a digital multimeter for any measurement that takes place is that of voltage measurement. All other measurements are derived from this basic measurement.

Accordingly the key to understanding how a digital multimeter works is in understanding this process.

There are many forms of analogue to digital converter, ADC. However the one that is most widely used in digital multimeter, DMMs is known as the successive approximation register or SAR. Some SAR ADCs may only have resolution levels of 12 bits, but those used in test equipment including DMMs generally have 16 bits or possibly more dependent upon the application. Typically for DMMs resolution levels of 16 bits are generally used, with speeds of 100k samples per second. These levels of speed are more than adequate for most DMM applications, where high levels of speed are not normally required.

SUCCESSIVE APPROXIMATION REGISTER ADC USED IN MOST DMMS

As the name implies, the successive approximation register ADC operates by successively homing in on the value of the incoming voltage.

The first stage of the process is for the sample and hold circuit to sample the voltage at the input of the DMM and then to hold it steady.

With a steady input voltage the register starts at half its full scale value. This would typically require the most significant bit, MSB set to "1" and all the remaining ones set to "0". Assuming that the input voltage could be anywhere in the range, the mid-range means that the ADC is set in the middle of the range and this provides a faster settling time. As it only has to move a maximum of the full scale rather than possibly 100%.

To see how it works take the simple example of an 4-bit SAR. Its output will start at 1000. If the voltage is less than half the maximum capability the comparator output will be low and that will force the register to a level of 0100. If the voltage is above this, the register will move to 0110, and so forth until it homes in on the nearest value.

It can be seen that SAR converters, need one approximating cycle for each output bit, i.e. an n-bit ADC will require n cycles.

DMM OPERATION

Although the analogue to digital converter forms the key element within the instrument, in order to fully understand how a digital multimeter works, it is necessary to look at some of the other functions around the ADC.

Although the ADC will take very many samples the overall digital multimeter will not display or return every sample taken. Instead the samples are buffered and averaged to achieve high accuracy and resolution. This will overcome the effects of small variations such as noise, etc., noise created by the analogue first stages of the DMM being an important factor that needs to be overcome to achieve the highest accuracy.

OPERATION FLOW DIAGRAM FOR OPERATION OF A DMM

Measurement time

One of the key areas of understanding how a digital multimeter works is related to the measurement time. Apart from the basic measurement there are a number of other functions that are required and these all take time. Accordingly the measurement time of a digital multimeter, DMM, may not always appear straightforward.

The overall measurement time for a DMM is made up from several phases where different activities occur:

- ***Switch time:*** The switch time is the time required for the instrument to settle after the input has been switched. This includes the time to settle after a measurement type has been changed, e.g. from voltage to resistance, etc. It also includes time to settle after the range has been changed. If auto-ranging is included the meter will need to settle if a range change is required.
- ***Settling time:*** Once the value to be measured has been applied to the input, a certain time will be required for it to settle. This will overcome any input capacitance levels when high impedance tests are made, or generally for the circuit and instrument to settle.
- ***Signal measurement time:*** This is the basic time required to make the measurement itself. For AC measurements, the frequency of operation must be taken into account because the minimum signal measurement time is based on the minimum frequency required of the measurement. For example, for a minimum frequency of 50 Hz, an aperture of four time the period is required, i.e. 80 ms for a 50Hz signal, or 67ms for a 60Hz signal, etc.
- ***Auto-zero time:*** When auto range is selected, or range changes are made, it is necessary to zero the meter to ensure accuracy. Once the correct range is selected, the auto-zero is performance for that range.
- ***ADC calibration time:*** In some DMMs a calibration is periodically performed. This must be accounted for, especially where measurements are taken under automatic or computer control.

It is always useful to know how a digital multimeter works in order to be able to make the best use of it and the most accurate measurements. However it should be remembered that different multimeters from different manufacturers may work in different ways. It is therefore always helpful to consult the manufacturer's instructions to understand how a particular digital multimeter works.

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Although the analogue to digital converter forms the key element within the instrument, in order to fully understand how a digital multimeter works, it is necessary to look at some of the other functions around the ADC.

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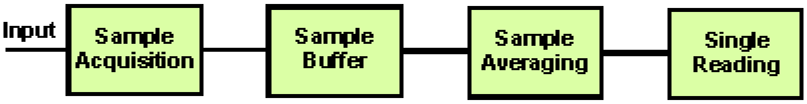
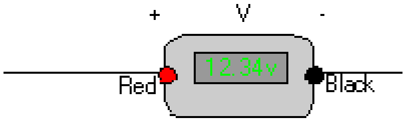


Operation flow diagram for operation of a DMM

VOLTMETER

In this section we'll look at how you use a voltmeter. Here's a representation of a voltmeter.



Voltmeter reads voltage, V, on scale

For our introduction to the voltmeter, we need to be aware of three items on the voltmeter.

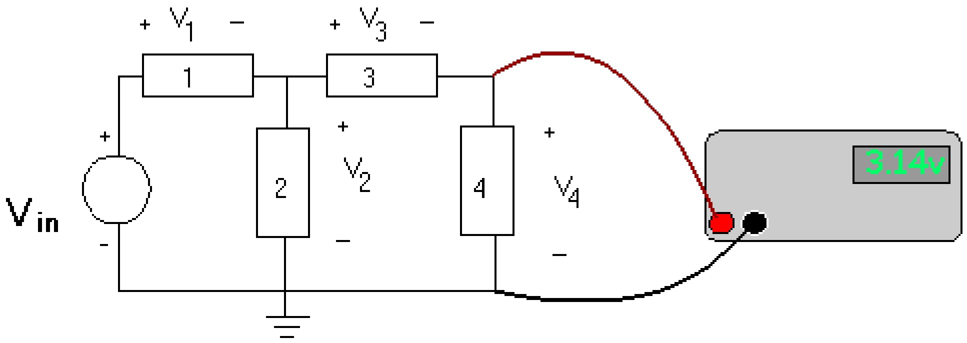
- The display. This is where the result of the measurement is displayed. You meter might be either analog or digital. If it's analog you need to read a reading off a scale. If it's digital, it will usually have an LED or LCD display panel where you can see what the voltage measurement is.
- The positive input terminal, and it's almost always red.
- The negative input terminal, and it's almost always black.

Next, you need to be aware of what the voltmeter measures. Here it is in a nutshell.

- A voltmeter measures the voltage difference between the positive input terminal of the voltmeter and the negative input terminal.

That's it. That's what it measures. Nothing more, nothing less - just that voltage difference. That means you can measure voltage differences in a circuit by connecting the positive input terminal and the negative input terminal to locations in a circuit.

We'll show a voltmeter connected to the circuit diagram - a mixed metaphor approach. Forgive us for that, but let's look at it.



This figure shows where you would place the leads if you wanted to measure the voltage across element #4.

- Notice that the voltmeter measures the voltage across element #4, $+V_4$.
- Notice the polarity definitions for V_4, and notice how the red terminal is connected to the "+" end of element #4. If you reversed the leads, by connecting the red lead to the "-" terminal on element #4 and the black lead to the "+" end of element #4, you would be measuring $-V_4$.

There are some important things to note about taking a voltage measurement. The most important point is this.

- Voltage is an across variable.
  - That means that when you measure voltage you measure a difference between two points in space.
  - There are other variables of this type. For example, if you use a pressure sensor, you measure the pressure difference between two points, much like you measure a voltage difference.
  - There are other kinds of variables. For example, there are numerous variables that are flow variables. Current and fluid flow variables are example of flow variables. They usually have units of something per second. (Current is couloumbs/sec, while water flow might be in gallons/sec. - for example.)
- When you measure a voltage the two terminals of the voltmeter (in the figure, the red terminal and the black terminal) are connected to the two points where the voltage appears that you want to measure. One terminal - say it is the red terminal - will then be at the same voltage as one of the points, and the other terminal - the black terminal - will

be at the same voltage as the other point. The meter then responds to the difference between these two voltages.

UNIT-II

PRINCIPLES OF TRANSFORMERS

The device which is used to stepping up or stepping down voltage is known as transformer. They can step up and step down A.C voltage only.

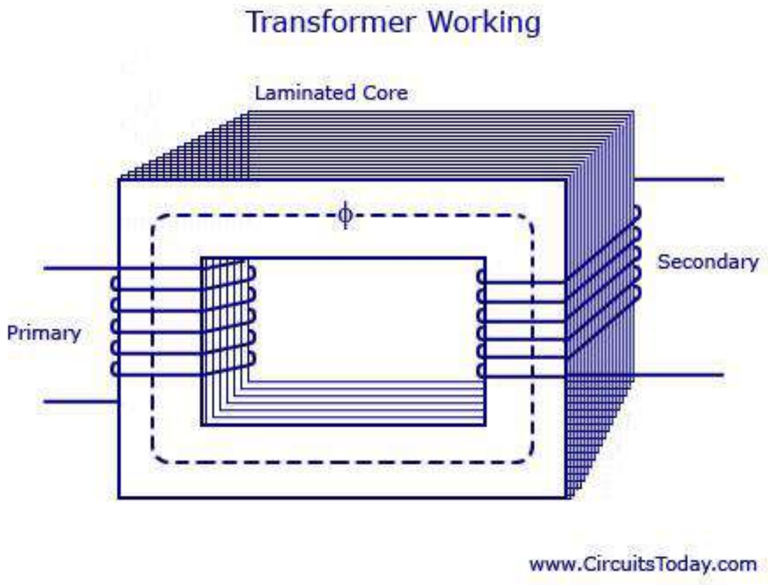
Principle of operation

A transformer is a static electric machine which transfers electrical energy from one circuit to another circuit without change in its frequency. Due to electromagnetic induction principle the transfer of energy takes place.

It consists of three essential parts:

(1) Primary winding
(2) Secondary winding
(3) Laminated Iron core

The A.C supply given to the winding is known as primary winding. The winding from which electric supply is taken is called secondary winding. The connection diagram is shown in below figure.



The two windings are wound over an iron core having low reluctance. The iron core is laminated to reduce caddy current loss.

The transformer works on the principle of mutual induction. When an A.C supply is given to primary winding an alternating flux is set up the core. This alternating flux cuts both the primary and the secondary winding. An emf is induced in the primary winding according to self induction principle. According to Faraday’s mutual induction principle of an emf is induced in the secondary winding. If we connect a load to the secondary winding current will flow through the load. In this way electrical energy is transferred from the primary circuit to the secondary circuit. The emf induced in the winding depends upon the number of turns of the winding. If the number of turns in the secondary winding is more than that of the primary winding. The emf induced in the secondary winding will be higher than the voltage applied to the primary winding. This type of transformers said to step up transformers.

If the number of turns in the secondary winding is less than that of the primary winding. The emf induced in the secondary winding will be less than the voltage applied to the primary winding. This type of transformers is said to be step down transformers.

TRANSFORMER CONSTRUCTION

For the simple construction of a transformer, you must need two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and from the steel core. The device will also need some suitable container for the assembled core and windings, a medium with which the core and its windings from its container can be insulated.

In order to insulate and to bring out the terminals of the winding from the tank, apt bushings that are made from either porcelain or capacitor type must be used.

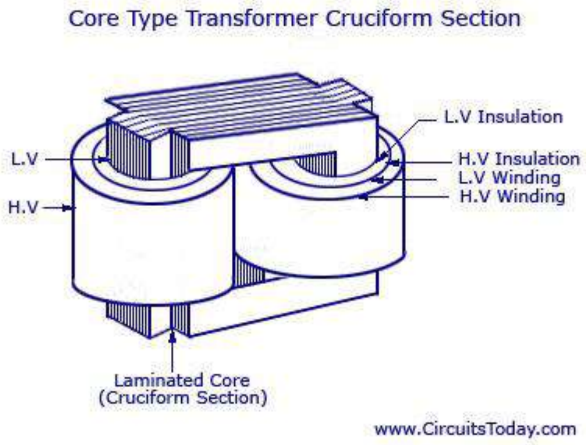
In all transformers that are used commercially, the core is made out of transformer sheet steel laminations assembled to provide a continuous magnetic path with minimum of air-gap included. The steel should have high permeability and low hysteresis loss. For this to happen, the steel should be made of high silicon content and must also be heat treated. By effectively laminating the core, the eddy-current losses can be reduced. The lamination can be done with the help of a light coat of core plate varnish or lay an oxide layer on the surface. For a frequency of 50 Hertz, the thickness of the lamination varies from 0.35mm to 0.5mm for a frequency of 25 Hertz.

TYPES OF TRANSFORMERS

The types of transformers differ in the manner in which the primary and secondary coils are provided around the laminated steel core. According to the design, transformers can be classified into two:

1. CORE- TYPE TRANSFORMER

In core-type transformer, the windings are given to a considerable part of the core. The coils used for this transformer are form-wound and are of cylindrical type. Such a type of transformer can be applicable for small sized and large sized transformers. In the small sized type, the core will be rectangular in shape and the coils used are cylindrical. The figure below shows the large sized type. You can see that the round or cylindrical coils are wound in such a way as to fit over a cruciform core section. In the case of circular cylindrical coils, they have a fair advantage of having good mechanical strength. The cylindrical coils will have different layers and each layer will be insulated from the other with the help of materials like paper, cloth, micarta board and so on. The general arrangement of the core-type transformer with respect to the core is shown below. Both low-voltage (LV) and high voltage (HV) windings are shown.


Core Type Transformer Cruciform Section

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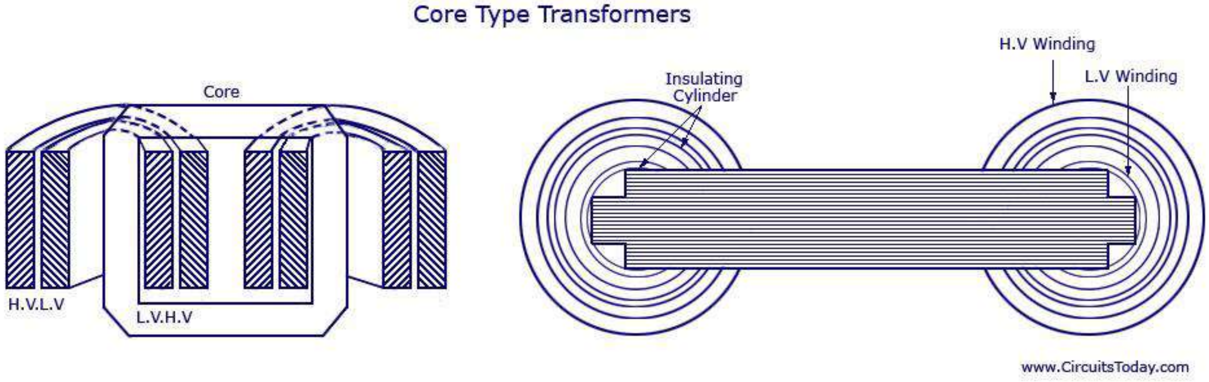
Core Type Transformers

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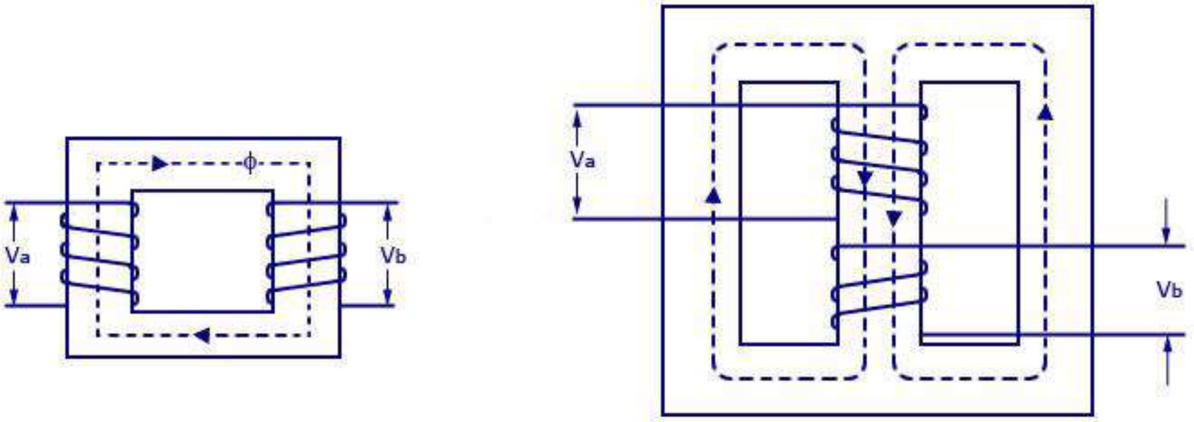
The low voltage windings are placed nearer to the core as it is the easiest to insulate. The effective core area of the transformer can be reduced with the use of laminations and insulation.

2. SHELL-TYPE TRANSFORMER

In shell-type transformers the core surrounds a considerable portion of the windings. The comparison is shown in the figure below.

Core Type and Shell Type Transformer Winding



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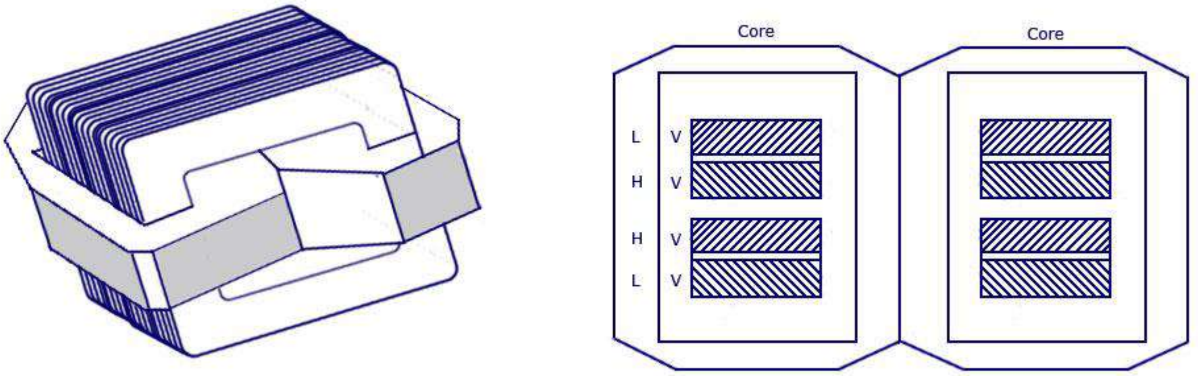
The coils are form-wound but are multi layer disc type usually wound in the form of pancakes. Paper is used to insulate the different layers of the multi-layer discs. The whole winding consists of discs stacked with insulation spaces between the coils. These insulation spaces form the horizontal cooling and insulating ducts. Such a transformer may have the shape of a simple rectangle or may also have a distributed form. Both designs are shown in the figure below:

Shell Type Transformers Rectangular Form



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Transformers can also be classified according to the type of cooling employed. The different types according to these classifications are:

1. OIL FILLED SELF-COOLED TYPE

Oil filled self cooled type uses small and medium-sized distribution transformers. The assembled windings and core of such transformers are mounted in a welded, oil-tight steel tanks provided with a steel cover. The tank is filled with purified, high quality insulating oil as soon as the core is put back at its proper place. The oil helps in transferring the heat from the core and the windings to the case from where it is radiated out to the surroundings. For smaller sized transformers the tanks are usually smooth surfaced, but for large size transformers a greater heat radiation area is needed, and that too without disturbing the cubical capacity of the tank. This is achieved by frequently corrugating the cases. Still larger sizes are provided with radiation or pipes.

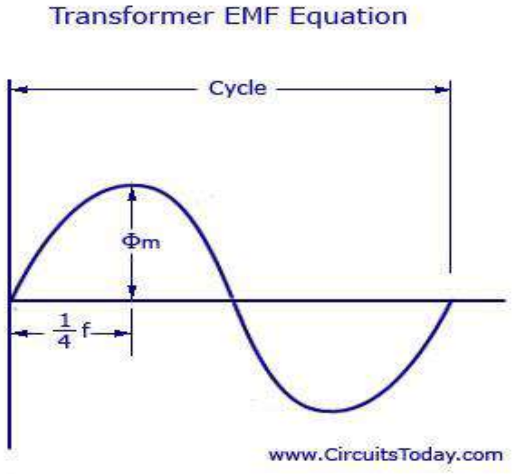
2. OIL FILLED WATER COOLED TYPE

This type is used for much more economic construction of large transformers, as the above told self cooled method is very expensive. The same method is used here as well- the windings and the core are immersed in the oil. The only difference is that a cooling coil is mounted near the surface of the oil, through which cold water keeps circulating. This water carries the heat from the device. This design is usually implemented on transformers that are used in high voltage transmission lines. The biggest advantage of such a design is that such transformers do not require housing other than their own. This reduces the costs by a huge amount. Another advantage is that the maintenance and inspection of this type is only needed once or twice in a year.

1. Air Blast Type

This type is used for transformers that use voltages below 25,000 volts. The transformer is housed in a thin sheet metal box open at both ends through which air is blown from the bottom to the top.

E.M.F Equation of a Transformer



Let, N_A = Number of turns in primary

N_B = Number of turns in secondary

$Ø_{max}$ = Maximum flux in the core in webers = B_{max} X A

f = Frequency of alternating current input in hertz (H_Z)

As shown in figure above, the core flux increases from its zero value to maximum value $Ø_{max}$ in one quarter of the cycle , that is in ¼ frequency second. Therefore, average rate of change of flux = $Ø_{max}$/ ¼ f = 4f $Ø_{max}$Wb/s. Now, rate of change of flux per turn means induced electro motive force in volts. Therefore, average electro-motive force induced/turn = 4f $Ø_{max}$volt. If flux Ø varies sinusoidally, then r.m.s value of induced e.m.f is obtained by multiplying the average value with form factor. Form Factor = r.m.s. value/average value = 1.11. Therefore, r.m.s value of e.m.f/turn = 1.11 X 4f $Ø_{max}$ = 4.44f $Ø_{max}$

Now, r.m.s value of induced e.m.f in the whole of primary winding = (induced e.m.f./turn) X Number of primary turns

Therefore,

$E_A = 4.44f\ N_AØ_{max} = 4.44fN_AB_mA$

Similarly, r.m.s value of induced e.m.f in secondary is

$E_B = 4.44f\ N_B\ Ø_{max} = 4.44fN_BB_mA$

In an ideal transformer on no load,

$V_A = E_A$ and $V_B = E_B$, where V_B is the terminal voltage.

VOLTAGE TRANSFORMATION RATIO (K)

From the above equations we get

$E_B/ E_A = V_B/ V_A = N_B/N_A = K$

This constant K is known as voltage transformation ratio.

(1) If $N_B>N_A$, that is K>1 , then transformer is called step-up transformer.

(2) If $N_B<1$, that is K<1 , then transformer is known as step-down transformer.

Again for an ideal transformer,

Input V_A = output V_A

$V_AI_A = V_BI_B$

Or, $I_B/I_A = V_A/V_B = 1/K$

Hence, currents are in the inverse ratio of the (voltage) transformation ratio.

CURRENT RATIO:

Current ratio is the ratio of the current flowing through the primary winding (l_1) to the current flowing through the secondary winding (l_2) in an ideal transformer

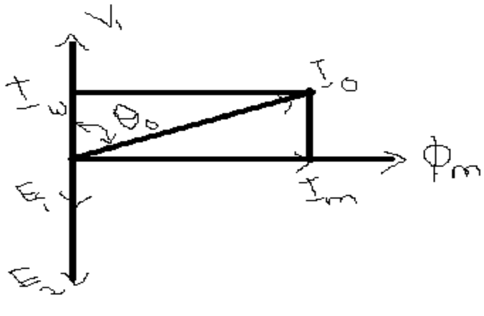
Apparent input power – apparent output power

$V_1 I_1 = V_2 I_2$

$E_2 / E_1 = N_2/N_1=l_1/l_2=K$

TRANSFORMER ON NO – LOAD:

When a voltage V_1 is applied to the primary winding the primary draws a small current I_0 . the current I_0 is lagging behind the applied voltage by θ_0 degrees as shown in the figure



The no load current I_0 has to components.

(1) . the component i_c (i_w) is in phase with the applied voltage V_1 . this is known as active (or) working iron loss component.

$I_c = I_0 \cos \theta_0$

(2) The component i_m lagging behinds v_1 by 90^0 is known as magnetizing component ie . $I_{m} = I_0 \sin \theta_{0.}$ This component of current produces alternating flux in the core , which links both the primary and the secondary windings. So this alternating magnetic flux is called mutual flux. The flux is in phase with the current i_m . this alternating flux induces an EMF , E_1 and $E_{2\,.}$ in the primary and secondary windings respectively. These two EMFs E_1 and $E_{2\,.}$ lag behind the flux by $90^{0.}$

(3) The power given to transformer during no load conditions is used to meet the iron loss in the transformer and the small amount of copper loss.

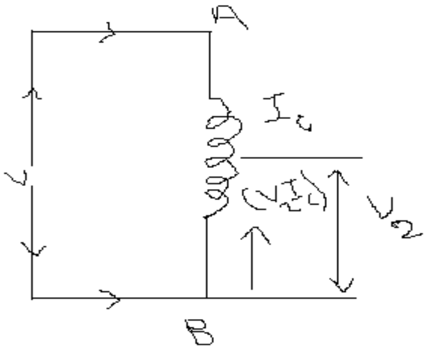
No load input power = $v_1 I_0 \cos \theta_0$ since I_0 is very small no load primary copper loss is negligibly small . hence no load power input is equal to iron loss or core loss of the transformer .

$\sqrt{i_m{}^2 + i_c{}^2} = \mathbf{i_o}$

If we add the voltage drop I_2R_2 and I_2x_2 ectopically with the terminal voltage V_2 then EMF, E_2 induced on the secondary side will be obtained.

AUTO TRANSFORMER

Auto transformer is a transformer which has one winding only. part of the winding is common to both primary and secondary. So the primary and secondary are not electrically isolated from each other. But theory and operation are similar to two winding transformer. Below figure shows the auto transformer.



In the fig, AB is the primary winding having N_1 number of turns. BC is the secondary winding having N_2 number of turns.

When the voltage is applied to the primary winding AB alternating magnetic flux is produced in the core. Due to the alternating magnetic flux an emf $E_1$is induced in the coil AB and emf E_2will be induced in the coil BC. when load is connected between the terminals BC power will be supplied to the load.

Advantages

1. Saving in conductor materials and less cost.
2. Power loss is reduced. So efficiency will be high.
3. Manufacturing cost is low
4. Can be used for obtaining variable voltage supply.

Disadvantages:

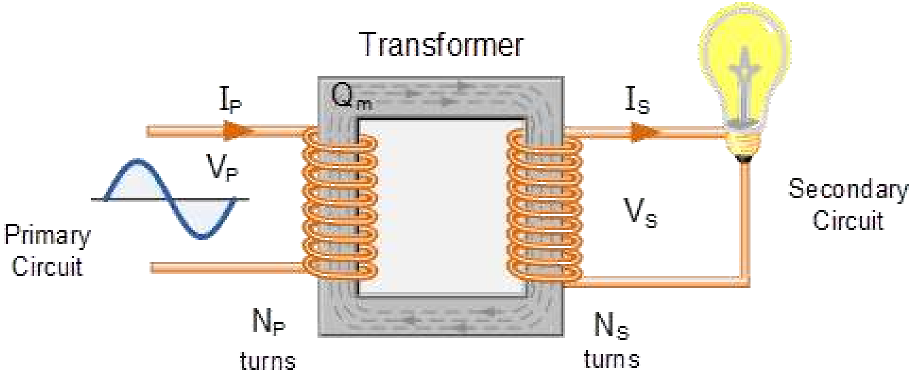
If there is a break in the secondary winding .full voltage flow from the primary side to the load.

Application of the auto transformer:

1. it is used as starters for 3 phase induction motors.
2. it is used in electrical furnace.
3. to give smooth variation of voltage to test circuits in the laboratories.
4. as a booster of supply voltage a small-extent .
5. three phase auto transformers are used in the interconnection of grids.

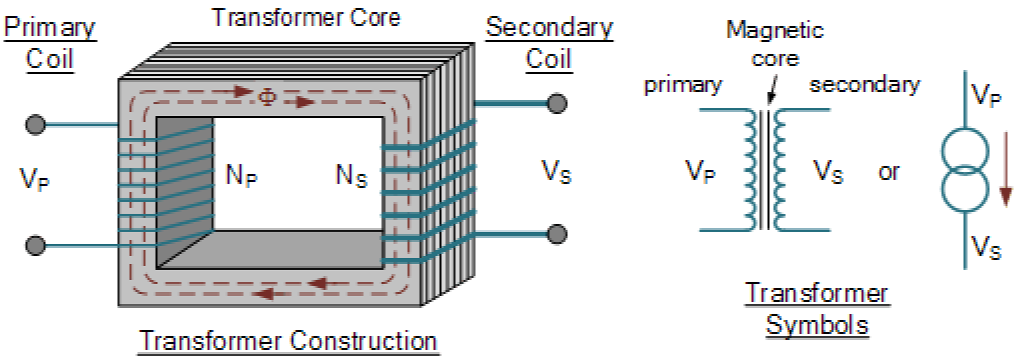
UNIT III

SINGLE PHASE VOLTAGE TRANSFORMER



In other words, for a transformer there is no direct electrical connection between the two coil windings, thereby giving it the name also of an **Isolation Transformer**. Generally, the primary winding of a transformer is connected to the input voltage supply and converts or transforms the electrical power into a magnetic field. While the job of the secondary winding is to convert this alternating magnetic field into electrical power producing the required output voltage as shown.

TRANSFORMER CONSTRUCTION (SINGLE-PHASE)



- Where:
- V_P - is the Primary Voltage

- V_S - is the Secondary Voltage
- N_P - is the Number of Primary Windings
- N_S - is the Number of Secondary Windings
- Φ (phi) - is the Flux Linkage

Notice that the two coil windings are not electrically connected but are only linked magnetically. A single-phase transformer can operate to either increase or decrease the voltage applied to the primary winding. When a transformer is used to “increase” the voltage on its secondary winding with respect to the primary, it is called a **Step-up transformer**. When it is used to “decrease” the voltage on the secondary winding with respect to the primary it is called a **Step-down transformer**.

However, a third condition exists in which a transformer produces the same voltage on its secondary as is applied to its primary winding. In other words, its output is identical with respect to voltage, current and power transferred. This type of transformer is called an “Impedance Transformer” and is mainly used for impedance matching or the isolation of adjoining electrical circuits.

The difference in voltage between the primary and the secondary windings is achieved by changing the number of coil turns in the primary winding (N_P) compared to the number of coil turns on the secondary winding (N_S).

As the transformer is a linear device, a ratio now exists between the number of turns of the primary coil divided by the number of turns of the secondary coil. This ratio, called the ratio of transformation, more commonly known as a transformers “turns ratio”, (TR). This turns ratio value dictates the operation of the transformer and the corresponding voltage available on the secondary winding.

It is necessary to know the ratio of the number of turns of wire on the primary winding compared to the secondary winding. The turns ratio, which has no units, compares the two windings in order and is written with a colon, such as 3:1 (3-to-1). This means in this example, that if there are 3 volts on the primary winding there will be 1 volt on the secondary winding, 3-

to-1. Then we can see that if the ratio between the number of turns changes the resulting voltages must also change by the same ratio, and this is true.

A transformer is all about “ratios”, and the turns ratio of a given transformer will be the same as its voltage ratio. In other words for a transformer: “turns ratio = voltage ratio”. The actual number of turns of wire on any winding is generally not important, just the turns ratio and this relationship is given as:

A TRANSFORMERS TURNS RATIO

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = n = \text{Turns Ratio}$$

$$\text{Efficiency, } \eta = \frac{\text{Secondary Watts (Output)}}{\text{Primary VA (Input)}}$$

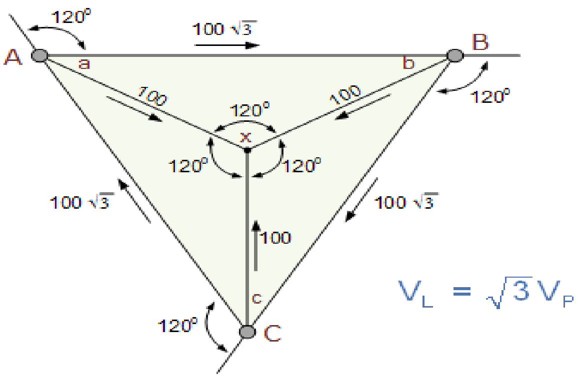
THREE PHASE TRANSFORMER BASICS

Thus far we have looked at the construction and operation of the single-phase, two winding voltage transformer which can be used increase or decrease its secondary voltage with respect to the primary supply voltage. But voltage transformers can also be constructed for connection to not only one single phase, but for two-phases, three-phases, six-phases and even elaborate combinations up to 24-phases for some DC rectification transformers.

If we take three single-phase transformers and connect their primary windings to each other and their secondary windings to each other in a fixed configuration, we can use the transformers on a three-phase supply.

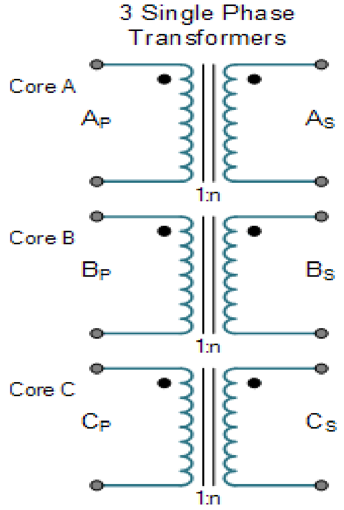
Three-phase, also written as 3-phase or 3φ supplies are used for electrical power generation, transmission, and distribution, as well as for all industrial uses. Three-phase supplies have many electrical advantages over Single-phase Power and when considering three-phase transformers we have to deal with three alternating voltages and currents differing in phase-time by 120 degrees as shown below.

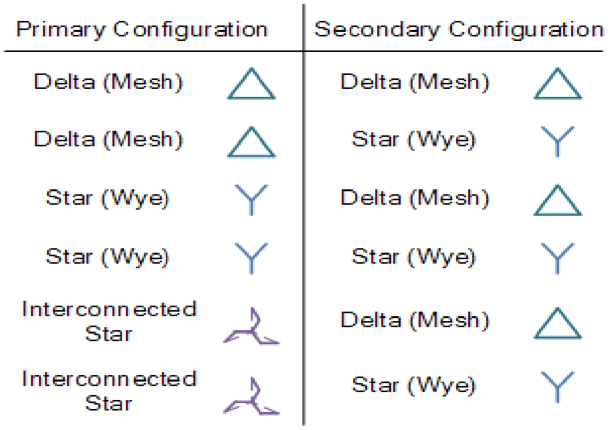
THREE PHASE VOLTAGES AND CURRENTS



A transformer can not act as a phase changing device and change single-phase into three-phase or three-phase into single phase. To make the transformer connections compatible with three-phase supplies we need to connect them together in a particular way to form a **Three Phase Transformer.**

THREE PHASE TRANSFORMER CONNECTIONS

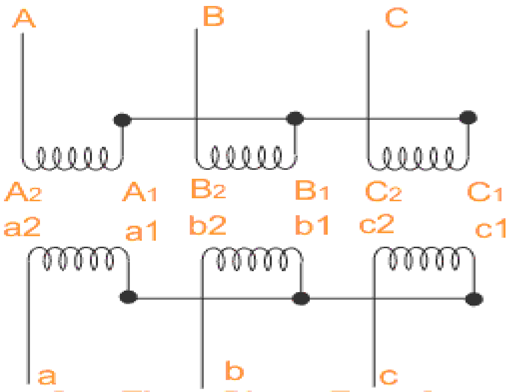




Primary Configuration		Secondary Configuration	
Delta (Mesh)	△	Delta (Mesh)	△
Delta (Mesh)	△	Star (Wye)	Y
Star (Wye)	Y	Delta (Mesh)	△
Star (Wye)	Y	Star (Wye)	Y
Interconnected Star	⅄	Delta (Mesh)	△
Interconnected Star	⅄	Star (Wye)	Y

CONNECTION OF THREE PHASE TRANSFORMER

STAR-STAR TRANSFORMER



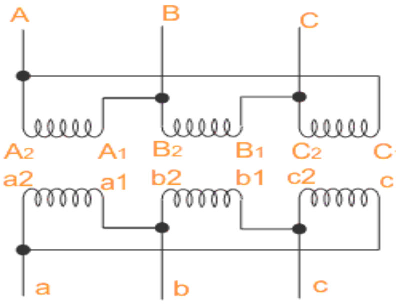
Star - Star Three Phase Transformer

Star-star transformer is formed in a 3 phase transformer by connecting one terminal of each phase of individual side, together. The common terminal is indicated by suffix 1 in the figure below. If terminal with suffix 1 in both primary and secondary are used as common terminal, voltages of primary and secondary are in same phase. That is why this connection is called zerodegree connection or 0° - connection.

If the terminals with suffix 1 is connected together in HV side as common point and the terminals with suffix 2 in LV side are connected together as common point, the voltages in primary and secondary will be in opposite phase. Hence, **star-star transformer** connection is called 180°-connection, of three phase transformer.

DELTA-DELTA TRANSFORMER

In **delta-delta transformer**, 1 suffixed terminals of each phase primary winding will be connected with 2 suffixed terminal of next phase primary winding.



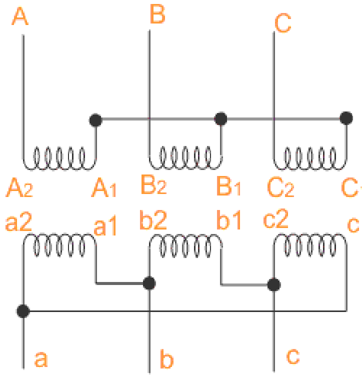
Delta - Delta Three Phase Transformer

If primary is HV side, then A_1 will be connected to B_2, B_1 will be connected to C_2 and C_1 will be connected to A_2. Similarly in LV side 1 suffixed terminals of each phase winding will be connected with 2 suffixed terminals of next phase winding. That means, a_1 will be connected to b_2, b_1 will be connected to c_2 and c_1 will be connected to a_2. If transformer leads are taken out from primary and secondary 2 suffixed terminals of the winding, then there will be no phase difference between similar line voltages in primary and secondary. This **delta delta transformer** connection is zero degree connection or 0°-connection.

But in LV side of transformer, if, a_2 is connected to b_1, b_2 is connected to c_1 and c_2 is connected to a_1. The secondary leads of transformer are taken out from 2 suffixed terminals of LV windings, and then similar line voltages in primary and secondary will be in phase opposition. This connection is called 180°-connection, of three phase transformer.

STAR-DELTA TRANSFORMER

Here in **star-delta transformer**, star connection in HV side is formed by connecting all the 1 suffixed terminals together as common point and transformer primary leads are taken out from 2 suffixed terminals of primary windings.



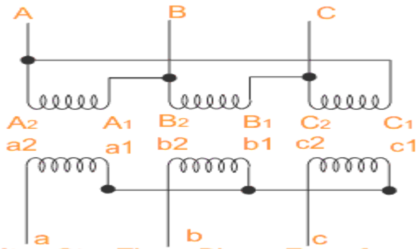
Star - Delta Three Phase Transformer

The delta connection in LV side is formed by connecting 1 suffixed terminals of each phase LV winding with 2 suffixed terminal of next phase LV winding. More clearly, a_1 is connected to b_2, b_1 is connected to c_2 and c_1 is connected to a_2. The secondary (here it considered as LV) leads are taken out from 2 suffixed ends of the secondary windings of transformer. The **transformer connection** diagram is shown in the figure beside. It is seen from the figure that the sum of the voltages in delta side is zero. This is a must as otherwise closed delta would mean a short circuit. It is also observed from the phasor diagram that, phase to neutral voltage (equivalent star basis) on the delta side lags by − 30° to the phase to neutral voltage on the star side; this is also the phase relationship between the respective line to line voltages. This **star delta transformer** connection is therefore known as − 30°-connection.

Star-delta + 30°-connection is also possible by connecting secondary terminals in following sequence. a_2 is connected to b_1, b_2 is connected to c_1 and c_2 is connected to a_1. The secondary leads of transformer are taken out from 2 suffixed terminals of LV windings,

DELTA-STAR TRANSFORMER

Delta-star transformer connection of three phase transformer is similar to star – delta connection. If any one interchanges HV side and LV side of star-delta transformer in diagram, it simply becomes delta – star connected 3 phase transformer. That means all small letters of star-delta connection should be replaced by capital letters and all small letters by capital in **delta-star transformer** connection.

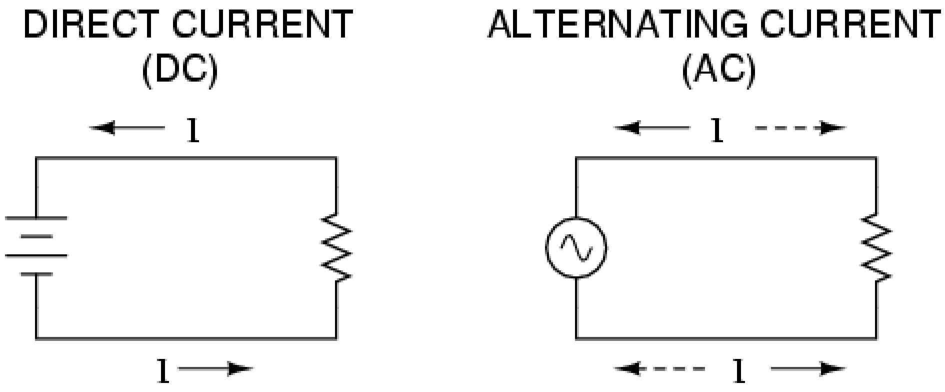


Delta - Star Three Phase Transformer

AC & DC SIGNAL

Most students of electricity begin their study with what is known as *direct current* (DC), which is electricity flowing in a constant direction, and/or possessing a voltage with constant polarity. DC is the kind of electricity made by a battery (with definite positive and negative terminals), or the kind of charge generated by rubbing certain types of materials against each other.

As useful and as easy to understand as DC is, it is not the only “kind” of electricity in use. Certain sources of electricity (most notably, rotary electro-mechanical generators) naturally produce voltages alternating in polarity, reversing positive and negative over time. Either as a voltage switching polarity or as a current switching direction back and forth, this “kind” of electricity is known as Alternating Current (AC): Figure below



SHORT CIRCUITING

As such the words suggest, the circuit becomes shorter. If there is a failure in insulation or some other means by which the two wires (phase and neutral) comes into electrical contact, the circuit gets shortened as the current always chooses the path which has got least resistance. Since the resistance of the shorted circuit is less a heavy current flows.

OVERLOADING

In house hold circuiting we are using parallel combination of the different appliances. Every instrument is connected in parallel to the supply. Whenever a new apparatus is switched on, it draws more current. If the current drawn by all the devices connected in a circuit is more than the maximum current rating for the given circuit, the condition is called overloading.

EARTHING

Earth refers to the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the Earth.

Electrical circuits may be connected to ground (earth) for several reasons. In mains powered equipment, exposed metal parts are connected to ground to prevent user contact with dangerous voltage if electrical insulation fails. Connections to ground limit the build-up of static electricity when handling flammable products or electrostatic-sensitive devices. In some telegraph and power transmission circuits, the earth itself can be used as one conductor of the circuit, saving the cost of installing a separate return conductor.

APPLICATIONS

The use of the term ground (or earth) is so common in electrical and electronics applications that circuits in portable electronic devices such as cell phones and media players as well as circuits in vehicles may be spoken of as having a "ground" connection without any actual connection to the Earth, despite "common" being a more appropriate term for such a connection. This is usually a large conductor attached to one side of the power supply (such as the "ground plane" on a printed circuit board) which serves as the common return path for current from many different components in the circuit.

EARTHINGTRANSFORMERS

In areas where earth point is not available, a neutral point is created using an earthing transformer. Earthing transformer, having the zig-zag (interstar) winding is used to achieve the required zero phase impendence stage which provides the possibility of neutral earthing condition. In addition an auxiliary windings can also be provided to meet the requirement of an auxiliary power supply.

Earthing transformers are usually oil immersed and may be installed outdoor. As for connection, the earthing can be connected directly, through an arc-suppression reactor or through a neutral earthing reactor or resistor. In cases where a separate reactor is connected between the transformer neutral and earth, the reactor and the transformer can be incorporated into the same tank.

FUSES

In order to prevent excessive currents flowing into the home circuit, electrical appliances and its cables, fuses and circuit breakers are wired into the live wire and used as safety devices.

- A fuse is usually made up of a tin-coated copper wire. When current exceeds its design rating value. The wire will overheat and melt, thus opening the electrical circuit. It will prevent further damage to the appliance or user. It cannot be reused.
- A circuit breaker is usually made up of a reusable spring-loaded type of switch. The function of the circuit breaker is similar to that of the fuse. If current exceeds its breaking setting, it will spring open and break the circuit as in a fuse. The device can be reused by resetting the spring-loaded switch.

APPLICATIONS

It is correct to fix the fuse or circuit breaker at the live wire before the appliance. When the circuit is loaded with excessive current, the fuse or circuit breaker will break and open the circuit. It will prevent overloading, burning or damaging the appliance.

CIRCUIT BREAKERS

- Connecting the fuse or circuit breaker to the neutral wire is incorrect, i.e., even when the circuit is opened due to excessive currents, the appliance may still be at live potential, creating possibility of an electric shock.

The current limit through the fuse (fuse rating) can be controlled by varying the thickness of the tin-coated copper wire. Thicker the wire, the larger the heating effect needed to melt the connection, thus permitting larger current to flow.

- Different fuse ratings and circuit breaker settings are used in different appliances according to their power requirements. The rating limits used is normally slightly higher than the normal current needed by the appliance.

COOLING OF TRANSFORMERS

The main source of heat generation in transformer is its copper loss or I^2R loss. Although there are other factors contribute heat in transformer such as hysteresis & eddy current losses but contribution of I^2R loss dominate them. If this heat is not dissipated properly, the temperature of the transformer will rise continually which may cause damages in paper insulation and liquid insulation medium of transformer. So it is essential to control the temperature with in permissible limit to ensure the long life of transformer by reducing thermal degradation of its insulation system. In electrical power transformer we use external **transformer cooling system** to accelerate the dissipation rate of heat of transformer.There are different **transformer cooling methods** available for trans former, we will now explain one by one.

No transformer is truly an 'ideal transformer' and hence each will incur some losses, most of which get converted into heat. If this heat is not dissipated properly, the excess temperature in transformer may cause serious problems like insulation failure. It is obvious that transformer needs a cooling system. Transformers can be divided in two types as (i) dry type transformers and (ii) oil immersed transformers. Different **cooling methods of transformers** are -

- For dry type transformers
    1. Air Natural (AN)

    2. Air Blast

- For oil immersed tranformers
    1. Oil Natural Air Natural (ONAN)
    2. Oil Natural Air Forced (ONAF)
    3. Oil Forced Air Forced (OFAF)
    4. Oil Forced Water Forced (OFWF)

COOLING METHODS FOR DRY TYPE TRANSFORMERS

Air Natural or Self air cooled transformer

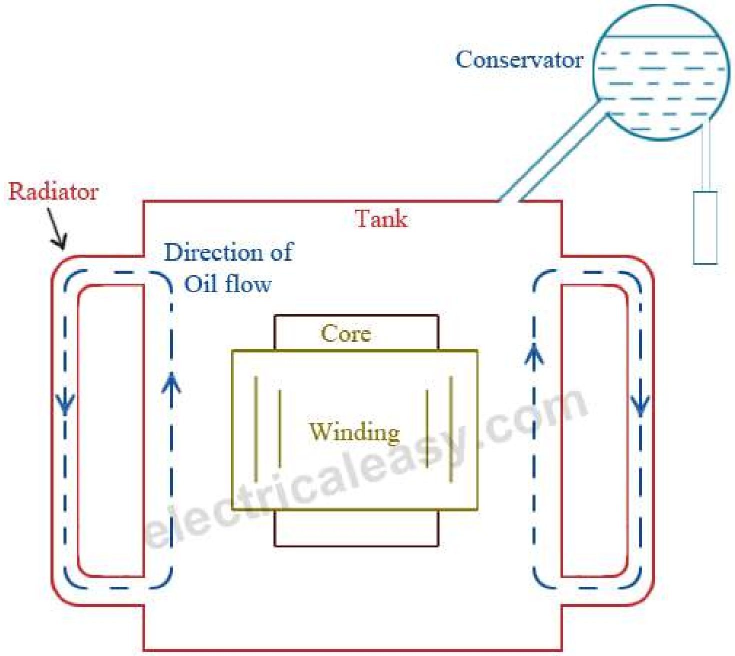
This method of transformer cooling is generally used in small transformers (upto 3 MVA). In this method the transformer is allowed to cool by natural air flow surrounding it.

Air Blast

For transformers rated more than 3 MVA, cooling by natural air method is inadequate. In this method, air is forced on the core and windings with the help of fans or blowers. The air supply must be filtered to prevent the accumulation of dust particles in ventilation ducts. This method can be used for transformers upto 15 MVA.

Cooling methods for Oil Immersed Transformers

Oil Natural Air Natural (ONAN)



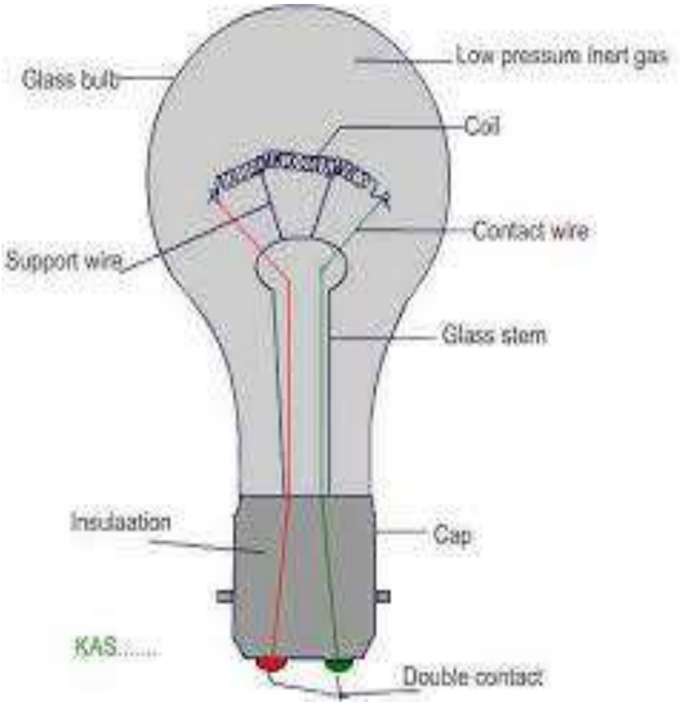
Oil Natural Air Natural (ONAN) - Cooling of Transformer

This method is used for oil immersed transformers. In this method, the heat generated in the core and winding is transferred to the oil. According to the principle of convection, the heated oil flows in the upward direction and then in the radiator. The vacant place is filled up by cooled oil from the radiator. The heat from the oil will dissipate in the atmosphere due to the natural air flow around the transformer. In this way, the oil in transformer keeps circulating due to natural convection and dissipating heat in atmosphere due to natural conduction. This method can be used for transformers upto about 30 MVA.

UNIT –IV

ELECTRICAL BULB

An incandescent light **bulb**, incandescent lamp or incandescent light globe is an **electric** light which produces light with a wire filament heated to a high temperature by an **electric** current passing through it, until it glows (see Incandescence). An incandescent light **bulb**, incandescent lamp or incandescent light globe is an **electric** light which produces light with a wire filament heated to a high temperature by an **electric** current passing through it, until it glows (see Incandescence).



FLUORESCENT LAMPS

PHYSICAL CHARACTERISTICS OF LAMPS

PRINCIPLES OF OPERATION

A fluorescent lamp generates light from collisions in a hot gas (‘plasma’) of free accelerated electrons with atoms– typically mercury – in which electrons are bumped up to higher energy levels and then fall back while emitting at two UV emission lines (254 nm and 185 nm). The thus created UV radiation is then converted into visible light by UV excitation of a fluorescent coating on the glass envelope of the lamp. The chemical composition of this coating is selected to emit in a desired spectrum.

CONSTRUCTION

A fluorescent lamp tube is filled with a gas containing low pressure mercury vapour and noble gases at a total pressure of about 0.3% of the atmospheric pressure. In the most common construction, a pair of filament emitters, one at each end of the tube, is heated by a current and is used to emit electrons which excite the noble gases and the mercury gas by impact ionisation. This ionisation can only take place in intact light bulbs. Therefore, adverse health effects from this ionisation process are not possible. Furthermore, lamps are often equipped with two envelopes, thus dramatically reducing the amount of UV radiation emitted.

ELECTRICAL ASPECTS OF OPERATION

A special electronic circuitry is needed to start the lamp and maintain currents at adequate levels for constant light emission. Specifically, the circuitry delivers high voltage to start the lamp and regulates the current flow through the tube. A number of different constructions are possible. In the simplest case only a resistor is used, which is relatively energy inefficient. For operation from alternating current (AC) mains voltage, the use of an inductive ballast is common and was known for failure before the end of the lamp lifetime inducing flickering of the lamp. The different circuits developed to start and run fluorescent lamps exhibit different properties, i.e. acoustic noise (hum) emission, lifetime (of the lamp and the ballast), energy efficiency and light intensity flicker. Today mostly improved circuitry is used, most especially with compact fluorescence lamps where the circuitry can not be replaced before the fluorescence lamps. This has reduced the occurrence of technical failures inducing effects as those listed above.

EMF

The part of the electromagnetic spectrum that comprises static fields, and fields up to 300 GHz is what is here referred to as electromagnetic fields (EMF). The literature on which kinds, and which strengths of EMF that are emitted from CFLs is sparse. However, there are several kinds of EMF found in the vicinity of these lamps. Like other devices that are dependent on electricity for their functions, they emit electric and magnetic fields in the low-frequency range (the distribution frequency 50 Hz and possibly also harmonics thereof, e.g. 150 Hz, 250 Hz etc. in Europe). In addition, CFLs, in contrast to the incandescent light bulbs, also emit in the high-frequency range of the EMF (30-60 kHz). These frequencies differ between different types of lamps.

FLICKER

All lamps will vary their light intensity at twice the mains (line) frequency, since the power being delivered to the lamp peaks twice per cycle at 100 Hz or 120 Hz. For incandescent lamps this flickering is reduced compared to fluorescence lamps by the heat capacity of the filament. If the modulation of the light intensity is sufficient to be perceived by the human eye, then this is defined as flicker. Modulation at 120 Hz cannot be seen, in most cases not even at 50 Hz (Seitz et al. 2006). Fluorescent lamps including CFLs that use high-frequency (kHz) electronic ballasts are, therefore, called "flicker free".

However, both incandescent (Chau-Shing and Devaney 2004) and "flicker free" fluorescent light sources (Khazova and O'Hagan 2008) produce hardly noticeable residual flicker. Defective lamps or circuitry can in some cases lead to flickering at lower frequencies, either only in part of the lamp or during the start cycle of some minutes.

LIGHT EMISSION, UV RADIATION AND BLUE LIGHT

There are characteristic differences between spectra emitted by fluorescent lamps and incandescent lamps because of the different principles of operation. Incandescent light bulbs are tuned in their colour temperature by specific coatings of the glass and are often sold either by the attribute ‘warm’ or ‘cold’ or more specifically by their colour temperature for professional lighting applications (photographic studios, clothing stores etc.). In the case of fluorescent lamps, the spectral emission depends on the phosphor coating. Thus, fluorescent lamps can be enriched for blue light (wavelengths 400-500 nm) in order to simulate daylight better in comparison to incandescent lamps. Like fluorescent lamps, CFL emit a higher proportion of blue light than incandescent lamps. There are internationally recognized exposure limits for the radiation (200-3000 nm) emitted from lamps and luminaries that are set to protect from photo biological hazards (International Electro technical Commission 2006). These limits also include radiation from CFLs.

The UV content of the emitted spectrum depends on both the phosphor and the glass envelope of the fluorescent lamp. The UV emission of incandescent lamps is limited by the temperature of the filament and the absorption of the glass. Some single-envelope CFLs emit

UV-B and traces of UV-C radiation at wavelength of 254 nm, which is not the case for incandescent lamps (Khazova and O´Hagan 2008). Experimental data show that CFLs produce more UVA irradiance than a tungsten lamp. Furthermore, the amount of UVB irradiance produced from single-envelope CFLs, from the same distance of 20 cm, was about ten times higher than that irradiated by a tungsten lamp (Moseley and Ferguson 2008).

UNINTERRUPTIBLE POWER SUPPLY (UPS)

An uninterruptible power supply (UPS) is a device that allows your computer to keep running for at least a short time when the primary power source is lost.

An uninterruptible power supply (UPS) is a device that allows your computer to keep running for at least a short time when the primary power source is lost. It also provides protection from power surges. A UPS contains a battery that "kicks in" when the device senses a loss of power from the primary source. If you are using the computer when the UPS notifies you of the power loss, you have time to save any data you are working on and exit gracefully before the secondary power source (the battery) runs out. When all power runs out, any data in your computer's random access memory (RAM) is erased. When power surges occur, a UPS intercepts the surge so that it doesn't damage your computer.

Software is available that automatically backs up (saves) any data that is being worked on when the UPS becomes activated.

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AUTOMATIC VOLTAGE STABILIZER

Voltage fluctuation has a negative impact on the electric circuit and may damage electrical devices. This problem can be easily solved by using an automatic voltage stabilizer. By taking a varying voltage and turning it into a constant voltage, the voltage regulator protects the electrical devices from voltage fluctuations in the power grid and extends their service life.

The DBW/SBW5 compensation type automatic voltage stabilizer consists of compensation transformer, regulating transformer, transmission mechanism, electric brush contact system, cabinet and analog control system. The transmission mechanism is composed of a servo motor, sprocket wheels, and a chain.

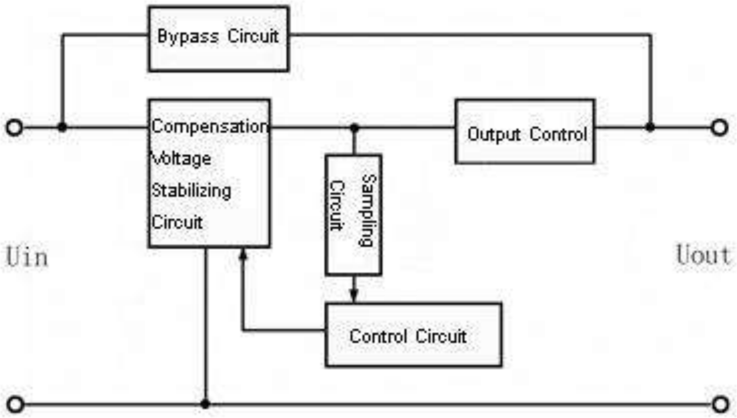
Our automatic voltage regulator features stepless voltage regulation, stable output, no wave distortion and no harmonic increment. The compensation range can reach ± 20% or ± 30% and the voltage regulation accuracy is adjustable between 1% and 5%. The capacity of single-phase and three-phase voltage regulators is 3 to 100 KVA and 10 to 3000 KVA respectively.

For the automatic voltage stabilizer with the rated capacity under 30 KVA, ring-shaped transformers are adopted for compensation and regulation, and all three phase are separately adjusted. For the AC voltage regulator with the rated capacity above 50 KVA, an E type transformer is used for compensation and a cylinder type transformation for regulation. All three phases are uniformly adjusted. Also, separate adjustment is available according to customer requirement.

Stable and reliable, our power converter comes with all the power protection functions. For example, when the output voltage is 10% greater or lower than the rated value, the voltage stabilizer will automatically bypass or cut off the output and then send out audible and visual alarm.

CIRCUIT STRUCTURE AND WORKING PRINCIPLE

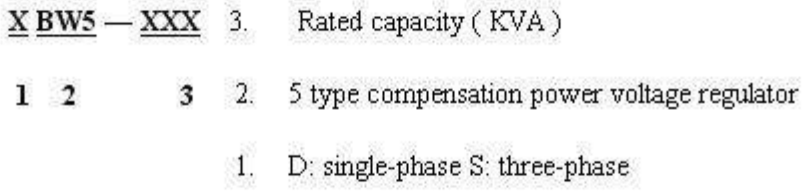
The DBW/SBW5 automatic voltage stabilizer is composed of compensation voltage stabilizing circuit, control circuit, sampling circuit, output control circuit, and bypass circuit. The compensation voltage stabilizing circuit, control circuit and sampling circuit form an automatic compensation voltage-stabilizing system.



DBW/SBW5 Automatic Voltage Stabilizer Schematic Diagram

Specifications and Technical Parameters

1. Model Name



X BW5 — XXX 3. Rated capacity (KVA)

1 2 3 2. 5 type compensation power voltage regulator

1. D: single-phase S: three-phase

WET GRINDER

A wet grinder is a specially designed kitchen appliance for the indian kitchen. The main use for the wet grinder is to grind soaked grains that are mainly used for making the south indian recipes

South Indian Idli and south indian dosa recipe.

The wet grinder is made up of a stainless steel drum with a base of granite stones which has a set of two grinding granite stones. The two grinding stones with a roller stone assembly which holds the stones together.

The wet grinders are slow grinding machines with the grinding stones rubbing each other they try to keep the temprature of the grains intact so the enzymes of the grains are restored.

The Wet grinder is available in 220 Volts and 110 Volts. The 110 Volts grinders are available for shipment in the United States.

DIFFERENT MODELS IN WET GRINDERS:

Wet grinder

1. Tilting countertop wet grinder

2. Conventional Wet grinders
3. Single stone traditional wet grinders
4. Commercial quick wet grinders

WATER HEATER

Water heating is a thermodynamic process that uses an energy source to heat water above its initial temperature. Typical domestic uses of hot water include cooking, cleaning, bathing, and space heating. In industry, hot water and water heated to steam have many uses.

Domestically, water is traditionally heated in vessels known as water heaters, kettles, cauldrons, pots, or coppers. These metal vessels that heat a batch of water do not produce a continual supply of heated water at a preset temperature. Rarely, hot water occurs naturally, usually from natural hot springs. The temperature varies based on the consumption rate, becoming cooler as flow increases.

Appliances that provide a continual supply of hot water are called water heaters, hot water heaters, tanks, boilers, heat exchangers, geysers, or calorifiers. These names depend on region, and whether they heat potable or non-potable water, are in domestic or industrial use, and their energy source. In domestic installations, potable water heated for uses other than space heating is also called domestic hot water (DHW).

Fossil fuels (natural gas, liquefied petroleum gas, oil), or solid fuels are commonly used for heating water. These may be consumed directly or may produce electricity that, in turn, heats water. Electricity to heat water may also come from any other electrical source, such as nuclear power or renewable energy. Alternative energy such as solar energy, heat pumps, hot water heat recycling, and geothermal heating can also heat water, often in combination with backup systems powered by fossil fuels or electricity.

Densely-populated urban areas of some countries provide district heating of hot water. This is especially the case in Scandinavia and Finland. District heating systems supply energy for water heating and space heating from waste heat from industries, power plants, incinerators, geothermal heating, and central solar heating. Actual heating of tap water is performed in heat exchangers at the consumers' premises. Generally the consumer has no in-building backup system, due to the expected high availability of district heating systems.

ELECTRIC IRON

A **clothing iron**, also called a **flatiron** or simply an **iron**, is a small appliance: a handheld piece of equipment with a flat, roughly triangular surface that, when heated, is used to press clothes to remove creases. It is named for the metal of which the device is commonly made, and the use of it is generally called ironing. Ironing works by loosening the ties between the long chains of molecules that exist in polymer fiber materials. With the heat and the weight of the ironing plate, the fibers are stretched and the fabric maintains its new shape when cool. Some materials, such as cotton, require the use of water to loosen the intermolecular bonds. Many materials developed in the twentieth century are advertised as needing little or no ironing.

The electric iron was invented in 1882 by Henry W. Seeley, a New York inventor. Seeley patented his "electric flatiron" on June 6, 1882.[1] His iron weighed almost 15 pounds and took a long time to warm up. Other electric irons had also been invented, including one from France (1882), but it used a carbon arc to heat the iron, a method which was dangerous.

Modern irons for home use can have the following features:

- A design that allows the iron to be set down, usually standing on its end, without the hot soleplate touching anything that could be damaged;
- A thermostat ensuring maintenance of a constant temperature;
- A temperature control dial allowing the user to select the operating temperatures (usually marked with types of cloth rather than temperatures: "silk", "wool", "cotton", "linen", etc.);
- An electrical cord with heat-resistant silicone rubber insulation;
- Injection of steam through the fabric during the ironing process;
- A water reservoir inside the iron used for steam generation;
- An indicator showing the amount of water left in the reservoir,
- Constant steam: constantly sends steam through the hot part of the iron into the clothes;
- Steam burst: sends a burst of steam through the clothes when the user presses a button;
- (advanced feature) Dial controlling the amount of steam to emit as a constant stream;
- (advanced feature) Anti-drip system;
- Cord control: the point at which the cord attaches to the iron has a spring to hold the cord out of the way while ironing and likewise when setting down the iron (prevents fires, is more convenient, etc.);

- (advanced feature) non-stick coating along the sole plate to help the iron glide across the fabric
- (advanced feature) Anti-burn control: if the iron is left flat (possibly touching clothes) for too long, the iron shuts off to prevent scorching and fires;
- (advanced feature) Energy saving control: if the iron is left undisturbed for several (10 or 15) minutes, the iron shuts off to save energy and prevent fires.
- Cordless irons: the iron is placed on a stand for a short period to warm up, using thermal mass to stay hot for a short period. These are useful for light loads only. Battery power is not viable for irons as they require more power than practical batteries can provide.
- (advanced feature) 3-way automatic shut-off
- (advanced feature) self-cleaning

REFRIGERATOR

A **refrigerator** (colloquially **fridge**) is a common household appliance that consists of a thermally insulated compartment and a heat pump(mechanical, electronic, or chemical) that transfers heat from the inside of the fridge to its external environment so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room. Refrigeration is an essential food storage technique in developed countries. Lower temperatures in a confined volume lower the reproduction rate of bacteria, so the refrigerator reduces the rate of spoilage.

A refrigerator maintains a temperature a few degrees above the freezing point of water.

Features

Newer refrigerators may include:

- Automatic defrosting
- A power failure warning that alerts the user by flashing a temperature display. It may display the maximum temperature reached during the power failure, and whether frozen food has defrosted or may contain harmful bacteria.
- Chilled water and ice from a dispenser in the door. Water and ice dispensing became available in the 1970s. In some refrigerators, the process of making ice is built-in so the user doesn't have to manually use ice trays. Some refrigerators have water chillers and water filtration systems.
- Cabinet rollers that lets the refrigerator roll out for easier cleaning
- Adjustable shelves and trays

- A status indicator that notifies when it is time to change the water filter
- An in-door ice caddy, which relocates the ice-maker storage to the freezer door and saves approximately 60 litres (2 cu ft) of usable freezer space. It is also removable, and helps to prevent ice-maker clogging.
- A cooling zone in the refrigerator door shelves. Air from the freezer section is diverted to the refrigerator door, to cool milk or juice stored in the door shelf.
- A drop down door built into the refrigerator main door, giving easy access to frequently used items such as milk, thus saving energy by not having to open the main door.
- A Fast Freeze function to rapidly cool foods by running the compressor for a predetermined amount of time and thus temporarily lowering the freezer temperature below normal operating levels. It is recommended to use this feature several hours before adding more than 1 kg of unfrozen food to the freezer. For freezers without this feature, lowering the temperature setting to the coldest will have the same effect.

MICROWAVE OVEN

A **microwave oven**, often colloquially shortened to **microwave**, is a kitchen appliance that heats food by bombarding it with electromagnetic radiationin the microwave spectrum causing polarized molecules in the food to rotate and build up thermal energy in a process known as dielectric heating. Microwave ovens heat foods quickly and efficiently because excitation is fairly uniform in the outer 25–38 mm of a dense (high water content) food item; food is more evenly heated throughout (except in thick, dense objects) than generally occurs in other cooking techniques.

Percy Spencer invented the first microwave oven after World War II from radar technology developed during the war. Named the "Radarange", it was first sold in 1947. Raytheon later licensed its patents for a home-use microwave oven that was first introduced by Tappan in 1955, but these units were still too large and expensive for general home use. The countertop microwave oven was first introduced in 1967 by the Amana Corporation, which was acquired in 1965 by Raytheon.

Microwave ovens are popular for reheating previously cooked foods and cooking vegetables. They are also useful for rapid heating of otherwise slowly prepared cooking items, such as hot butter, fats, and chocolate. Unlike conventional ovens, microwave ovens usually do not directly brown or caramelize food, since they rarely attain the necessary temperatures to produce Maillard reactions. Exceptions occur in rare cases where the oven is used to heat frying-oil and other very oily items (such as bacon), which attain far higher temperatures than that of boiling water. The boiling-range temperatures produced in high-water-content foods give microwave ovens a limited role in professional cooking,[1] since it usually makes them unsuitable for achievement of culinary effects where the flavors produced by the higher temperatures of frying, browning, or baking are needed. However, additional kinds of heat sources can be added to microwave packaging, or into combination microwave ovens, to produce these other heating effects, and microwave heating may cut the overall time needed to prepare such dishes. Some modern microwave ovens may be part of an over-the-range unit with built-in extractor hoods.

UNIT V

ELECTRIC HEATING

Electric heating is any process in which electrical energy is converted to heat. Common applications include heating of buildings, cooking, and industrial processes.

An electric heater is an electrical appliance that converts electrical energy into heat. The heating element inside every electric heater is simply an electrical resistor, and works on the principle of Joule heating: an electric current flowing through a resistor converts electrical energy into heat energy.

A heat pump uses an electric motor to drive a refrigeration cycle, drawing heat from a source such as ground water or outside air and directing it into the space to be warmed. Such systems can deliver two or three units of heating energy for every unit of purchased energy.

Design variations:

Although they all use the same physical principle to generate heat, electric heaters differ in the way they deliver that heat to the environment. Several types are described in the sections below.Radiative heaters or "space heaters"

Radiative heaters contain a heating element that reaches a high temperature. The element is usually packaged inside a glass envelope resembling a light bulb and with a reflector to direct the energy output away from the body of the heater. The element emits infrared radiation that travels through air or space until it hits an absorbing surface, where it is partially converted to heat and partially reflected. This heat directly warms people and objects in the room, rather than warming the air. This style of heater is particularly useful in areas which unheated air flows through. They are also ideal for basements and garages where spot heating is desired. More generally, they are an excellent choice for task-specific heating.

They operate silently. Radiant heaters present the greatest potential danger to ignite nearby furnishings due to the focused intensity of their output and lack of overheat protection.

Convection heaters:

In a convection heater, the heating element heats the air next to it by conduction. Hot air is less dense than cool air, so it rises due to buoyancy, allowing more cool air to flow in to take its place. This sets up a constant current of hot air that leaves the appliance through vent holes and heats up the surrounding space. They are ideally suited for heating a closed space. They operate silently and have a lower risk of ignition hazard in the event that they make unintended contact with furnishings compared to radiant electric heaters. This is a good choice for long periods of time or if left unattended. They are very safe heaters and there is a very low chance of getting burned

In the United Kingdom, these appliances are sometimes called electric fires, because they were originally used to replace open fires.

Fan heaters or "forced convection heaters"

A fan heater is a variety of convection heater that includes an electric fan to speed up the airflow. This reduces the thermal resistance between the heating element and the surroundings, allowing heat to be transferred more quickly.

They operate with considerable noise caused by the fan. They have a moderate risk of ignition hazard in the event that they make unintended contact with furnishings. This type of heater is a good choice for quick heating of enclosed spaces; however, they should not be left unattended

They work by converting electricity into heat using metals as heating elements. The metals have high resistance that permit a certain amount of current to flow though them to provide the required heat. Electrical energy is changed into heat energy and the the relationship between the wattage and Btu/hr is:

1 Watt = 3.415 Btu/hr.

There are three types of electric resistance heating wires that are in used today:

- Open Wire consists of nickel chromium resistance wire which is mounted on ceramic or mica insulation. For safety reason, they must be protected and should not be contacted by users or metal objects. This protection is vital to prevent the danger of electric shock.
- Open Ribbon is similar in material to the open wire type but has more surface area that are exposed for air contact. It too must be protected to prevent the danger of electric shock to the users.
- Tubular cased wire uses nickel chromium resistance wire that is surrounded by a magnesium oxide powder which are then enclosed in a heat resistance steel tube. This tube protects the users from the danger of electric shock.

ELECTRICAL RESISTANCE HEATING

Electrical resistance heating is used by the environmental restoration industry for remediation of contaminated soil and groundwater. ERH consists of constructing electrodes in the ground, applying alternating current (AC) electricity to the electrodes and heating the subsurface to temperatures that promote the evaporation of contaminants. Volatilized contaminants are captured by a subsurface vapor recovery system and conveyed to the surface along with recovered air and steam. Similar to Soil vapor extraction, the air, steam and volatilized contaminants are then treated at the surface to separate water, air and the contaminants. Treatment of the various streams depends on local regulations and the amount of contaminant.

Some low volatility organic contaminants have a short hydrolysis half life. For contaminants like these, i.e. 1,1,2,2-Tetrachloroethane and 1,1,1-trichloroethane, hydrolysis can be the primary form of remediation. As the subsurface is heated the hydrolysis half life of the contaminant will decrease as described by the Arrhenius equation. This results in a rapid degradation of the contaminant. The hydrolysis by-product may be remediated by conventional ERH, however the majority of the mass of the primary contaminant will not be recovered but rather will degrade to a by-product.

There are predominantly two electrical load arrangements for ERH: three-phase and six-phase. Three-phase heating consists of electrodes in a repeating triangular or delta pattern. Adjacent electrodes are of a different electrical phase so electricity conducts between them as shown in Figure 1. The contaminated area is depicted by the green shape while the electrodes are depicted by the numbered circles.

Electrode spacing and operating time can be adjusted to balance the overall remediation cost with the desired cleanup time. A typical remediation may consist of electrodes spaced 15 to 20 feet apart with operating times usually less than a year. The design and cost of an ERH remediation system depends on a number of factors, primarily the volume of soil/groundwater to be treated, the type of contamination, and the treatment goals. The physical and chemical properties of the target compounds are governed by laws that make heated remediations advantageous over most conventional methods. The electrical energy usage required for heating the subsurface and volatilizing the contaminants can account for 5 to 40% of the overall remediation cost.

There are several laws that govern an ERH remediation. Dalton’s law governs the boiling point of a relatively insoluble contaminant. Raoult’s law governs the boiling point of mutually soluble co-contaminants and Henry’s law governs the ratio of the contaminant in the vapor phase to the contaminant in the liquid phase.

Dalton's Law:

For mutually insoluble compounds Dalton’s Law states that the partial pressure of a non aqueous phase liquid (NAPL) is equal to its vapor pressure, and that the NAPL in contact with water will boil when the vapor pressure of water plus the vapor pressure of the VOC is equal to ambient pressure. When a VOC-steam bubble is formed the composition of the bubble is proportional to the composite’s respective vapor pressures.

Raoult's Law:

For mutually soluble compounds, Raoult’s Law states that the partial pressure of a compound is equal to its vapor pressure times its mole fraction. This means that mutually soluble contaminants will volatilize slower than if there was only one compound present.

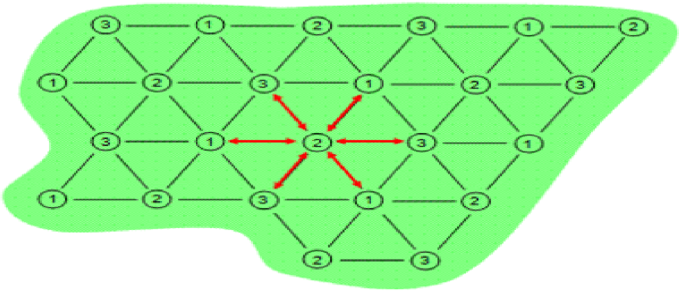
Henry's Law:

Henry’s law describes the tendency of a compound to join air in the vapor phase or dissolve in water. The Henry’s Law constant, sometimes called coefficient, is specific to each compound, varies with temperature, and predicts the amount of contaminant that will stay in the vapor phase or transfer to the liquid phase when exiting the condenser.

Weaknesses:

- Weaknesses of ERH include heat losses on small sites. Treatment volumes that have a large surface area but are thin with respect to depth will have significant heat losses which makes ERH less efficient. The minimum treatment interval for efficient ERH remediation is approximately 10 vertical feet.
- Co-contaminants like oil or grease make remediation more difficult. Oil and grease cause a Raoult’s Law effect which requires more energy to remove the contaminants.
- Peat or high organic carbon in the subsurface will preferentially adsorb VOCs due to van der Waals forces. This preferential adsorption will increase the amount of energy required to remove the VOCs from the subsurface.

- Fuel sites are less-commonly treated by ERH because other less-expensive remediation technologies are available and because fuel sites are usually thin (resulting in significant heat losses).
- Sites within landfills are also challenging because metallic debris can distort the electric current paths. ERH is more uniform in natural soil or rock.
- Strengths:
- ERH is adaptable to all soil types and sedimentary bedrock. ERH is also effective in both the vadose and saturated zones. Certain lithologies can limit traditional methods of remediation by preventing a reliable removal/destruction pathway for the contamination of concern. Because electricity can and does travel through any lithology that contains some water, ERH can be effective in any soil type.
- By forming buoyant steam bubbles during the heating process, ERH creates a carrier gas that transports the contamination of concern up and out of any soil type. ERH is not capable of desiccating the subsurface. In order for the subsurface to conduct electricity, there must be water present in the subsurface. Conductivity will cease before the subsurface is desiccated.
- ERH is commonly applied under active buildings or manufacturing facilities. Electrodes can be installed above grade within a fenced area or below grade to allow for unrestricted surface access to the treatment area.
- Although principally used for contaminant source areas, ERH can be used to achieve low remedial goals such as maximum contaminant levels, MCLs, for drinking water.
- After ERH treatment, elevated subsurface temperatures will slowly cool over a period of months or years and return to ambient. This period with elevated temperatures is an important part of the remediation process. The elevated temperatures will enhance Bioremediation, hydrolysis and iron reductive dehalogenation.



Six-phase heating consists of six electrodes in a hexagonal pattern with a neutral electrode in the center of the array. The six-phase arrays are outlined in blue in Figure 2 below. Once again the contaminated area is depicted by the green shape while the electrodes are depicted by the numbered circles. In a six-phase heating pattern there can be hot spots and cold spots depending on the phases that are next to each other. For this reason, six-phase heating typically works best on small circular areas that are less than 65 feet in diameter.

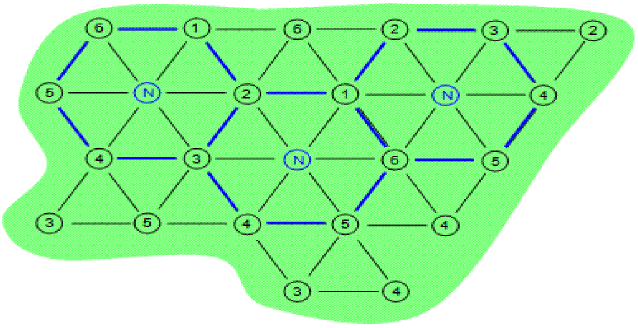


Fig 2. Typical six-phase ERH arrangement

ERH is typically most effective on volatile organic compounds (VOCs). The chlorinated compounds per chloro ethylene, trichloroethylene, and cis- or trans- 1,2-dichloroethylene are contaminants that are easily remediated with ERH. The table shows contaminants that can be remediated with ERH along with their respective boiling points. Less volatile contaminants like xylene or diesel can also be remediated with ERH but energy requirements increase as the volatility decreases.

INDUCTION HEATING

Induction heating is the process of heating an electrically conducting object (usually a metal) by electromagnetic induction, where eddy currents (also called Foucault currents) are generated within the metal and resistance leads to Joule heating of the metal. An induction heater (for any process) consists of an electromagnet, through which a high-frequency alternating current (AC) is passed. Heat may also be generated by magnetic hysteresis losses in materials that have significant relative permeability. The frequency of AC used depends on the object size, material type, coupling (between the work coil and the object to be heated) and the penetration depth.

Applications:

Induction heating of 25 mm metal bars using 15 kW at 450 kHz.

Induction heating allows the targeted heating of an applicable item for applications including surface hardening, melting, brazing and soldering and heating to fit. Iron and its alloys respond best to induction heating, due to their ferromagnetic nature. Eddy currents can, however, be generated in any conductor, and magnetic hysteresis can occur in any magnetic material. Induction heating has been used to heat liquid conductors (such as molten metals) and also gaseous conductors (such as a gas plasma - see Induction plasma technology). Induction heating is often used to heat graphite crucibles (containing other materials) and is used extensively in the semiconductor industry for the heating of silicon and other semiconductors. Utility frequency (50/60 Hz) induction heating is used for many lower cost industrial applications as inverters are not required.

Induction furnace:

An induction furnace uses induction to heat metal to its melting point. Once molten, the high-frequency magnetic field can also be used to stir the hot metal, which is useful in ensuring that alloying additions are fully mixed into the melt. Most induction furnaces consist of a tube of water-cooled copper rings surrounding a container of refractory material. Induction furnaces are used in most modern foundries as a cleaner method of melting metals than a reverberator furnace or acupola. Sizes range from a kilogram of capacity to a hundred tones capacity.

Induction furnaces often emit a high-pitched whine or hum when they are running, depending on their operating frequency. Metals melted include iron and steel, copper,aluminium, and precious metals. Because it is a clean and non-contact process it can be used in a vacuum or inert atmosphere. Vacuum furnaces make use of induction heating for the production of specialty steels and other alloys that would oxidize if heated in the presence of air.

Induction welding:

A similar, smaller-scale process is used for induction welding. Plastics may also be welded by induction, if they are either doped with ferromagnetic ceramics (where magnetic hysteresis of the particles provides the heat required) or by metallic particles.

Seams of tubes can be welded this way. Currents induced in a tube run along the open seam and heat the edges resulting in a temperature high enough for welding. At this point the seam edges are forced together and the seam is welded. The RF current can also be conveyed to the tube by brushes, but the result is still the same — the current flows along the open seam, heating it

Induction cooking:

In induction cooking, an induction coil in the cook-top heats the iron base of cookware. Copper-bottomed pans, aluminium pans and other non-ferrous pans are generally unsuitable. The heat induced in the base is transferred to the food via (metal surface) conduction. Benefits of induction cookers include efficiency, safety (the induction cook-top is not heated itself) and speed. Both permanently installed and portable induction cookers are available.

Induction brazing:

Induction brazing is often used in higher production runs. It produces uniform results and is very repeatable.

Induction sealing:

Induction heating is used in cap sealing of containers in the food and pharmaceutical industries. A layer of aluminum foil is placed over the bottle or jar opening and heating by induction to fuse it to the container. This provides a tamper-resistant seal, since altering the contents requires breaking the foil. [1]

Heating to fit:

Induction heating is often used to heat an item causing it to expand prior to fitting or assembly. Bearings are routinely heated in this way using utility frequency (50/60 Hz) and a laminated steel transformer type core passing through the centre of the bearing.

Heat treatment:

Induction heating is often used in the heat treatment of metal items. The most common applications are induction hardening of steel parts, induction soldering/brazing as a means of joining metal components and induction annealing to selectively soften an area of a steel part.

Induction heating can produce high power densities which allow short interaction times to reach the required temperature. This gives tight control of the heating pattern with the pattern following the applied magnetic field quite closely and allows reduced thermal distortion and damage.

This ability can be used in hardening to produce parts with varying properties. The most common hardening process is to produce a localized surface hardening of an area that needs wear-resistance, while retaining the toughness of the original structure as needed elsewhere. The depth of induction hardened patterns can be controlled through choice of induction-frequency, power-density and interaction time.

Limits to the flexibility of the process arise from the need to produce dedicated inductors for many applications. This is quite expensive and requires the marshalling of high current densities in small copper inductors, which can require specialized engineering and 'copper-fitting'

HIGH FREQUENCY EDDY CURRENT HEATING

Eddy currents (also called **Foucault currents**[1]) are circular currents induced within conductors by a changing magnetic field in the conductor, due to Faraday's. Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field. They can be induced within nearby stationary conductors by a time-varying magnetic field created by an AC electromagnet or transformer, for example, or by relative motion between a magnet and a nearby conductor. The magnitude of the current in a given loop is proportional to the strength of the magnetic field, the area of the loop, and the rate of change of flux, and inversely proportional to the resistivity of the material.

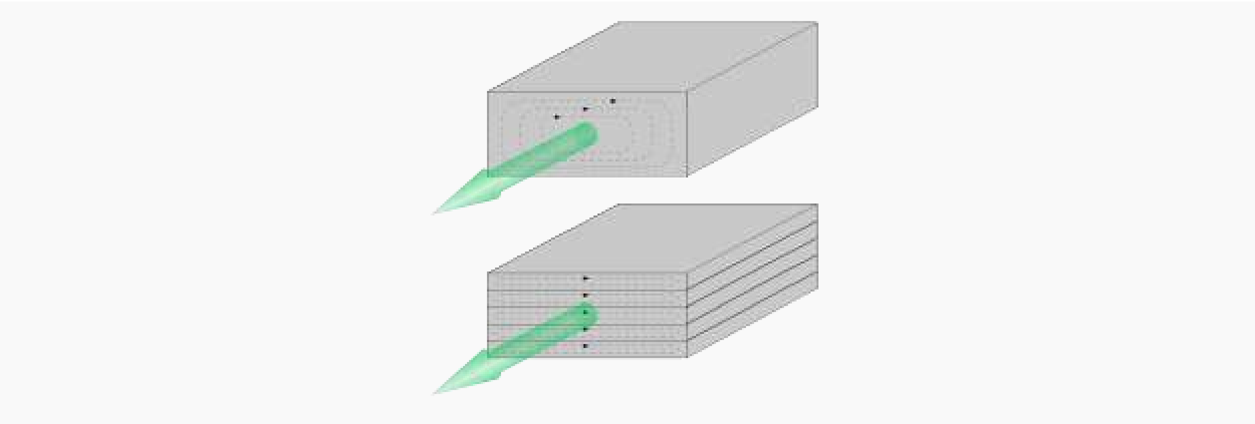
By Lenz's law, an eddy current creates a magnetic field that opposes the magnetic field that created it, and thus eddy currents react back on the source of the magnetic field. For example, a nearby conductive surface will exert a drag force on a moving magnet that opposes its motion, due to eddy currents induced in the surface by the moving magnetic field. This effect is employed in eddy current brakes which are used to stop rotating power tools quickly when they are turned off.

The current flowing through the resistance of the conductor also dissipates energy as heat in the material. Thus eddy currents are a source of energy loss in alternating current (AC) inductors, transformers, electric motors and generators, and other AC machinery, requiring special construction such as laminated magnetic cores to minimize them. Eddy currents are also used to heat objects in induction heating furnaces and equipment, and to detect cracks and flaws in metal parts using eddy-current testing instruments

Eddy currents in conductors of non-zero resistivity generate heat as well as electromagnetic forces. The heat can be used for induction. The electromagnetic forces can be used for levitation, creating movement, or to give a strong braking effect. Eddy currents can also have undesirable effects, for instance power loss in transformers. In this application, they are minimized with thin plates, by lamination of conductors or other details of conductor shape.
Self-induced eddy currents are responsible for the skin effect in conductors.[3] The latter can be used for non-destructive testing of materials for geometry features, like micro-cracks. A similar effect is the proximity effect, which is caused by externally induced eddy currents.

The swirling current set up in the conductor is due to electrons experiencing a Lorentz force that is perpendicular to their motion. Hence, they veer to their right, or left, depending on the direction of the applied field and whether the strength of the field is increasing or declining. The resistivity of the conductor acts to damp the amplitude of the eddy currents, as well as straighten their paths. Lenz's law states that the current swirls in such a way as to create an induced magnetic field that opposes the phenomenon that created it. In the case of a varying applied field, the induced field will always be in the opposite direction to that applied

An object or part of an object experiences steady field intensity and direction where there is still relative motion of the field and the object (for example in the center of the field in the diagram), or unsteady fields where the currents cannot circulate due to the geometry of the conductor. In these situations charges collect on or within the object and these charges then produce static electric potentials that oppose any further current. Currents may be initially associated with the creation of static potentials, but these may be transitory and small.



Lamination of conductors parallel to the field lines reduce eddy currents

Eddy currents generate resistive losses that transform some forms of energy, such as kinetic energy, into heat. This Joule heating reduces efficiency of iron-core transformers and electric motors and other devices that use changing magnetic fields. Eddy currents are minimized in these devices by selecting core materials that have low electrical conductivity (e.g., ferrites) or by using thin sheets of magnetic material, known as laminations.

Electrons cannot cross the insulating gap between the laminations and so are unable to circulate on wide arcs. Charges gather at the lamination boundaries, in a process analogous to the Hall effect, producing electric fields that oppose any further accumulation of charge and hence suppressing the eddy currents. The shorter the distance between adjacent laminations (i.e., the greater the number of laminations per unit area, perpendicular to the applied field), the greater the suppression of eddy currents.

Power dissipation of eddy currents:

Under certain assumptions (uniform material, uniform magnetic field, no skin effect, etc.) the power lost due to eddy currents per unit mass for a thin sheet or wire can be calculated from the following equation:

$$P = \frac{\pi^2 B_{\rm p}^2 d^2 f^2}{6k\rho D},$$

where

P is the power lost per unit mass (W/kg),

B_p is the peak magnetic field (T),

d is the thickness of the sheet or diameter of the wire (m),

f is the frequency (Hz),

k is a constant equal to 1 for a thin sheet and 2 for a thin wire,

ρ is the resistivity of the material (Ω m), and

D is the density of the material (kg/m^3).

This equation is valid only under the so-called quasi-static conditions, where the frequency of magnetisation does not result in the skin effect; that is, the electromagnetic wave fully penetrates the material.

Skin effect:

In very fast-changing fields, the magnetic field does not penetrate completely into the interior of the material. This skin effectrenders the above equation invalid. However, in any case increased frequency of the same value of field will always increase eddy currents, even with non-uniform field penetration.

The penetration depth for a good conductor can be calculated from the following equation

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}},$$

where δ is the penetration depth (m), f is the frequency (Hz), μ is the magnetic permeability of the material (H/m), and σ is the electrical conductivity of the material (S/m).

Diffusion equation:

The derivation of a useful equation for modelling the effect of eddy currents in a material starts with the differential, magneto static form of Ampère's Law,[8] providing an expression for the magnetizing field **H** surrounding a current density **J**:

$$\nabla \times \mathbf{H} = \mathbf{J}.$$

Taking the curl on both sides of this equation and then using a common vector calculus identity for the curl of the curl results in

$$\nabla \left(\nabla \cdot \mathbf{H} \right) - \nabla^2 \mathbf{H} = \nabla \times \mathbf{J}.$$

From Gauss's law for magnetism, $\nabla \cdot \mathbf{H} = 0$, so

$$-\nabla^2 \mathbf{H} = \nabla \times \mathbf{J}.$$

Using Ohm's law, $\mathbf{J} = \sigma \mathbf{E}$, which relates current density **J** to electric field **E** in terms of a material's conductivity σ, and assuming isotropic homogeneous conductivity, the equation can be written as

$$-\nabla^2 \mathbf{H} = \sigma \nabla \times \boldsymbol{E}.$$

Using the differential form of Faraday's law, $\nabla \times \mathbf{E} = -\partial \mathbf{B}/\partial t$, this gives

$$\nabla^2 \mathbf{H} = \sigma \frac{\partial \mathbf{B}}{\partial t}.$$

By definition, $\mathbf{B} = \mu_0(\mathbf{H} + \mathbf{M})$, where **M** is the magnetization of the material and μ_0 is the vacuum permeability. The diffusion equation therefore is

$$\nabla^2 \mathbf{H} = \mu_0 \sigma \left(\frac{\partial \mathbf{M}}{\partial t} + \frac{\partial \mathbf{H}}{\partial t} \right).$$

DIELECTRIC HEATING

Dielectric heating, also known as electronic heating, RF heating, high-frequency heating is the process in which a high-frequency alternating electric field, or radio wave or microwave electromagnetic radiation heats a dielectric material. At higher frequencies, this heating is caused by molecular dipole rotation within the dielectric.

RF dielectric heating at intermediate frequencies, due to its greater penetration over microwave heating, shows greater promise than microwave systems as a method of very rapidly heating and uniformly preparing certain food items, and also killing parasites and pests in certain harvested crops

Mechanism

Molecular rotation occurs in materials containing polar molecules having an electrical dipole moment, with the consequence that they will align themselves in an electromagnetic field. If the field is oscillating, as it is in an electromagnetic wave or in a rapidly oscillating electric field, these molecules rotate continuously aligning with it. This is called dipole rotation, or dipolar polarization. As the field alternates, the molecules reverse direction. Rotating molecules push, pull, and collide with other molecules (through electrical forces), distributing the energy to adjacent molecules and atoms in the material. Once distributed, this energy appears as heat.

Temperature is the average kinetic energy (energy of motion) of the atoms or molecules in a material, so agitating the molecules in this way increases the temperature of the material. Thus, dipole rotation is a mechanism by which energy in the form of electromagnetic radiation can raise the temperature of an object. There are also many other mechanisms by which this conversion occurs

Dipole rotation is the mechanism normally referred to as dielectric heating, and is most widely observable in the microwave oven where it operates most efficiently on liquid water, and much less so on fats and sugars. This is because fats and sugar molecules are far less polar than water molecules, and thus less affected by the forces generated by the alternating electromagnetic fields. Outside of cooking, the effect can be used generally to heat solids, liquids, or gases, provided they contain some electric dipoles.

Dielectric heating involves the heating of electrically insulating materials by dielectric loss. A changing electric field across the material causes energy to be dissipated as the molecules attempt to line up with the continuously changing electric field. This changing electric field may be caused by an electromagnetic wave propagating in free space (as in a microwave oven), or it may be caused by a rapidly alternating electric field inside a capacitor.

In the latter case there is no freely propagating electromagnetic wave, and the changing electric field may be seen as analogous to the electric component of an antenna near. In this case, although the heating is accomplished by changing the electric field inside the capacitive cavity at radio-frequency (RF) frequencies, no actual radio waves are either generated or absorbed. In this sense, the effect is the direct electrical analog of magnetic induction heating, which is also near-field effect (and also does not involve classical radio waves)

Frequencies in the range of 10–100 MHz are necessary to cause efficient dielectric heating, although higher frequencies work equally well or better, and in some materials (especially liquids) lower frequencies also have significant heating effects, often due to more unusual mechanisms. For example, in conductive liquids such as salt water, "ion-drag" causes heating, as charged ions are "dragged" more slowly back and forth in the liquid under influence of the electric field, striking liquid molecules in the process and transferring kinetic energy to them, which is eventually translated into molecular vibrations and thus into thermal energy.

Dielectric heating at low frequencies, as a near-field effect, requires a distance from electromagnetic radiator to absorber of less than about 1/6th of a wavelength ($\lambda/2\pi$) of the source frequency. It is thus a contact process or near-contact process, since it usually sandwiches the material to be heated (usually a non-metal) between metal plates that set up to form what is effectively a very large capacitor, with the material to be heated acting as the dielectric inside the capacitor.

At very high frequencies, the wavelength of the electromagnetic field becomes shorter than the distance between the metal walls of the heating cavity, or than the dimensions of the walls themselves. This is the case inside a microwave oven. In such cases, conventional far-field electromagnetic waves form (the cavity no longer acts as a pure capacitor, but rather as an antenna), and are absorbed to cause heating, but the dipole-rotation mechanism of heat deposition remains the same. However, microwaves are not efficient at causing the heating effects of low frequency fields that depend on slower molecular motion, such as those caused by ion-drag

Use of RF electric fields in dielectric heating:

The use of high-frequency electric fields for heating dielectric materials had been proposed in the 1930s. For example, U.S. Patent 2,147,689 (application by Bell Telephone Laboratories, dated 1937) states "This invention relates to heating systems for dielectric materials and the object of the invention is to heat such materials uniformly and substantially simultaneously throughout their mass.

It has been proposed therefore to heat such materials simultaneously throughout their mass by means of the dielectric loss produced in them when they are subjected to a high voltage, high frequency field." This patent proposed radio frequency (RF) heating at 10 to 20 megahertz (wavelength 15 to 30 meters) Such wavelengths were far longer than the cavity used, and thus made use of near-field effects and not electromagnetic waves. (Commercial microwave ovens use wavelengths only 1% as long).

RESISTANCE WELDING

Electric resistance welding (**ERW**) refers to a group of welding processes such as spot and seam welding that produce coalescence of faying surfaces where heat to form the weld is generated by the electrical resistance of material combined with the time and the force used to hold the materials together during welding. Some factors influencing heat or welding temperatures are the proportions of the work pieces, the metal coating or the lack of coating, the electrode materials, electrode geometry, electrode pressing force, electrical current and length of welding time

Small pools of molten metal are formed at the point of most electrical resistance (the connecting or "faying" surfaces) as an electrical current (100–100,000A) is passed through the metal. In general, resistance welding methods are efficient and cause little pollution, but their applications are limited to relatively thin materials and the equipment cost can be high

Spot welding:

Spot welding is a resistance welding method used to join two or more overlapping metal sheets, studs, projections, electrical wiring hangers, some heat exchanger fins, and some tubing. Usually power sources and welding equipment are sized to the specific thickness and material being welded together. The thickness is limited by the output of the welding power source and thus the equipment range due to the current required for each application. Care is taken to eliminate contaminants between the faying surfaces. Usually, two copper electrodes are simultaneously used to clamp the metal sheets together and to pass current through the sheets.

When the current is passed through the electrodes to the sheets, heat is generated due to the higher electrical resistance where the surfaces contact each other. As the electrical resistance of the material causes a heat buildup in the work pieces between the copper electrodes, the rising temperature causes a rising resistance, and results in a molten pool contained most of the time between the electrodes. As the heat dissipates throughout the work piece in less than a second (resistance welding time is generally programmed as a quantity of AC cycles or milliseconds) the molten or plastic state grows to meet the welding tips.

When the current is stopped the copper tips cool the spot weld, causing the metal to solidify under pressure. The water cooled copper electrodes remove the surface heat quickly, accelerating the solidification of the metal, since copper is an excellent conductor. Resistance spot welding typically employs electrical power in the form of direct current, alternating current, medium frequency half-wave direct current, or high-frequency half wave direct current.

The advantages of the method include efficient energy use, limited work piece deformation, high production rates, easy automation, and no required filler materials. When high strength in shear is needed, spot welding is used in preference to more costly mechanical fastening, such as riveting. While the shear strength of each weld is high, the fact that the weld spots do not form a continuous seam means that the overall strength is often significantly lower than with other welding methods, limiting the usefulness of the process. It is used extensively in the automotive industry— cars can have several thousand spot welds. A specialized process, called shot welding, can be used to spot weld stainless steel.

The subsequent cooling and combination of the materials forms a “nugget” alloy of the two materials with larger grain growth. Typically, high weld energies at either short or long weld times, depending on physical characteristics, are used to produce fusion bonds. The bonded materials usually exhibit excellent tensile, peel and shear strengths. In a reflow braze bond, a resistance heating of a low temperature brazing material, such as gold or solder, is used to join either dissimilar materials or widely varied thick/thin material combinations. The brazing material must “wet” to each part and possess a lower melting point than the two work pieces. The resultant bond has definite interfaces with minimum grain growth. Typically the process requires a longer (2 to 100 ms) heating time at low weld energy. The resultant bond exhibits excellent tensile strength, but poor peel and shear strength.

Seam welding:

"Seam welding" redirects here. For the geometrical welding configuration, see welding joint.

Resistance seam welding is a process that produces a weld at the faying surfaces of two similar metals. The seam may be a butt joint or an overlap joint and is usually an automated process. It differs from butt welding in that butt welding typically welds the entire joint at once and seam welding forms the weld progressively, starting at one end. Like spot welding, seam welding relies on two electrodes, usually made from copper, to apply pressure and current. The electrodes are disc shaped and rotate as the material passes between them. This allows the electrodes to stay in constant contact with the material to make long continuous welds. The electrodes may also move or assist the movement of the material.

A transformer supplies energy to the weld joint in the form of low voltage, high current AC power. The joint of the work piece has high electrical resistance relative to the rest of the circuit and is heated to its melting point by the current. The semi-molten surfaces are pressed together by the welding pressure that creates a fusion bond, resulting in a uniformly welded structure.

Most seam welders use water cooling through the electrode, transformer and controller assemblies due to the heat generated. Seam welding produces an extremely durable weld because the joint is forged due to the heat and pressure applied. A properly welded joint formed by resistance welding is typically stronger than the material from which it is formed.

A common use of seam welding is during the manufacture of round or rectangular steel tubing. Seam welding has been used to manufacture steel beverage cans but is no longer used for this as modern beverage cans are seamless aluminum.

ELECTRIC ARC WELDING

Arc welding is a type of welding that uses a welding power supply to create an electric arc between an electrode and the base material to melt the metals at the welding point. They can use either direct (DC) or alternating (AC) current, and consumable or non-consumable electrodes. The welding region is usually protected by some type of shielding, vapor, or slag. Arc welding processes may be manual, semi-automatic, or fully automated. First developed in the late part of the 19th century, arc welding became commercially important in shipbuilding during the Second World War. Today it remains an important process for the fabrication of steel structures and vehicles.

Power supplies:

To supply the electrical energy necessary for arc welding processes, a number of different power supplies can be used. The most common classification is constant current power supplies and constant voltage power supplies. In arc welding, the voltage is directly related to the length of the arc, and the current is related to the amount of heat input. Constant current power supplies are most often used for manual welding processes such as gas tungsten arc welding and shielded metal arc welding, because they maintain a relatively constant current even as the voltage varies.

This is important because in manual welding, it can be difficult to hold the electrode perfectly steady, and as a result, the arc length and thus voltage tend to fluctuate. Constant voltage power supplies hold the voltage constant and vary the current, and as a result, are most often used for automated welding processes such as gas metal arc welding, flux cored arc welding, and submerged arc welding. In these processes, arc length is kept constant, since any fluctuation in the distance between the wire and the base material is quickly rectified by a large change in current. For example, if the wire and the base material get too close, the current will rapidly increase, which in turn causes the heat to increase and the tip of the wire to melt, returning it to its original separation distance.

The direction of current used in arc welding also plays an important role in welding. Consumable electrode processes such as shielded metal arc welding and gas metal arc welding generally use direct current, but the electrode can be charged either positively or negatively. In welding, the positively charged anode will have a greater heat concentration and, as a result, changing the polarity of the electrode has an impact on weld properties. If the electrode is positively charged, it will melt more quickly, increasing weld penetration and welding speed. Alternatively, a negatively charged electrode results in more shallow welds.

Non-consumable electrode processes, such as gas tungsten arc welding, can use either type of direct current (DC), as well as alternating current (AC). With direct current however, because the electrode only creates the arc and does not provide filler material, a positively charged electrode causes shallow welds, while a negatively charged electrode makes deeper welds Alternating current rapidly moves between these two, resulting in medium-penetration welds. One disadvantage of AC, the fact that the arc must be re-ignited after every zero crossing, has been addressed with the invention of special power units that produce a square wave pattern instead of the normal sine wave, eliminating low-voltage time after the zero crossings and minimizing the effects of the problem

Duty cycle is a welding equipment specification which defines the number of minutes, within a 10 minute period, during which a given arc welder can safely be used. For example, an 80 A welder with a 60% duty cycle must be "rested" for at least 4 minutes after 6 minutes of continuous welding.[5] Failure to observe duty cycle limitations could damage the welder. Commercial- or professional-grade welders typically have a 100% duty cycle.

Consumable electrode methods:

Shielded metal arc welding:

One of the most common types of arc welding is shielded metal arc welding(SMAW), which is also known as manual metal arc welding (MMAW) or stick welding. An electric current is used to strike an arc between the base material and a consumable electrode rod or *stick*. The electrode rod is made of a material that is compatible with the base material being welded and is covered with a flux that gives off vapors that serve as a shielding gas and provide a layer of slag, both of which protect the weld area from atmospheric contamination.

The electrode core itself acts as filler material, making a separate filler unnecessary. The process is very versatile, requiring little operator training and inexpensive equipment. However, weld times are rather slow, since the consumable electrodes must be frequently replaced and because slag, the residue from the flux, must be chipped away after welding. Furthermore, the process is generally limited to welding ferrous materials, though specialty electrodes have made possible the welding of cast iron, nickel, aluminium,copper and other metals. The versatility of the method makes it popular in a number of applications including repair work and construction.

Gas metal arc welding (GMAW), commonly called *MIG* (for metal/inert-gas), is a semi-automatic or automatic welding process with a continuously fed consumable wire acting as both electrode and filler metal, along with an inert or semi-inert shielding gas flowed around the wire to protect the weld site from contamination

Flux-cored arc welding (FCAW) is a variation of the GMAW technique. FCAW wire is actually a fine metal tube filled with powdered flux materials. An externally supplied shielding gas is sometimes used, but often the flux itself is relied upon to generate the necessary protection from the atmosphere. The process is widely used in construction because of its high welding speed and portability.

Submerged arc welding (SAW) is a high-productivity welding process in which the arc is struck beneath a covering layer of granular flux. This increases arc quality, since contaminants in the atmosphere are blocked by the flux. The slag that forms on the weld generally comes off by itself and, combined with the use of a continuous wire feed, the weld deposition rate is high. Working conditions are much improved over other arc welding processes since the flux hides the arc and no smoke is produced. The process is commonly used in industry, especially for large products.[9] As the arc is not visible, it is typically automated. SAW is only possible in the 1F (flat fillet), 2F (horizontal fillet), and 1G (flat groove) positions.

Heat and sparks:

Because many common welding procedures involve an open electric arc or flame, the risk of burns from heat and sparks is significant. To prevent them, welders wear protective in the form of heavy leather gloves and protective long sleeve jackets to avoid exposure to extreme heat, flames, and sparks.

Eye damage:

Auto darkening welding hood with 90×110 mm cartridge and 3.78×1.85 in viewing area

Exposure to the brightness of the weld area leads to a condition called arc eye in which ultraviolet light causes inflammation of the cornea and can burn the retinas of the eyes. Welding goggles and helmets with dark face plates - much darker than those in sunglasses or oxy-fuel goggles - are worn to prevent this exposure. In recent years, new helmet models have been produced featuring a face plate that automatically self-darkens electronically. To protect bystanders, transparent welding curtains often surround the welding area. These curtains, made of a polyvinyl plastic film, shield nearby workers from exposure to the UV light from the electric arc

OCCUPATIONAL HAZARDS DUE TO CHEMICAL REACTIONS.

It is estimated that more than 13 million workers in the United States are potentially exposed to chemicals that can be absorbed through the skin. Dermal exposure to hazardous agents can result in a variety of occupational diseases and disorders, including occupational skin diseases (OSD) and systemic toxicity. Historically, efforts to control workplace exposures to hazardous agents have focused on inhalation rather than skin exposures. As a result, assessment strategies and methods are well developed for evaluating inhalation exposures in the workplace; standardized methods are currently lacking for measuring and assessing skin exposures.

SD are the second most common type of occupational disease and can occur in several different forms including:

- Irritant contact dermatitis,
- Allergic contact dermatitis,
- Skin cancers,
- Skin infections,
- Skin injuries, and
- Other miscellaneous skin diseases.

Contact dermatitis is one of the most common types of occupational illness, with estimated annual costs exceeding $1 billion.

Workers at risk of potentially harmful exposures of the skin include, but are not limited to, those working in the following industries and sectors:

- Food service
- Cosmetology
- Health care
- Agriculture
- Cleaning
- Painting
- Mechanics
- Printing/lithography
- Construction

Anatomy and Functions of the Skin:

The skin is the body's largest organ, accounting for more than 10 percent of body mass. The skin provides a number of functions including:

- protection,
- water preservation,
- shock absorption,
- tactile sensation,
- calorie reservation,
- vitamin D synthesis,
- temperature control, and

- lubrication and waterproofing.

Skin Hazards:

Causes of OSD include chemical agents, mechanical trauma, physical agents, and biological agents.

- **Chemical agents** are the main cause of occupational skin diseases and disorders. These agents are divided into two types: primary irritants and sensitizers. Primary or direct irritants act directly on the skin though chemical reactions. Sensitizers may not cause immediate skin reactions, but repeated exposure can result in allergic reactions.

A worker's skin may be exposed to hazardous chemicals through:

- direct contact with contaminated surfaces,
- deposition of aerosols,
- immersion, or
- splashes.

- **Physical agents** such as extreme temperatures (hot or cold) and radiation (UV/solar radiation).
- **Mechanical trauma** includes friction, pressure, abrasions, lacerations and contusions (scrapes, cuts and bruises).
- **Biological agents** include parasites, microorganisms, plants and other animal materials.

Dermal Absorption:

Dermal absorption is the transport of a chemical from the outer surface of the skin both into the skin and into the body. Studies show that absorption of chemicals through the skin can occur without being noticed by the worker, and in some cases, may represent the most significant exposure pathway. Many commonly used chemicals in the workplace could potentially result in systemic toxicity if they penetrate through the skin (i.e. pesticides, organic solvents). These chemicals enter the blood stream and cause health problems away from the site of entry.

The rate of dermal absorption depends largely on the outer layer of the skin called the stratum corneum (SC). The SC serves an important barrier function by keeping molecules from passing into and out of the skin, thus protecting the lower layers of skin. The extent of absorption is dependent on the following factors:

- Skin integrity (damaged vs. intact)

- Location of exposure (thickness and water content of stratum corneum; skin temperature)
- Physical and chemical properties of the hazardous substance
- Concentration of a chemical on the skin surface
- Duration of exposure
- The surface area of skin exposed to a hazardous substance