Fundamental terms used in AC winding

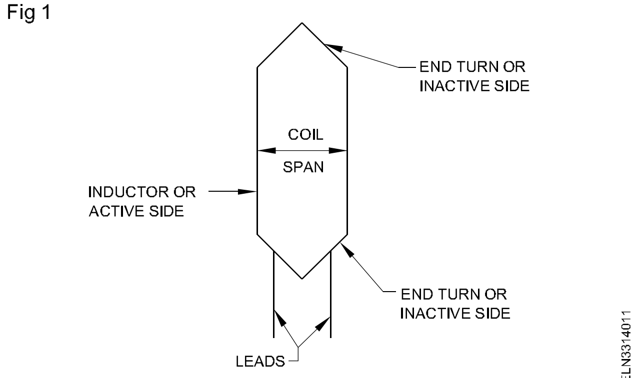
Objectives: At the end of this lesson you shall be able to
- **state the terms used in AC winding**
- **explain the different types of AC winding.**

Fundamental terms used in AC Winding: Before taking up AC winding, the trainee should be familiar with the terms used in AC winding as explained in the following paragraphs.

Coil : A number of turns connected in series is called a coil. A coil has two active sides and two inactive sides.

Turn: It is the closed path of the conductor which is formed by connecting the two inductors under two dissimilar poles N and S. (Fig 1)

Fig 1



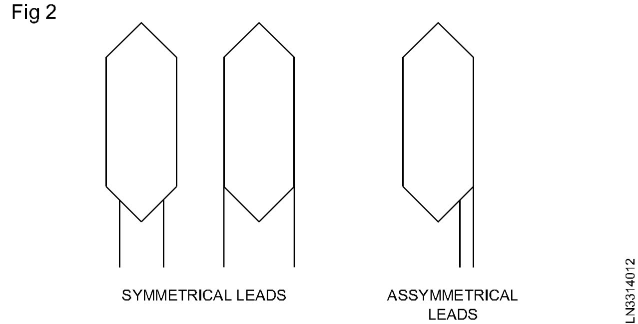
Active side of a coil : It is that part of the coil which lies in the slots of the core. It is also known as an inductor. (Fig 1)

Inactive side of a coil : It is the portion of the coil which joins the two active sides of a coil. (Fig 1)

Leads of a coil : These are the two ends of a coil which are used for the connection. Leads are also known as jumpers which may be symmetrical or unsymmetrical as shown in Fig 2.

Pole pitch : The distance between the centre of two adjacent opposite poles is called the pole pitch. Pole pitch is measured in terms of slots or coil sides.

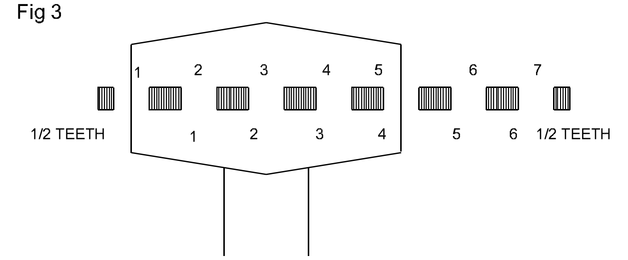
Fig 2



$$\text{Pole pitch} = \frac{\text{No. of slots in the stator}}{\text{No. of poles}}$$

Coil pitch/span and coil throw : The distance between the two active sides of a coil under adjacent dissimilar poles is called coil pitch/span. Fig 3 shows the coil pitch/span and coil throw (i.e. coil pitch/span = 4 and coil throw is 1-5).

Fig 3



Pitch factor : Winding pitch need not be equal to the pole pitch. If the pole pitch and winding pitch are equal, the winding is called full pitched winding. If the winding pitch is less than the pole pitch, the winding is called fractional pitch winding or short pitch winding. While rewinding, the original winding pitch should not be changed. The machine designer would have chosen the winding pitch after considering the different factors required for the better performance of the machine. Any change in the original winding pitch of a machine will affect the performance of that machine. If the winding pitch is 4, then the coil throw is 1 to 5, and one side of the coil is placed in slot No.1 and the other side of the coil is inserted in slot No.5 as shown in Fig 3. Then the winding pitch is 5-1 = 4. The ratio between the winding pitch and pole pitch is called the pitch factor.

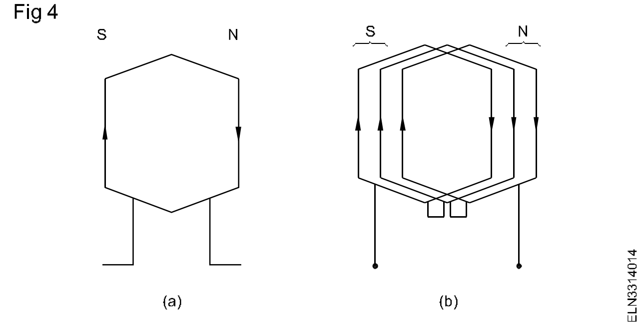
$$\text{Pitch factor} = \frac{\text{Winding pitch}}{\text{Pole pitch}}$$

Short pitch winding is usually used in almost all machines except variable speed motors. The reasons for adopting short pitch winding are given below.

1 Winding requires less copper.
2 Copper loss is less.
3 Efficiency of the machine is increased.
4 Winding occupies less space.
5 In alternators, the winding produces uniform sine wave.

Coil group : When you observe the direction of the current flow in a coil, you will see current in the two coil sides have opposite directions as shown in Fig 4(a).

Fig 4



Accordingly the current in a single coil produces two dissimilar poles. In an ordinary winding, according to the design, one or more coils may be connected in series to form a group as shown in Fig 4(b).(Three coils form one group) The total number of coil groups in a winding is equal to the number of phases multiplied by the number of poles.

Total No.of coil groups = No. of phases x No. of poles

$$\text{Coil group per phase} = \frac{\text{Total No. of coil groups}}{\text{No. of phases}}$$

Coil group per phase per pole =

$$\frac{\text{Total No. of coil groups}}{\text{No. of phases x No. of poles}}$$

Further the number of coils in a group per phase per pole

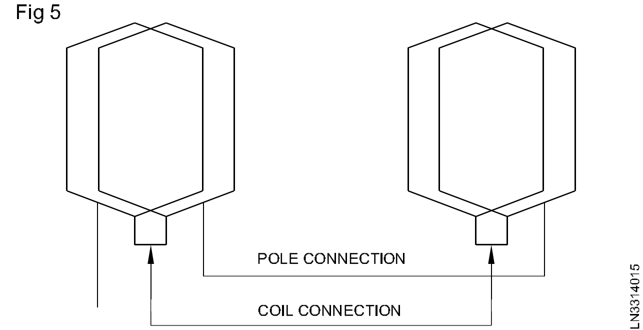
$$= \frac{\text{Total number of coils}}{\text{No. of phases x No. of poles}}$$

$$= \frac{\text{Total number of coils}}{\text{Total number of groups}}$$

Coil connections : The connection which joins a coil lead of one coil to the other coil lead of the same coil group is called 'coil connection' and is shown in Fig 5.

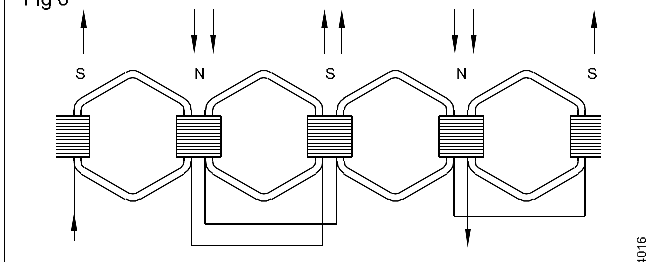
Pole connection : The connection which joins a coil group of one phase to another coil group of the same phase of the winding is called pole connection or group connection, and is shown in Fig 5.

Fig 5



Whole-coil winding: A whole coil winding is one in which the number of coils per phase is equal to the number of poles in the machine. Refer to Fig 6.

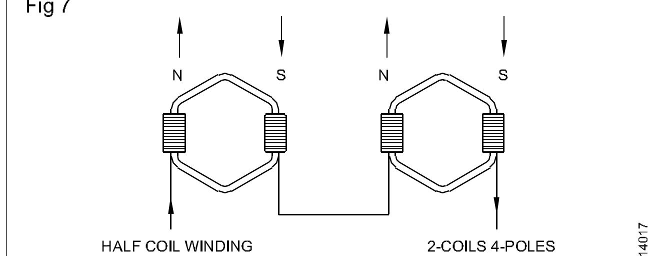
Fig 6



FULL COIL WINDING 4-COILS 4-POLES RIGHT TO RIGHT OR LEFT TO LEFT CONNECTION

Half coil winding : A half coil winding is one in which the number of coils per phase is equal to half the number of poles in the machines. Half coil winding is generally done in the winding of ceiling fans, double speed motors etc. Refer to Fig 7.

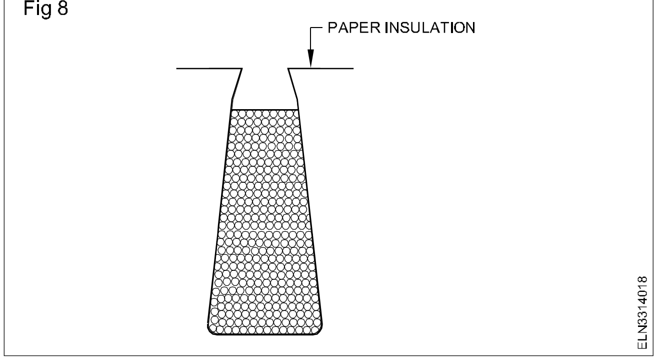
Fig 7



RIGHT TO LEFT OR LEFT TO RIGHT CONNECTION

Single layer winding : In single layer winding each slot contains only one coil side as shown in Fig 8 and the number of coils in the machine is equal to half the number of slots in the stator or armature. In single layer winding the coil pitch is usually taken in odd numbers.

Fig 8



Double layer winding : In double layer winding each slot contains two coil sides (i.e.one upper and one lower) as shown in Fig 9 and the number of coils is equal to the number of slots in the stator.

Balanced winding : When the coil groups contain the same number of coils per phase per pole the winding is termed as 'balanced winding'. It is also known as 'Even Group' winding and is shown in Fig 10.

Unbalanced winding : If the coil group contains an unequal number of coils per phase per pole then the winding is called 'unbalanced winding'. It is also sometimes called 'odd group' winding and is shown in Fig 11.

It is important that there must be an equal number of coils in each phase whether the winding is balanced or unbalanced as shown in Figs 10 and 11.

Fig 9

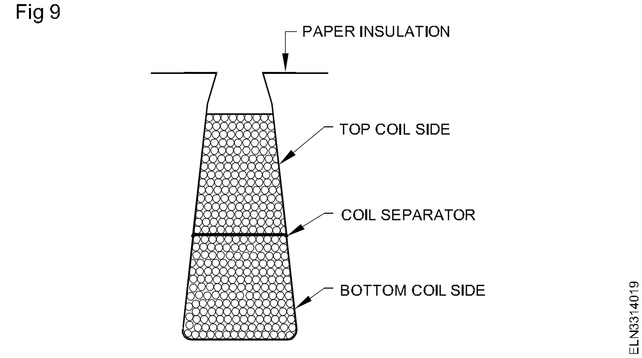
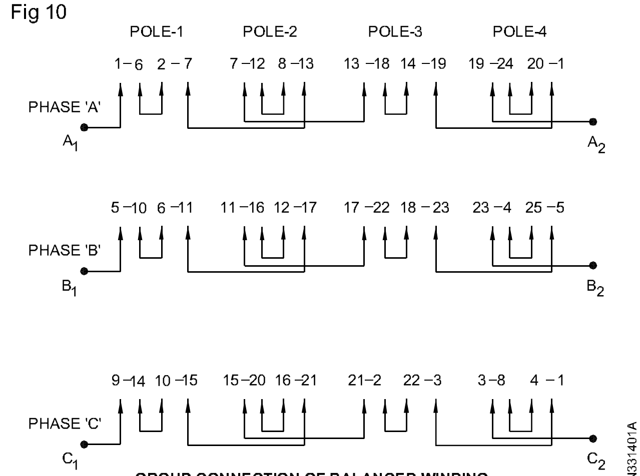
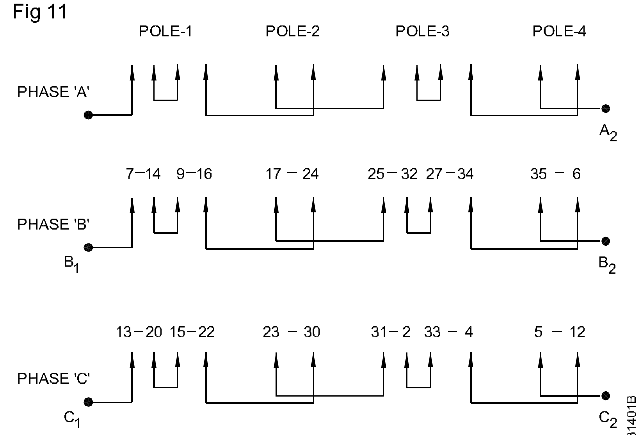


Fig 10



GROUP CONNECTION OF BALANCED WINDING

Fig 11



GROUP CONNECTION OF UNBALANCED WINDING

Concentrated winding : If in any winding the number of coils/pole/phase is one, then the winding is known as 'concentrated winding'. In this winding each coil side occupies one slot.

Distributed winding : In this winding the number of coil/pole/phase is more than one - arranged in different slots. In this case each coil has the same pole pitch.

Partially distributed winding: In this winding the coil sides do not occupy all the slots, but some slots remain empty and they are called dummy slots.

Fully distributed winding : It is a winding in which not a single slot remain empty.

Different types of AC Windings

The types of AC windings according to shape are as follows.

a Basket winding

b Concentric winding

c Skein winding

d Flat loop Non-overlapped winding

e Flat loop overlapped or chain winding

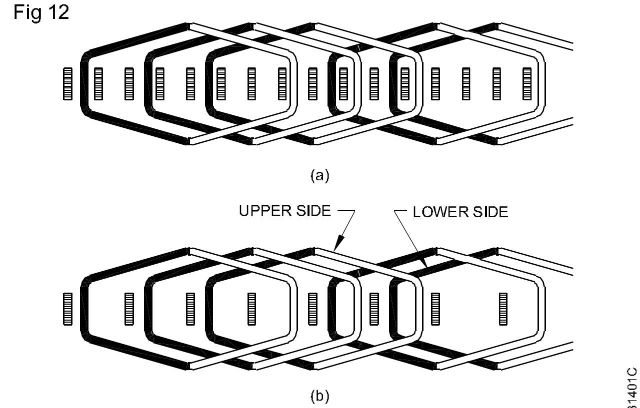
f Skew winding

g Diamond coil winding

h Involute coil winding

Basket winding : After the completion of the winding, the ends of the winding resemble the weaving of a basket and hence it is known as basket winding. Basket winding is of two types. a) Single layer basket winding as shown in Fig 12a, double layer basket winding as shown in Fig 12b.

Fig 12



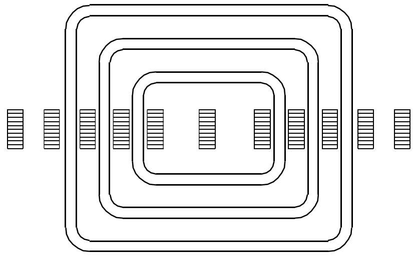
BASKET WINDING

Concentric (or box type) winding : This winding has two or more than two coils in a group, and the coils in each group have the same centre. In each group, the coil pitch is not equal, and, therefore, do not overlap each other.

In this winding the coil pitches are not equal and each coil of the group has a difference of 2 slots in its pitch. Though it requires more labour to insert coils due to different coil spans, the design allows more cooling space. This winding is usually provided in single phase motor winding. This is shown in Fig 13.

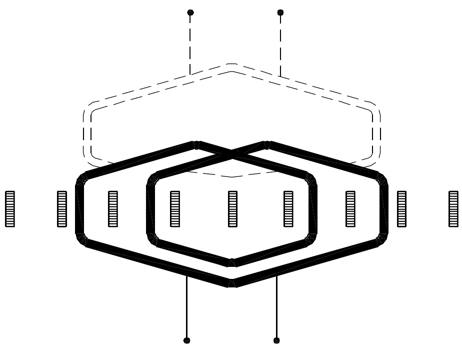
Skein winding : In skein winding, a long coil of sufficient length is first wound and then inserted in one slot. The remainder of the length is turned and inserted in the adjacent slots as shown in Fig 14.

Fig 13



CONCENTRIC WINDING

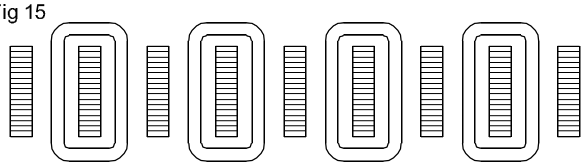
Fig 14



SKEIN WINDING

Flat loop non-overlapped winding : The coils of this winding do not overlap each other, and hence is known as 'flat loop non-overlap winding'. In such a winding each group has only one coil as shown in Fig 15.

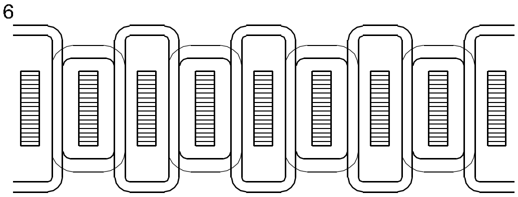
Fig 15



FLAT LOOP NON-OVER LAPPED WINDING

Flat loop overlapped or chain winding : In this winding, the number of coil/pole/phase is more than one having different pitches and the coils overlap each other in the form of a chain as shown in Fig 16.

Fig 16



FLAT LOOP OVERLAPPED WINDING OR CHAIN WINDING

Skew winding : The coil sides of this winding are unequal and as such allows greater space for heat radiation. This winding is shown in Fig 17.

Diamond coil winding : The shape of the coil used in this winding is just like a diamond as shown in Fig 18 and the coil occupies more space.

Involute coil winding : This type of coil is first made in the shape of a diamond coil and then it is pressed at inactive coil sides to attain a shape of involute coil as shown in Fig 19.

Fig 17

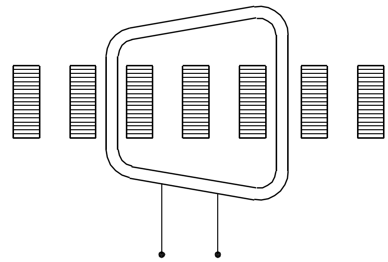


Fig 18

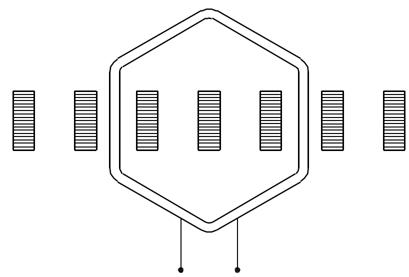
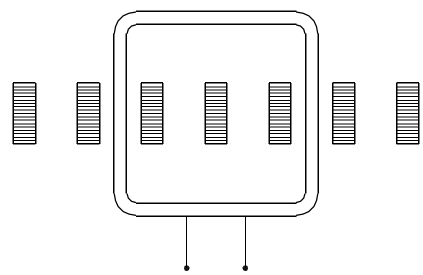


Fig 19



Electrical degrees: A pair of poles contain 360° electrical degrees. That is each pole has 180°. As such the number of electrical degrees in a motor depends upon the number of poles.

For 2 poles - 360° electrical degrees

For 4 poles - 720° electrical degrees

For 6 poles - 1080° electrical degrees

The slot angle could be calculated by the formula

$$\text{Slot angle} = \frac{180 \times \text{No. of poles}}{\text{Total No. of slots}}$$

Alternatively,

$$\text{Slot angle} = \frac{360 \times \text{pair of poles}}{\text{Total No. of slots}}$$

Phase dispalcement : For a single phase, the starting winding and running winding should be displaced by 90°. For example if the slot angle is 30°, the starting winding will be started in say, first slot and the running winding will be started in the fourth slot.

Example : The following is the insulation specification for Class 'B' motors.

Slot liner : One layer of 0.175 mm thick press paper with 0.25 mm thick fibre glass backed mica are used as a slot liner. This shall extend 10 mm beyond each end of the core.

Coil separator : In the case of multi-layer winding 0.375 mm thick press paper and fibre glass mica in combination are to be used and this should extend 10 mm beyond each end of the cores.

Wedge separator/packing strip : 0.375 mm thick melanex is used in between the slot liner and wedge. This should extend 10 mm beyond each end of the core.

Wedge : 2 mm or 3 mm vulcanised fibre is used. This should extend 6 mm beyond each end of the core.

Over hang inter-phase insulation : 0.25 mm varnished fibre glass cloth in the form of half moon is used as inter-phase insulation between coils of different phases. The separators after insulation should be bound with the coils by 0.15 mm varnished fibre glass chord.

Hand winding process

Objectives: At the end of this lesson you shall be able to
- **state the advantages of hand winding**
- **explain the method of hand winding.**

Hand winding may be used in split phase motors for both the starting and running winding. In this method, the winding wires are inserted in the slots, one turn at a time, starting with the inner coils until the winding operation is completed.

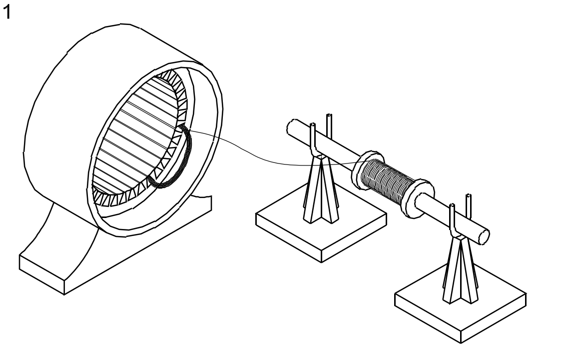
There are two main advantages in this method of winding.

1 A tight winding is possible, where the slot room is limited.

2 A winding former is not necessary.

The stator to be wound and the spool of winding wire are to be arranged as shown in Fig 1.

Fig 1



Assuming that the slots are properly insulated, the side of the stator where the connection end is to be placed is located and guide paper is placed in the respective slots.

The procedure for hand winding is as given below.

1 Set up the reel of selected size winding wire on a reel rack with a suitable tensioning device.

2 Insert the winding wire into a slot for the start of the inner coil having a smaller pitch.

3 Lace the winding wire through the identified slots according to the data, maintaining the tension.

4 After winding the designated turns in the first coil, continue the winding for the next larger coil according to the selected pole pitch.

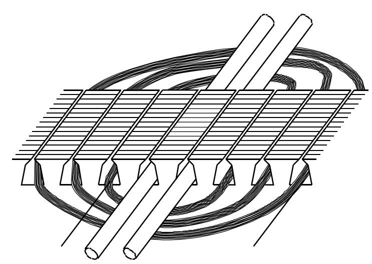
5 After winding the designated turns in the second coil, continue the winding for the next larger coil according to the selected pole pitch.

Complete the entire pole winding and take out the end connections.

6 Place wooden dowels as shown in Fig 2 in the empty slots to hold coils in position while winding.

7 Cut the wire and wedge the winding permanently in place if the slot contains only one coil side.

Fig 2



8 If the bottom coil side only is placed in the slots of the double layer winding, push temporary loose fitting wooden or fibre wedges in place for each slot until the stator is completed.

9 Remove the dowels.

10 Continue steps 2 to 9 for every pole until the bottom (main) winding of the stator is wound.

11 Set up a reel of the required size winding wire for the top (starting) winding.

12 Proceed to rewind the starting winding according to the collected data, following the above steps.

3 phase squirrel cage induction motor winding (single layer distributed winding)

Objectives: At the end of this lesson you shall be able to
- **explain the winding terms and calculations pertaining to single layer distributed type winding**
- **explain how to draw the end and coil connection diagrams**
- **state how to draw the ring and developed diagrams.**

Distributed type winding: The most common type of winding found in 3-phase motors is the distributed type winding. A distributed type winding is one in which the size of all the coils, coil pitch and shape will be the same as these coils are normally former wound. By virtue of the arrangement of these coils in slots, the coils overlap each other. Distributed winding may be of single or double layer type.

Single layer winding : Single layer winding is one in which there will be as many coils as half the number of slots. For example 6 coils in the case of 12 slots, 12 coils in case of 24 slots, 18 coils in the case of 36 slots and so on. In short, there will be only one coil side per slot.

Calculation for single layer distributed winding : The winding data of the distributed single layer winding will be within the following limitation. (As an example 3- phase, 24 slots, 12 coils, 4 poles is illustrated below).

I Grouping

$$\text{i) No. of coils/phase} = \frac{\text{Total No. of coils}}{\text{No. of phases}}$$

As in the example

No. of coils per phase = 12/3 = 4 coils/phase.

ii For whole coil connection

$$\text{No. of coils/phase/pole} = \frac{\text{Total No. of coils}}{\text{No. of phases x No. of poles}}$$

As in the example

$$\text{No. of coils/phase/pole} = \frac{12}{3 \times 4} = 1 \text{ coil/phase/pole}$$

iii) For half coil connection

$$\text{No. of coils/phase/pair of poles} = \frac{\text{Total No. of coils}}{\text{No. of phases x pair of poles}}$$

As in the example

$$\text{For each phase and pair of poles} = \frac{12}{3 \times 2}$$
$$= 2 \text{ coils / phase / pair of poles}$$

> **For the example taken, half coil connection is possible for distributed winding by taking full pitch and placing coil in alternate two slots., but it is not in practice. Hence whole coil connection is taken as an example.**

II Pitch

$$\text{Pole pitch} = \frac{\text{Total No. of slots}}{\text{No. of poles}}$$

As in the example, pole pitch = 24/4 = 6 slots.

ii) Coil pitch

In AC winding the relation between the coil pitch and the pole pitch is given below.

a) Coil pitch = Pole pitch — Then the winding is called full pitch winding.

b) Coil pitch < Pole pitch — Then the winding is called fractional pitch - short chorded winding.

c) Coil pitch > Pole pitch — Then the winding is called as fractional pitch - long chorded winding.

Further, if the winding is double layer, all the above 'a', 'b' and 'c' are possible. But for single layer distributed winding as the coils should be placed in alternate slots only, the coil pitch ought to be in odd number.

As in the example, coil pitch = pole pitch = 24/4 = 6 slots.

Here 6 is an even number and winding cannot be of full pitch, so the next alternative is to select a fractional pitch. Therefore the coil pitch can be taken either as 5 or 7. Normally AC windings should either have full pitch or short chorded fractional pitch. Hence a suitable pitch is taken of 5 slots.

iii) Coil throw

The coil throw for coil pitch '5' as in the example is 1 - 6.

III Electrical degrees

i) Total electrical degrees = 180^o x No. of poles

(180^o is the distance between poles)

$$\text{ii) Slot distance} = \frac{180^0 \text{ x No. of poles}}{\text{No. of slots}}$$

As in the example: Slot distance = (180x4)/24 = 30^o

IV Phase displacement

i) For three-phase winding, displacement between the phases should be 120^o.

ii) Phase displacement in terms of slots = 120^o/slot distance

As in the example, 120°/30° = 4 slots

V Winding sequence

In three-phase winding the distance between the starting end of one phase to the starting end of another phase should have 120° electrical degrees. Hence we should arrange the winding such that

‘A’ phase starts from say 1st slot

‘B’ phase starts from 1st slot + 120° and

‘C’ phase starts from 1st slot + 120° + 120°.

As in the above example, ‘A’ phase starts from say 1st slot

‘B’ phase should start from 1+4 = 5th slot

‘C’ phase should start from 1+4+4 = 9th slot.

VI Arrangement of coils

As the winding is in a single layer, the coil shall be placed in alternate slots i.e. if one coil side of coil number one is placed in slot number one which is an odd number, the other coil side of the first coil should be laid in an even number slot. Hence placement of coils should start in slot numbers 1,3,5,7,9 and so on leaving the slot numbers 2,4,6,8 and so on to receive the other coil sides of the coils.

As in the example the 12 coils are to be laid in slots (pitch = 5 slots)

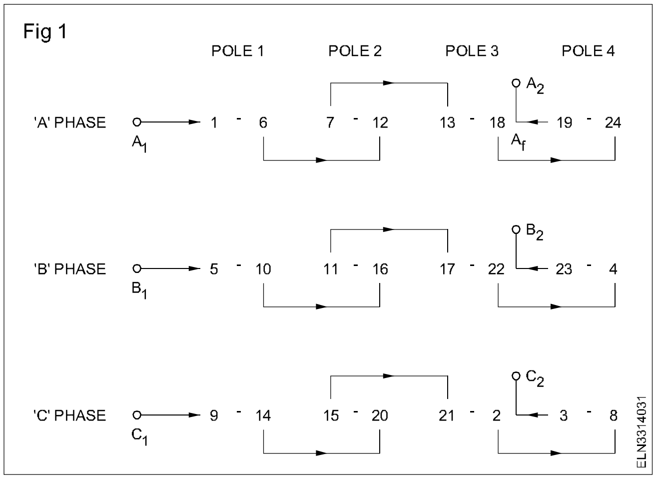
1-6, 3-8, 5-10, 7-12, 9-14, 11-16, 13-18, 15-20,

17-22, 19-24, 21-26(2), 23-28(4).

VII End connections

As discussed, for grouping of coils in normal practice, the end connections shall be whole coil connection. As in the example in Fig 1.

Fig 1



VIII Coil connections

In whole coil connection, the connection of the coil group shall be from finish to finish and start to start for the group of coils.

There are several ways of connecting the coils in groups. Fig 2 shows one method and Fig 3 shows another method. However, you are advised to check the formation of the poles with the help of a ring diagram and clock rule. The procedure is explained in the subsequent paras.

Fig 2

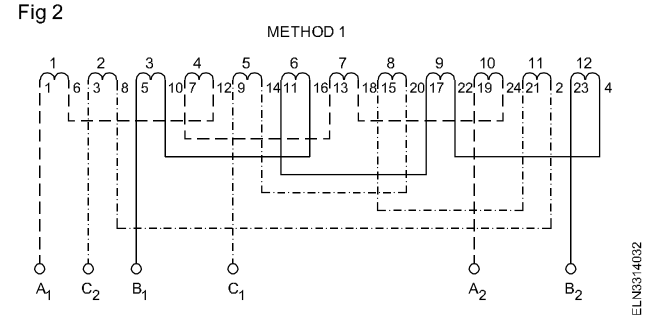
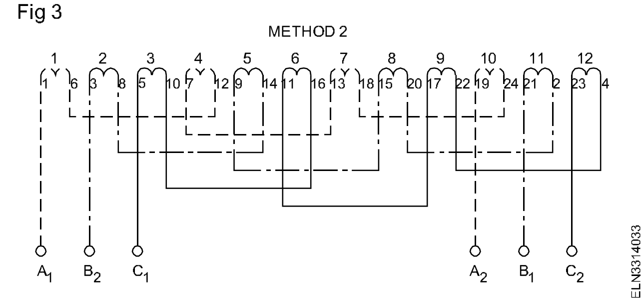


Fig 3

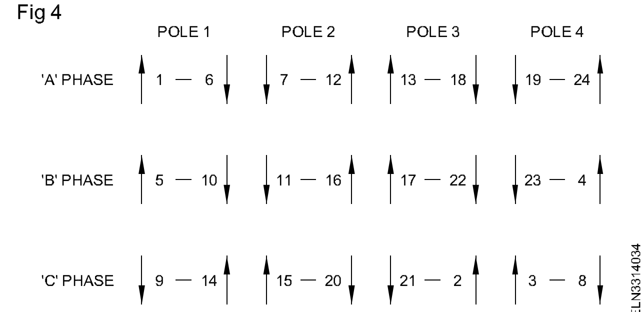


XI Ring diagram

Cross check the end connections as follows. Write the end connection table and mark the direction of current using the clock rule. Note that when three-phase supply is given to the windings, and if two phases carry current inward , the third phase will carry current outward.

Referring to method 1 shown in Fig 2, the current direction in the coil sides could be marked as shown in Fig 4.

Fig 4



Now arrange the slots in the sequential order and mark the direction of current in the slots accordingly by arrows which ultimately shall represent production of the required number of poles as shown in Fig 5.

Developed winding diagram: The development winding diagram will give a clear picture of the coil sides in relevant slots grouping, coil end connections and lead termination. A 24 slots, 12 coil, 4 pole, 3 phase single layer distributed winding development diagram is shown in Fig 6 for your guidance.

Fig 5

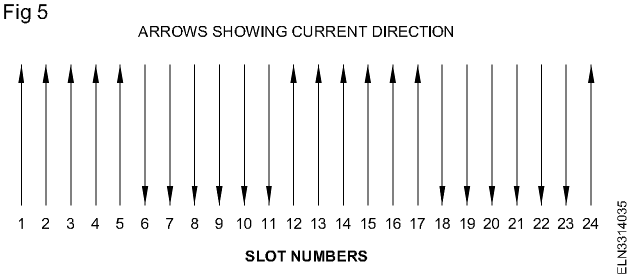
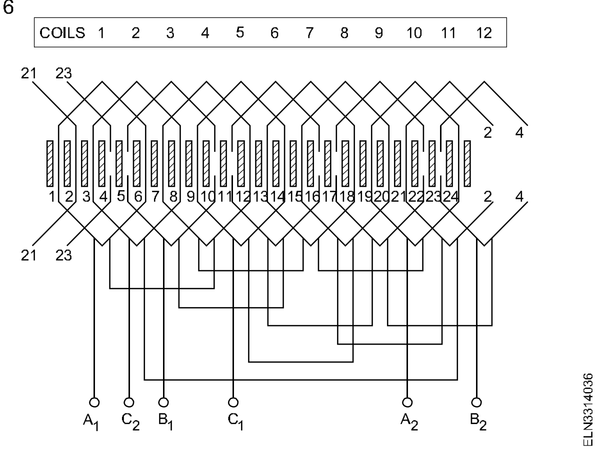


Fig 6



Method of placing coils in a basket or distributed winding

Objectives: At the end of this lesson you shall be able to
- **state the various methods employed to prepare gang or group of coils**
- **explain the method of placing coils in the single layer basket winding**
- **explain the method of placing coils in a double layer basket winding.**

The procedure outlined below is common for single or three-phase distributed winding. However this type of basket (distributed) winding is very popular in three phase motors.

The coils can be wound using a single former and then they can be interconnected by coil connections as shown in Fig 1. Most of the three-phase motors with the exception of very large ones with formed windings, use coils wound in groups as shown in Fig 2.

Fig 1

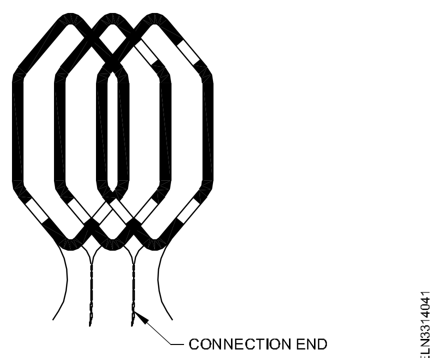
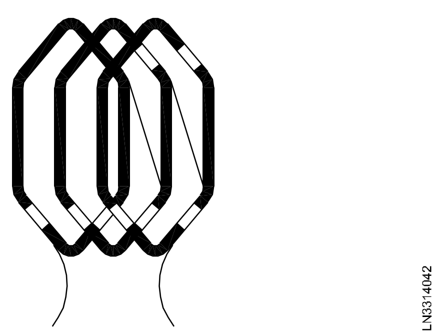


Fig 2



The number of coils in each group will depend on the number of phases and number of poles. This practice of winding coils in groups is called group or gang winding.

In group winding several coils are wound before the wire is cut. This saves time and space by eliminating the necessity of connecting coils to one another then soldering them and then insulating them.

Fig 3 shows a winding head mounted on a bench type coil winding drive. The wire is wound around six wheels mounted on a shaft. Other types of forms are also used. Fig 4 shows a coil winder for producing oval or round coils.

Fig 3

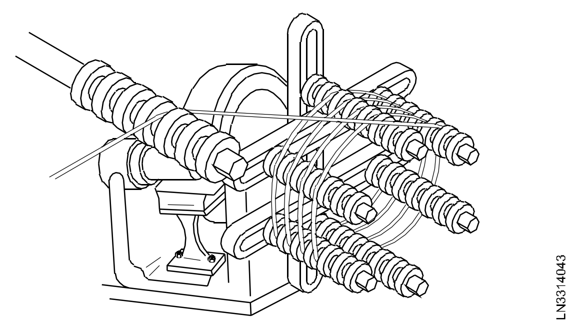
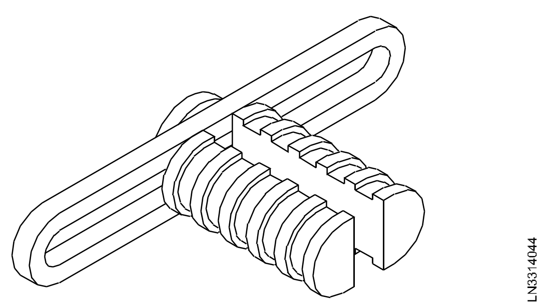
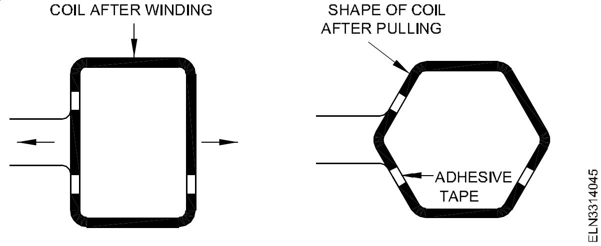


Fig 4



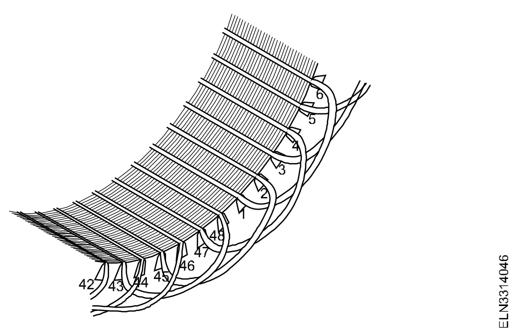
Coils for small motors may be wound in rectangular form and then two sides shaped into a diamond shape by pulling at the centre of the opposite ends as shown in Fig 5. Insertion of coils in single layer basket winding (formed individual coils).

Fig 5



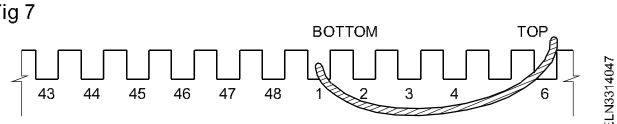
In single layer winding there are half the number of coils as there are slots. For example a machine with 12 coils and 24 slots will have single layer winding. The appearance of a single layer winding is shown in Fig 6 in which the coil pitch is 1-6. While placing coils in a single layer we have to place the coil sides in alternate slots only.

Fig 6



Let us take for example a 48 slot 24 coil 8 pole motor with the coil pitch of 1 to 6. Fig 7 illustrates the way in which the single layer winding is to be placed in the slot. This will be noticed from the diagrams there is only one coil side per slot. Fig 7 shows one coil side of the first coil placed in slot number 1.

Fig 7



Generally any slot can be identified as slot 1 with the help of chalk markings or a spot of paint. The other coil side of the same coil is left out on the core. This coil is called a throw coil. The left out coil side may lie in the right hand side as shown in Fig 7 or left hand side of the stator, when viewed from the connection end. However this depends upon the original winding pattern. The coil overhanging ends can be wrapped up to 2/3 of the length with a cotton tape of 0.175 mm thickness. To avoid the inserted coil turns from coming out of the slot while handling other coils, it is preferred to wedge temporarily the slot using a foot (Skill Information 1203) soon after the insertion of coil is over. In single layer winding the coil sides should be placed in alternate slots as shown in Fig 8.

In Fig 8 coil 1 is placed in slot No.1 and the other coil side of the same coil is left over the stampings. To avoid damage to the left out coil side, a leatheroid paper of width larger than the width of the core is placed between the core and the coil as shown in Fig 8. After placing the coil side in the slot use the awl to fold the insulation paper (slot liner) one side over the other, slip the separator paper over the folding and then slip the formed fibre or bamboo wedge over the top of the coil. The wedge should extend about 3 to 6 mm beyond the slot liner. The procedure is shown in Fig 9.

Fig 8

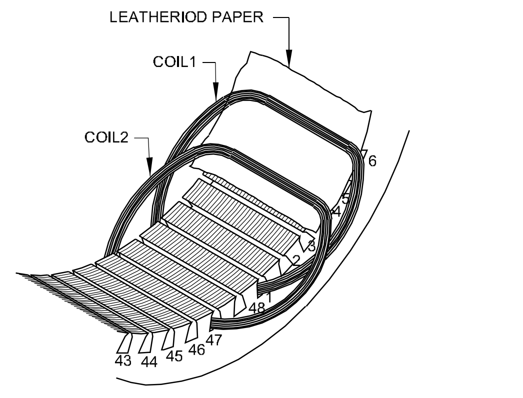
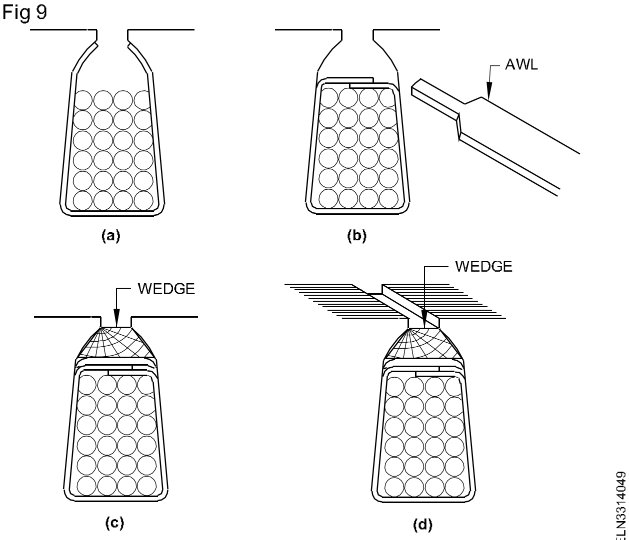


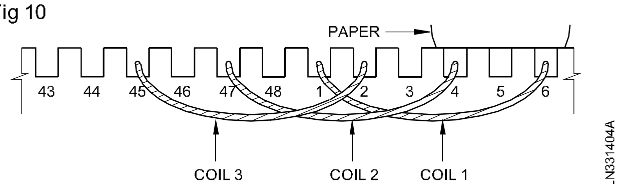
Fig 9



Some prefer to wedge the slots temporarily till all the coils are inserted and the winding is tested for grounding. Once the test results are o.k., then permanently wedge the slots.

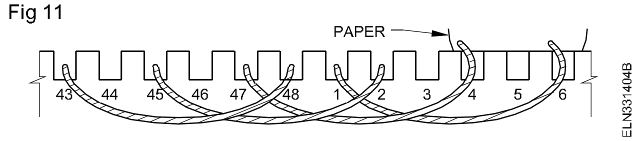
In the next step left coil side of coil 2 is placed in slot number 47 (leaving slot No.48 which is adjacent to slot No.1) and the right coil side of coil 2 is left in the core. (Fig 8) Next place left side of the coil 3 in slot number 45 and leave the right side of the coil over the core. Remember to extend the leatheroid paper insulation between the core and the coil. By examination it will be found that the left out (right) coil side of coil No.3 which has left coil side inserted in slot No.45 should be inserted in slot 2 according to the assigned coil pitch. Now insert the left out right coil side of coil 3 in slot No.2 as shown in Fig 10.

Fig 10



In general, unless the left out coil side of any coil falls, according to the assigned pitch, next to the occupied slot, proceed further to insert one coil side only. Again proceed to insert the left coil side of coil 4 in slot No.43 and the right coil side of coil 4 in slot No.48 as shown in Fig 11.

Fig 11



Proceed likewise to fill up the slots and complete the insertion of coils in the slots.

Insertion of coils in double layer (lap) winding

Let us consider a 3-phase machine with 24 slots, 24 coils, 4 poles and having a slot pitch of 1-6 and a coil pitch 1-12 in terms of coil sides.

ASSUMPTION: Individual coils numbering 24 are former wound and kept ready . Procedure given below is for the developed winding diagram shown in Fig 12.

Accordingly Fig 13 shows the numbered slots. Table 1 shows the position of the coil sides in the slots. The coil sides in the bottom are given odd numbers and the coil sides of top are given even numbers.

Fig 13

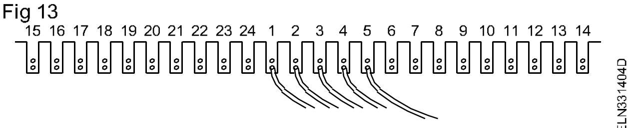
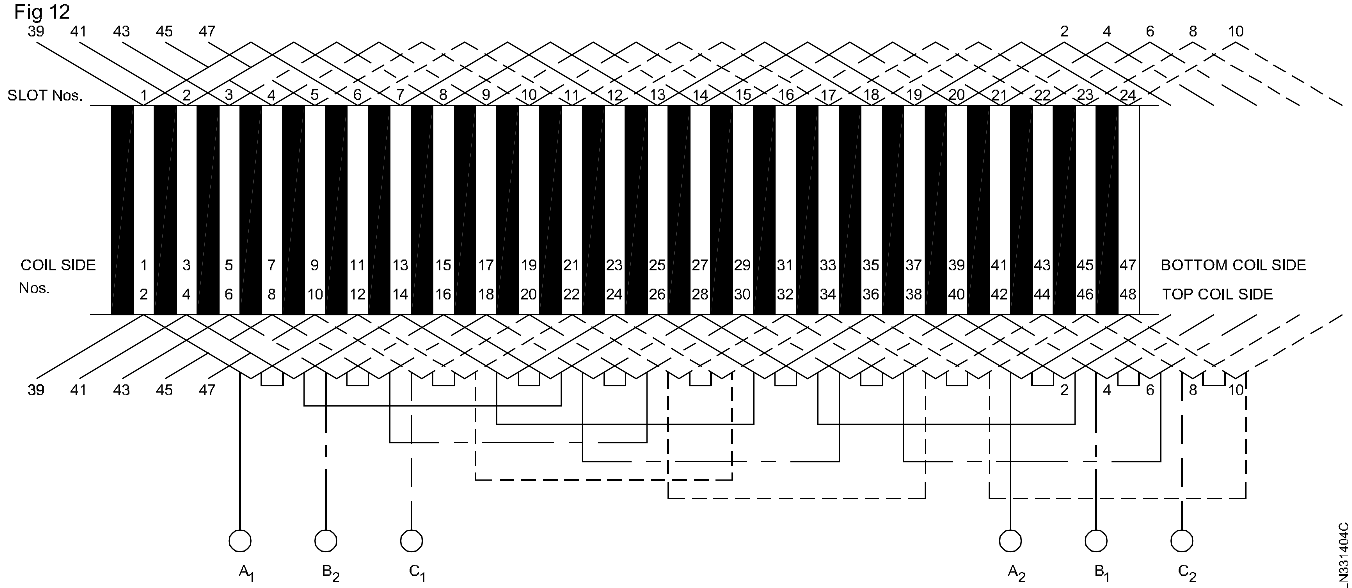


Table 1

Slot	Bottom	Top
1	1	2
2	3	4
3	5	6
4	7	8
5	9	10
6	11	12
7	13	14
8	15	16
9	17	18
10	19	20
11	21	22
12	23	24
13	25	26
14	27	28
15	29	30
16	31	32
17	33	34
18	35	36
19	37	38
20	39	40
21	41	42
22	43	44
23	45	46
24	47	48

Fig 12

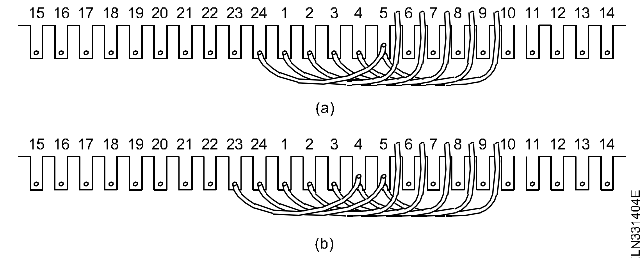


Winding is arranged such that looking from the connection end, the bottom coil is on the left side and the top coil sides is in the right side as shown in Figs 13 and 14.

Further the connection end of the winding in the stator is to be identified from the data with respect to the terminal box.

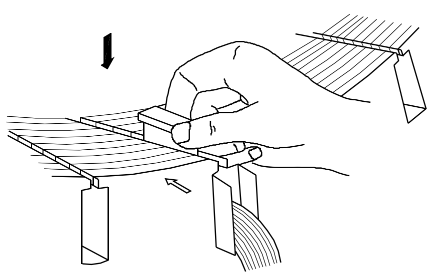
Referring to the developed diagram (Fig 12) and Table 1, if the bottom coil side 1 is inserted in slot 1, then the other coil side of the same coil which is 12, should be inserted in the slot number 6 as a top coil side. As such there should be a certain approved procedure to start the winding.

Fig 14



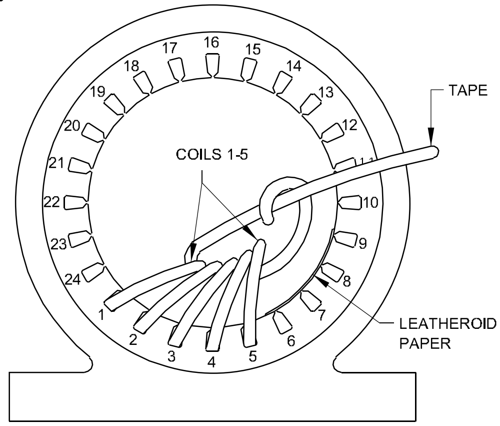
Proceed as, first insert one coil in slot number 5 and leave the other coil side on the core. Use a suitable fibre foot or wedge for slot 5 to secure the winding. (Fig 15). To avoid damage to the insulation in the process of winding, insert a thick leatheroid paper of a width larger than the core between the left out coil side and the core, as shown in Fig 8. Let the length of the leatheroid paper be sufficient enough to cover 5 coil sides at a stretch.

Fig 15



Insert the coils in slot numbers 4,3,2 and 1 in sequence as shown in Fig 13 and wedge them temporarily as shown in Fig 15. Let the other coil side lie on the core with the protected leatheroid paper between the coils and the core. These coils are called throw coils. For the protection of insulation of the throw coil you can tie the bunch of coil sides together with a cotton tape and tie the whole lot to the stator as shown in Fig 16. Remember to ensure the leatheroid paper is well kept between the bunched coils and the core.

Fig 16



Use of coil separation : Before inserting the top coil side over the bottom coil side of the same slot it is necessary to insulate the coil sides inside the slot by the use of coil seperators. This is because each coil side within one slot may belong to different phases and the voltage between them may be high.

To insulate the coil sides from each other within the slot follow the procedure shown in Fig 17 for both open and semi-closed slots. A creased separator or insulation paper of proper width, length and thickness (usually 0.25 to 0.375 mm) is used as insulation between the top and bottom coil sides in the slot. Slide an awl over the bottom coil side as shown in Fig 18a and press it over the bottom coil and slide the separator underneath the awl as shown in Fig 18b. Let the separator project about 10mm beyond the core on either side.

Fig 17

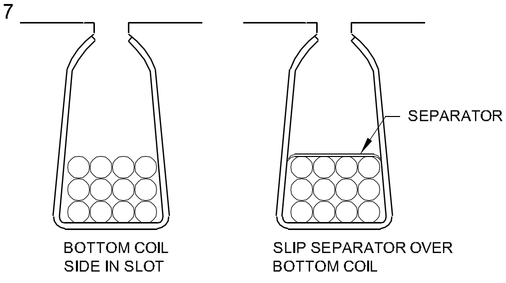
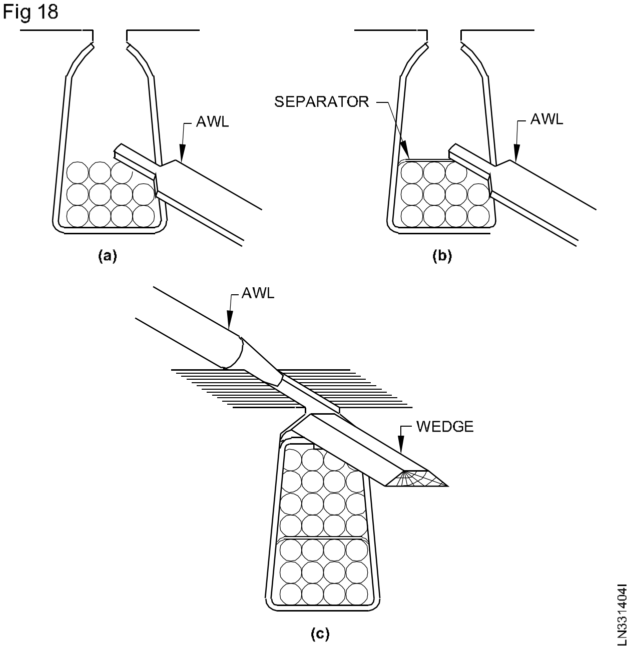
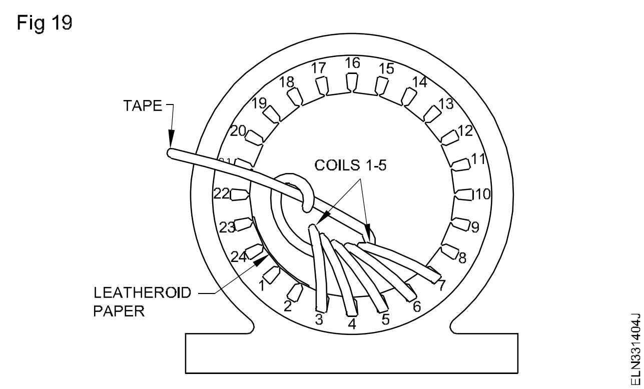


Fig 18



Method of overlapping : Now insert one coil side in slot number 24 (coil side 47) and the other coil side of the same coil (coil side 10) in slot number 5 as the top coil over the bottom coil side 9. Likewise insert another coil side 45 of a next coil in slot number 23 and the other coil side 7 of the same coil in slot number 4. Proceed likewise till you reach slot number 6. During this process as you reach near about the 10th slot or much earlier you will feel the hindrance of the throw coils which are tied to the stator. At that time untie the cotton tape from the stator and tie the bunch in the opposite side of the stator as shown in Fig 19 with a leatheroid paper in between the coils and the core.

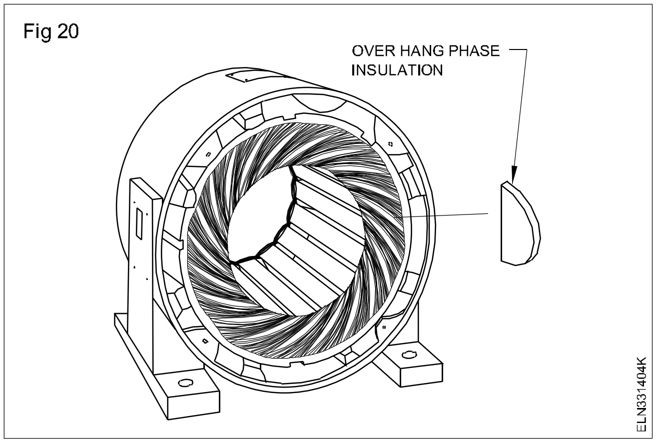
While tieing the cotton tape see that the slot number 6 is easily approchable without any difficulty. After inserting the bottom coil side 11 in slot 6 insert the corresponding other coil side 22 in slot 11 as the top coil side. After inserting the top coil side fold the slot liners one side over the other, insert the separator and the wedge.



Now untie the throw coil bunch and release the free end of the coil in slot 5 and insert the same as top coil side in slot 10. Proceed likewise to insert the coils from slots 4,3,2 and 1 in the corresponding slots.

Overhang Insulation : Now cut and prepare the leatheroid paper to the shape of half moon as in the original which is to be used as phase insulation between the overhanging coils. According to the developed diagram coil sides 1 and 3 form the first phase, 5 and 7 the second phase and 9 and 11 form the 3rd phase. Identify these coils and start inserting the leatheroid paper between 3 and 5 as well as between 7 and 9.

Thus proceed to insert this phase insulation for the entire winding as shown in Fig 20. If you find the space between these coils is less, you may use a fibre wedge to prime the coils to facilitate insertion of the leatheroid paper. Do not use too much force which may crack the slot liner insulation and result in grounding the coils with the stator core.



End connections : There are three types of connections to be made - first the coil connection for coil grouping, second for connecting the coil groups in one phase, and thirdly connecting the lead wires. Better to proceed one by one in the above sequence. Any connection to be made in winding the wires should start with proper identification of the coil ends. For a beginner, it may be necessary to refer to the developed diagram, connection diagram, as well as the actual winding often to eradicate the confusion.

Three-phase induction motor winding (single layer - concentric type - half coil connection)

Objectives: At the end of this lesson you shall be able to
- **state the general requirements pertaining to the concentric type of winding in 3-phase motors**
- **state the merits and demerits of concentric type winding**
- **explain the preparation of a winding table for concentric type winding**
- **explain how to draw the end and coil connection diagrams**
- **explain how to draw the developed and ring diagrams.**

3-phase concentric winding : In general, concentric winding is found in single phase motors, and occasionaly, this type of winding is also used for 3-phase motors.

This concentric winding has to have two or more coils in a group consisting of different pitches. Further in 3- phase concentric winding, all the three phases consist of the same number of coils, and produce similar concentric poles. Stepped formers are used to prepare coils for concentric winding.

Merits and Demerits of concentric winding: This type of winding has some merits and demerits also.

Merits

1 This type of winding has more space for cooling.

2 No need of raising (lifting) the coil sides to interleave them during the winding.

3 It is easy to shape the coils uniformly.

4 Possible to save copper, because in distributed winding all the coils are of the same size; on the other hand in concentric winding, coil groups only will be uniform, but coils of different pitches in concentric form are used.

5 As there is no interleaving of the coil sides, the winding could be done by machine resulting in faster production.

6 It is easy to make the end connection.

7 Easy to wind, as there is no overlapping of coils.

Demerits

1 Skilled labour is required to insert the coils in the slots.

2 A stepped former is required.

3 Not as efficient as basket winding.

1 Grouping

The example given below will clarify the following:

a whether concentric type of winding is possible for a given stator

b If yes, whether it should be half coil or whole coil connnected winding.

Example

3-phase induction motor having 36 slots 12 coils 4 pole stator

We have

$$\text{No. of coils per phase} = \frac{\text{Total No. of coils}}{\text{No. of phases}}$$

$$= \frac{12}{3} = 4 \text{ coils/phase}$$

For whole coil connection

$$\text{No. of coils/phase/pole} = \frac{\text{No. of coils/phase}}{\text{No. of poles}}$$

$$= \frac{4}{4} = 1 \text{ coils/phase/pole}$$

As such there will be only one coil in a group. But concentric winding should have two or more coils in a group. In this case concentric winding is not possible. Alternatively grouping can be done for half-coil connection, i.e.

$$\text{No. of coils/phase/pair of poles} = \frac{\text{Total No. of coils}}{\text{No. of phase x No. of pair of poles}}$$

$$\text{As per the example } \frac{12}{3 \times 2} = 2 \text{ coils}$$

i.e. 2 coils/phase/pair of poles.

As per the above example, only half-coil connected concentric winding is possible whereas for the following example having data 48 slots, 24 coils, 4-pole, 3-phase stator winding both whole coil and half coil connections are possible. Hence it is necessary to trace the group connection very carefully before stripping the stator to determine whether the winding connection is whole coil or half coil.

2 Pitch

1 Pole pitch $= \frac{\text{No . of slots}}{\text{No . of poles}}$

As per the example $= \frac{24}{4}$ 6 slots

As the winding is concentric, there should be 2 or more pitches normally. According to the above example 2 pitches for half-coil connections are required.

Further it is necessary to have the average pitch equal i.e. to the pole pitch.

(i.e.) coil pitch = pole pitch ± 1

As per the example coil pitch is 6 ± 1.

Therefore outer coil pitch = 6 + 1 = 7

and inner coil pitch will be = 6 - 1 = 5

(i.e.) Coil throw = 1 - 8 and 1 - 6 In practice it is written as 1 - 8 and 2 - 7.

3 Electrical degrees

i Total electrical degrees = 180° x No. of poles.

As per the example = $180^\circ \times 4 = 720^\circ$.

ii Slot distance in degrees $= \frac{180^\circ \times 4}{\text{No.of slots}}$

$$= \frac{180^\circ \times 4}{24} = 30^\circ$$

4 Phase displacement

i For three-phase winding phase displacement should be equal to 120°

ii Phase displacement in terms of slots

$$= \frac{120^\circ}{\text{slot distance in degrees}}$$

As per the example $= \frac{120^\circ}{30^\circ} = 4$ slots

5 Winding sequence

As per the example

A phase starts from 1st slot.

B phase starts from 1+4 = 5th slot and

C phase starts from 1+4+4 = 9th slot.

6 Arrangement of coils

As in the example 12 coils with pitches as 7 & 5 slots.

1-8,2-7; 5-12, 6-11; 9-16, 10-15; 13-20, 14-19; 17-24, 18-23; 21-4, 22-3.

Grouping of coils

The coil should start from every alternate 2 slots (i.e.) 2 slots for top sides and two slots for bottom sides. As per the example, coils start from 1 & 2, 5 & 6, 9 & 10, 13 & 14, 17 & 18, 21 & 22.

As the connection is half-coil type, with the help of one group of coils, 2 poles need to be created. Hence grouping is as follows:

A	B	C
1-8, 2-7	5-12, 6-11	9-16, 10-15
13-20, 14-19	17-24, 18-23	21-4, 22-3

In whole coil connection, the starting end connection is from the alternative groups (i.e.) if 'A' starts from the first group, 'B' starts from third group and 'C' starts from fifth group. Whereas in half-coil connection, the starting ends will be from continous group, if 'A' starts from the first group, 'B' starts from second group and 'C' starts from the third group. Refer to the developed diagram given in Fig 49.

7 **End connections** (Fig 1): Half coil connection.(End to start and start to end)

Coil connections : Half coil connection. (Fig 2)

In half coil connection, the connection of the coil group shall be from the finish end to the start end and then from the start end to the finish end of the group coils as shown in Fig 2.

Development diagram : Draw the development diagram showing the coil group and end connection. As an example a development diagram is shown in Fig 3.

Fig 1

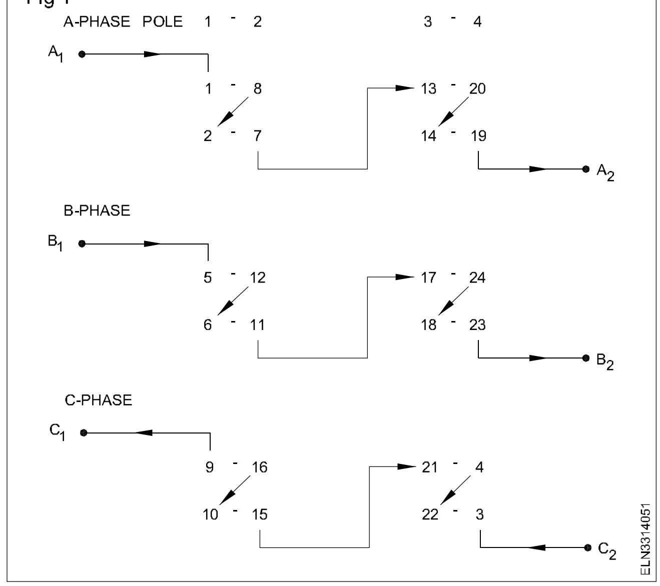


Fig 2

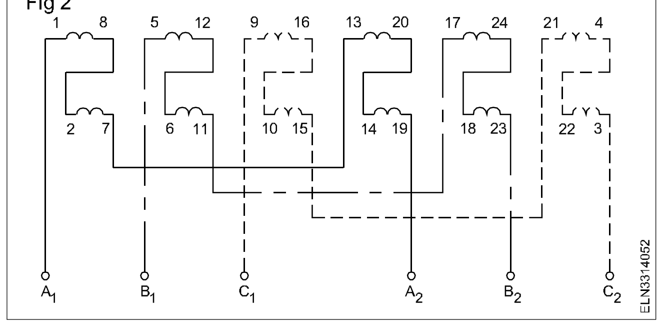
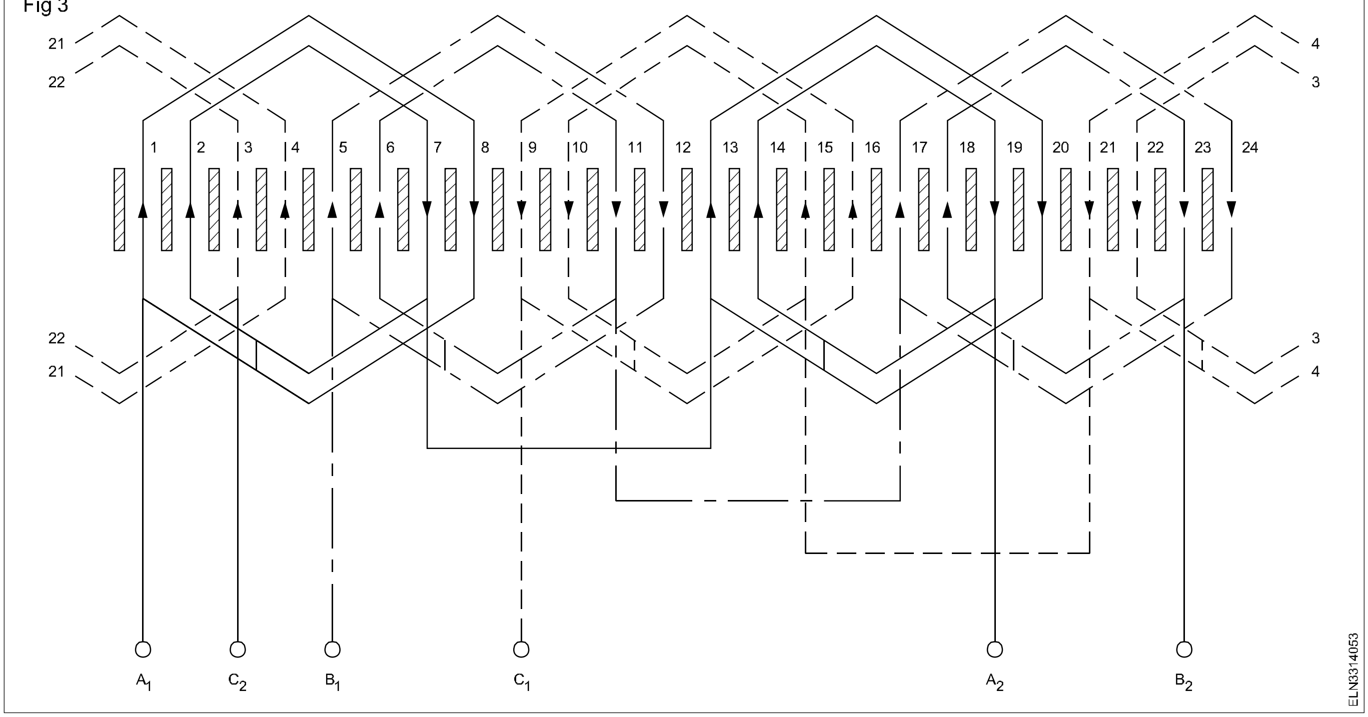


Fig 3



10 Ring diagram

Cross check the end connection with the help of the ring diagram as explained below. Write the end connection table and mark the direction of current using the clock rule. Note that when a three-phase supply is given to the windings at an instant, and if two phases carry current in one direction, the third phase carries current in the opposite direction as shown in Fig 4.

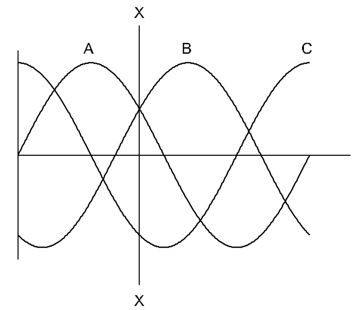
PHASE	P_1 & P_2	P_3 & P_4
A phase	↑1 - 8↓	↑13 - 20↓
	↑2 - 7↓	↑14 - 19↓
B phase	↑5 - 12↓	↑17 - 24↓
	↑6 - 11↓	↑18 - 23↓
C phase	↓9 - 16↑	↓21 - 4↑
	↓10 -15↑	↓22 - 3↑

Refer to Fig 4 in which at the instant shown in x-x we have phases A and B as positive polarity and C has negative polarity.

Mark the direction of current in the slot and it shall represent production of the required number of poles as per the example given below.

Whenever you come across a 3-phase induction motor having a single layer concentric type half coil winding follow the above mentioned procedure and prepare the winding table. Subsquently draw the end connection, development and ring diagrams.

Fig 4



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↑ ↑ ↑ ↑ ↑ ↑	↓ ↓ ↓ ↓ ↓ ↓	↑ ↑ ↑ ↑ ↑ ↑	↓ ↓ ↓ ↓ ↓ ↓
1 2 3 4 5 6	7 8 9 10 11 12	13 14 15 16 17 18	19 20 21 22 23 24
N	S	N	S

3 phase squirrel cage induction motor - double layer distributed type winding

Objectives: At the end of this lesson you shall be able to

- **explain the meaning of double layer winding**
- **explain the winding terms and calculations pertaining to double layer distributed type winding**
- **draw the end and coil connection diagrams**
- **draw the ring and developed diagrams.**

There are different types of winding used in 3-phase AC motors. Some of the 3-phase windings are double layer, that is, there will be as many coils as the number of slots. For example 12 coils in the case of 12 slots, 24 coils in the case of 24 slots. 36 coils in the case of 36 slots, 48 coils in the case 48 slots.Further in the case of distributed winding the size of all the coils, pitch and shape will be the same as these coils are normally former wound. By virtue of the arrangement of these coils in slots, they overlap each other just like in a woven basket. This is also a type of distributed winding.

In double layer winding each slot contains two coil sides i.e. the bottom half contains the left hand coil side while the top half contains the right coil side of some other coil.

Calculations for double layer distributed winding : The winding data of the distributed double layer winding will be within the following limitations. As an example 3-phase double layer distributed winding for an induction motor having 36 slots 36 coils 4 poles is discussed below.

I Grouping

1 $$\text{No. of coils/phase} = \frac{\text{Total No. of coils}}{\text{No. of phase}}$$

As per the example,

$$\text{No. of coils/phase} = \frac{36}{3} = 12 \text{ coils per phase.}$$

2. No. of coils/phase/per pole =

$$\frac{\text{Total no. of coils}}{\text{No. of phase x No. of poles}}$$

$$\text{No. of coils/phase/pole} = \frac{36}{3 \times 4} = 3 \text{ coils/phase/pole}$$

II Pitch

1 $$\text{Pole pitch} = \frac{\text{No. of slots}}{\text{No. of poles}}$$

$$\text{As per the example, pole pitch} = \frac{36}{4} = 9 \text{ slots}$$

2 **Coil pitch :** Similar to the single layer winding the coil pitch can be short-chorded, long-chorded or equal to the pole pitch. The pitch of the double layer distributed winding may be odd or even number. As per the example, the pole pitch is equal to 36/4 = 9 slots and the no. of coils per group is 3. Hence the coil pitch may vary from 9 $\pm$ 3 that is 6,7 or 8 in the case of short corded winding, 9 in the case of full pitch winding and 10,11 or 12 in the case of long chorded winding. Hence the possible coil throws can be taken as

1 to 7 and 1 to 8 for short chorded winding

1 to 9 and 1 to 10 for full pitched winding

1 to 11, 1 to 12 and 1 to 13 for long chorded winding.

Normally the winding is designed for either short chorded or full pitch. Occasionally a long chord is used by the designer in double speed winding. The reason for not using long chorded winding is, it requires more chord length resulting in the requirement of more copper, and hence, increased heat losses.

3 **Coil throw :** According to the above example the coil throw for the coil pitch of 8 will be 1-9.

III Electrical degrees :

Total electrical degrees = 180° x No. of poles

[180° distance between poles]

$$\text{Slot distance in degrees} = \frac{\text{Total electrical degrees}}{\text{No. of slots}}$$

$$= \frac{180° \times \text{No. of poles}}{\text{No. of slots}}$$

$$\text{As per the example } \frac{180 \times 4}{36} = 20°$$

IV Phase displacement

i. For three-phase winding each phase winding should be displaced by 120 electrical degrees.

ii. Phase displacement in terms of slots =

$$\frac{120° \text{ (Electrical)}}{\text{Slot distance in degrees}}$$

$$\text{As per the example } \frac{120°}{20°} = 6 \text{ slots}$$

V Winding sequence : In three-phase winding, the starting end of one phase winding to the starting end of the second phase winding should have a distance of 120 electrical degrees.

Hence if the 'A' phase starts say in the Ist slot then the 'B' phase should start from the Ist slot+120°.

Further 'C' phase should start from the Ist slot+120°+120°.

As in the example 'A' phase starts from, say, 1st slot

'B' phase should start from 1+ 6 = 7th slot and

'C' phase should start from 1+ 6 + 6 = 13th slot.

VI Placing of the coils in double layer winding: As the winding is double layer, the laying of coils should start in adjacent slots.

That is the coils should be placed in slot 1, slot 2, slot 3 and so on.

As in the above example the arrangement of coils for the selected pitch 8 will be as given below:

Fractional pitch Short chorded winding

Pitch 8 **Coil throw 1-9**

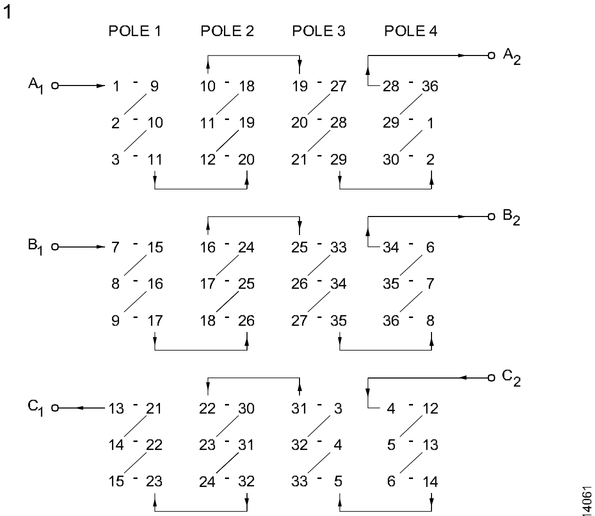
Pole	A-Group	C-Group	B-Group
P1	1-9, 2-10, 3-11	4-12, 5-13, 6-14	7-15, 8-16, 9-17
P2	10-18, 11-9, 12-20	13-21,14-22,15-23	16-24,17-25,18-26
P3	19-27, 20-28,21-29	22-30,23-31,24-32	25-33,26-34, 27-35
P4	28-36, 29-1, 30-2	31-3, 32-4, 33-5	34-6, 35-7, 36-8

Though the possible pitches are 6,7,8,9,10,11 and 12 the above example is given for the pitch equal to 8 only. Trainees are advised to write the table for other pitches to have a better understanding of the winding.

VII End connections : Draw the end connections as shown in Fig 1.

VIII Coil connections : In whole coil connection, the connection of coil groups shall be from the finish end to the finish end and the start end to the start end of the group of coils of the same phase. Either of the following two methods shown in Figs 2 and 3 could be followed.

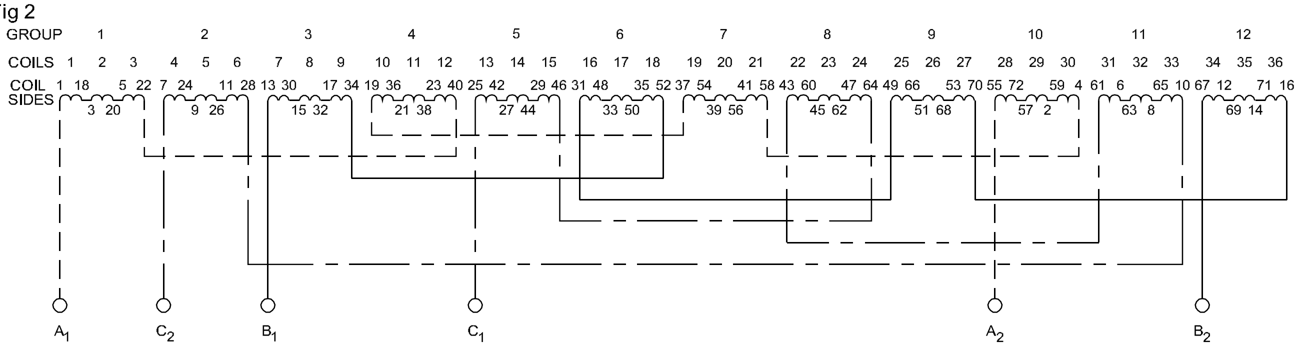
Fig 1



GROUP AND PHASE CONNECTION OF WINDING

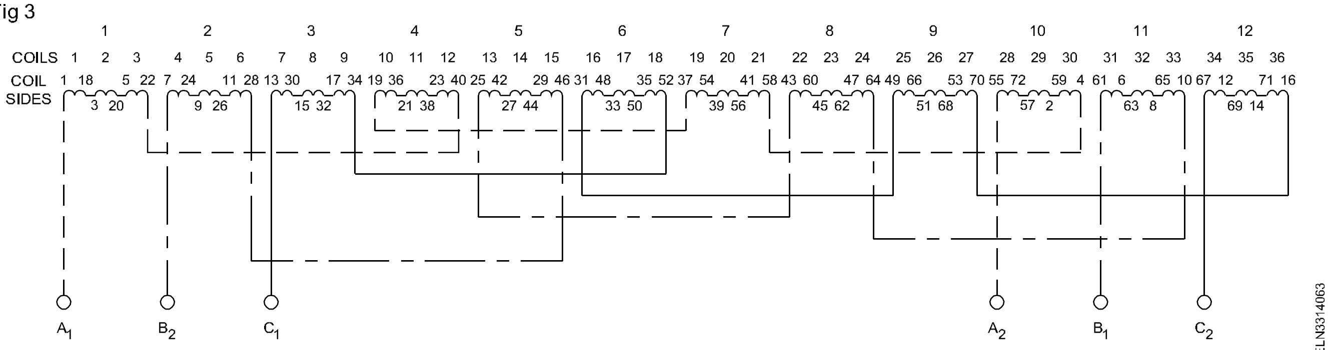
METHOD 1

Fig 2



METHOD 2

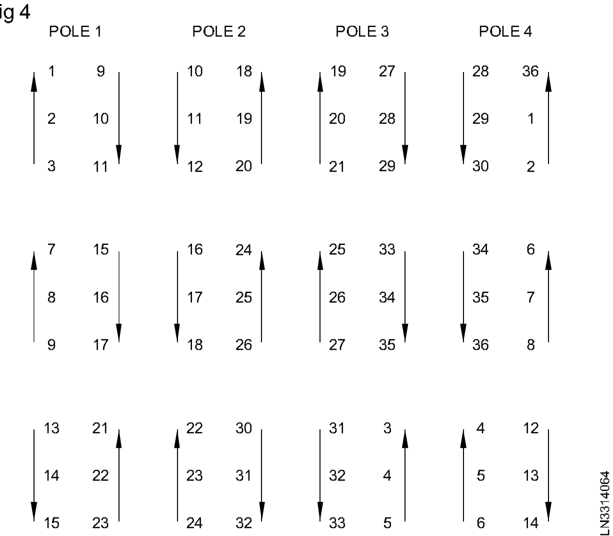
Fig 3



IX Cross check the end connections: Write the end connections table as illustrated below in Fig 4 and mark the direction of currents using the clock rule.

When three phase supply is given to the 3-phase winding, if two phases carry current inwards, the third phase will carry current outwards.

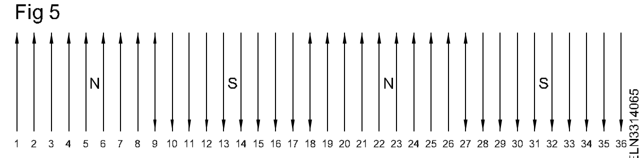
Fig 4



X Ring diagram

Mark the direction of current in the respective slots and then check the production of the required number of poles as shown with ring diagram. (Fig 5)

Fig 5



As per the above ring diagram, in all 4 poles are produced. One pole is produced at each of the area contained by the eight slots. In slots 9,18,27 and 36 coil sides carry current in the opposite directions and hence, the flux in those slots gets neutralized. This happens in the short chorded winding. Based on the above information draw the developed diagram.

XI Developed diagram

A developed diagram is shown in Fig 6 in which the connections are shown for the method 1 referring to Fig 2.

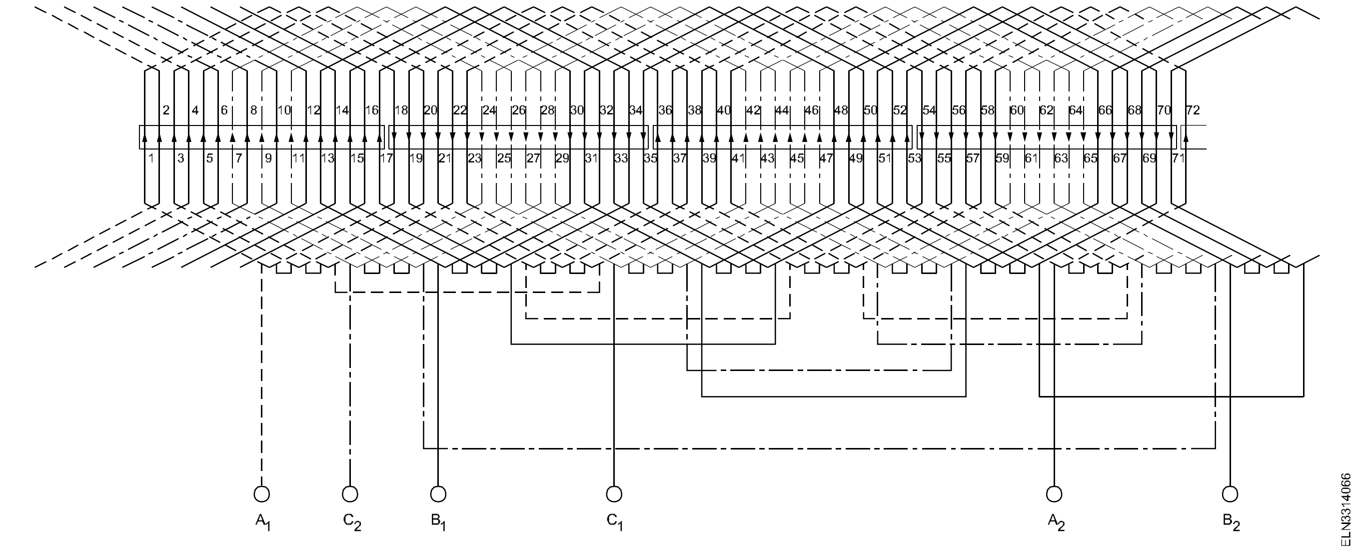
XII Fractional pitches

After the group and lead connections are over, the sleeved joints are to be tied with the overhang with the help of hemp threads. Follow the instructions contained in Ex.3.2.03 to complete the job.

Winding is then to be tested and varnished.

The motor is then to be assembled and test run for atleast eight hours to check its performance on no load. Wherever loading facilities are availabe the newly wound motor can be checked for its load performance.

Fig 6



Testing of windings

Objectives: At the end of this lesson you shall be able to
- **test the rewound motor for continuity and measure the coil resistance**
- **test the coils of the winding for short circuit using internal growler or voltmeter or ohmmeter**
- **test the winding for ground and insulation resistance**
- **test the winding for correct magnetic polarity using a magnetic compass or screwdriver or a search coil**
- **test the 3-phase winding for equal value of phase currents**
- **test the newly wound motor under no-load.**

After the motor is rewound the following tests are carried out in the windings.

1 Continuity test/resistance test.

2 Short circuit test/growler test.

3 Insulation resistance test.

4 Polarity test.

5 Unbalanced current test - for 3-phase winding.

6 No-load test.

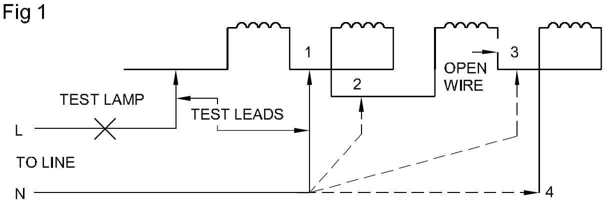
Continuity test/resistance test : This test is done to check up the continuity of each winding. If there is any open in the winding, it is to be rectified.

The usual cause of an open circuit in a winding is loose connection or break in the winding wire. The open circuit may be located by connecting one lead of the test lamp to one end of the winding and touching the other lead to the end of each coil end in sequence in the same phase.

Refering to Fig 1, if the lamp does not glow at point 3 but glows at point 2 then the third coil is faulty. If the lamp glows at 2 and 3 but not at 4 then the fourth coil is faulty. By repeating this process the coil which has the open circuit, can be identified.

Similarly, the other winding can also be tested for open circuit.

Fig 1



The resistance of each coil may be measured by a low range ohmmeter. The resistance of each coil must be the same. The high value of resistance or infinity value indicates open in the windings.

If there is any open in one coil, that coil can be bypassed and left out in the chain of windings. Then the motor can run, but if the open is in more than one coil, bypassing of the coil is not possible. This type of repairing is possible for small capacity motors where the winding has a large number of coils. Ex: Ceiling fans. But this procedure should be avoided as far as possible.

If the polarity of one or two coils in a multiple pole fan motor is changed the fan will run slowly and produces more heat.

Short circuit test/growler test : Two or more turns that contact each other electrically will cause a short circuit in the winding. This short circuit will cause excessive heat to be developed during the operation of the machine.

Short circuit can be detected by any one of the following methods.

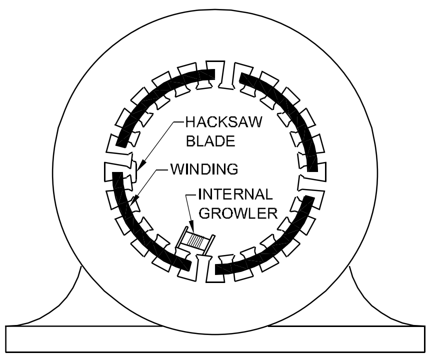
a Internal growler method

b Voltage drop test

c Ohmmeter method.

Internal growler method : The internal growler consists of a coil of wire wound on a laminated iron core and connected to 240V AC supply. After the stator is removed the growler is placed on the core of the stator and moved from slot to slot as shown in Fig 2. A shorted coil will be indicated by rapid vibration of a metal blade provided with the growler and in some types of internal growlers, glow of the neon lamp provided with the growler indicates short in winding.

Fig 2



THE GROWLER METHOD OF TESTING FOR SHORTS IN THE STATOR

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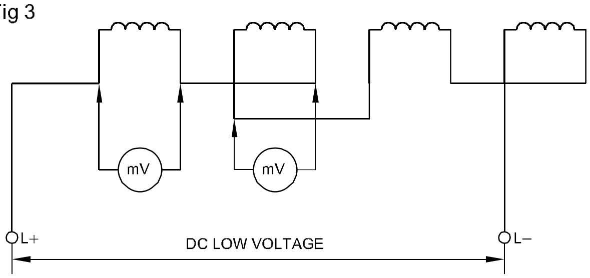
Voltage drop method : In this method the winding is connected to a low voltage DC supply as shown in Fig 3 and the voltage drop is measured across each coil by a millivoltmeter. The voltage drop across good coils will be the same whereas voltage drop across shorted coils will be low.

Fig 3



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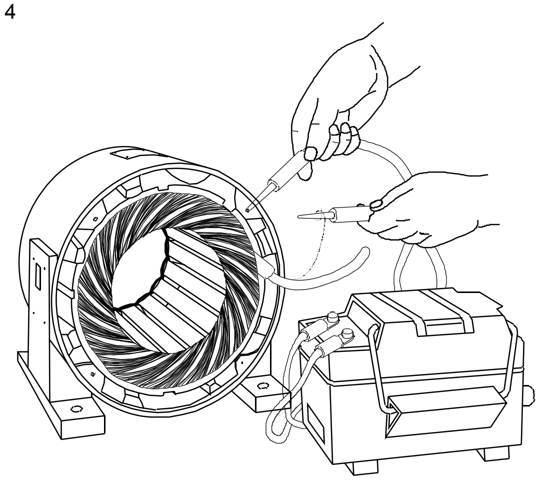
Ohmmeter method : For this method, measure the resistance of the each coil by a low range ohmmeter or Kelvin bridge or Post Office Box. All the coils should read the same value of resistance. The coil which reads lower resistance than the other coils or that which reads zero resistance is assumed to be shorted and needs replacement. On the other hand the coil which reads high resistance when compared to similar coils or which reads infinite value of resistance indicates open in that particular coil.

Ground test and insulation/resistance test : Grounded winding may cause a fuse to blow up or it may cause the winding to smoke, depending on the extent of the ground. It may give shock to persons when they come in contact with the frame which is not properly earthed.

The aim of this test is to check any direct connection between windings and earth(ground). For this, the neutral of the supply is connected to the body of the machine and the phase wire is connected through a series test lamp. The open end of the test lamp is touched to each end of the winding in sequence. If the lamp remains dark it means winding is not grounded and if it glows, the winding is earthed. This is a fast, rough practical method.

If a Megger is used for testing the grounded winding, one terminal of the Megger is connected to the body and other to the windings as shown in Fig 4. If the pointer of the Megger shows infinity, the winding is correct and there is no connection between the windings and the body. Insulation resistance between windings and the body of the machine is measured by a 500 volts Megger and the readings so obtained shall not be less than 1 Megohm in the case of 3-phase and single phase motors. For additional safety 2 megohms are necessary in the case of ceiling and table fans.

Fig 4



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Polarity Test: Correct coil group connection in the winding ensures correct polarity. If there is any confusion in the coil group connections then the polarity test is necessary to be carried out to check proper polarity.

There are three methods recommended as explained below.

a Magnetic compass method

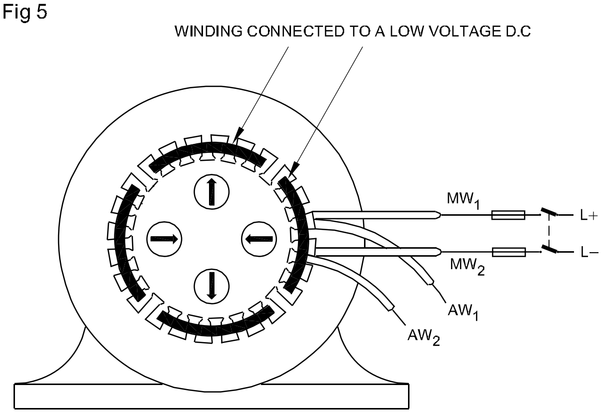
b Two screwdrivers method

c Search coil method

Magnetic compass method : In this method, the stator is placed in a horizontal position and a low DC voltage is applied to the winding. The compass needle is then held inside the stator and moved slowly from one pole area to another pole area as shown in Fig 5. The compass needle will reverse itself on each pole if the winding is correctly connected. If there is same direction of indication between two adjacent poles, a reverse pole is indicated.

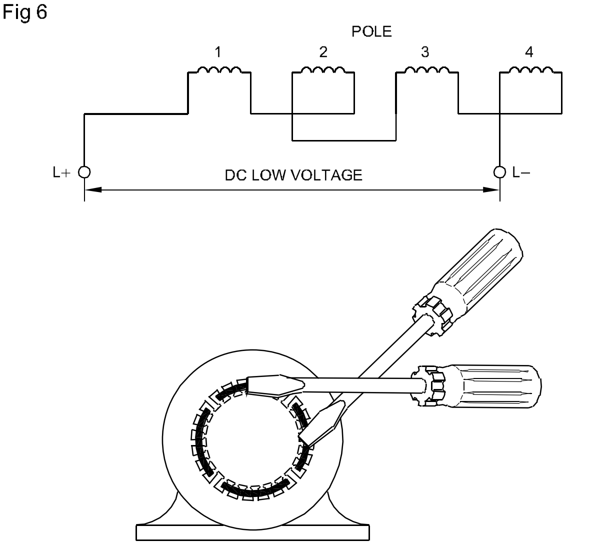
Two screwdrivers method : In this method, the stator is placed in vertical position and a low voltage DC is applied to winding in case of 3-phase to individual phase. A screwdriver is placed on the core at the centre of one pole area, and another on the next pole area centre. If in adjacent poles the polarity is correct the screwdrivers will be attracted as shown in Fig 6. If the polarity is incorrect the screwdrivers will repel each other. If it is found that one pole has wrong polarity, that can be corrected by reversing two lead connections of that coil group.

Fig 5



THE COMPASS METHOD OF TESTING FOR REVERSED POLES

Fig 6

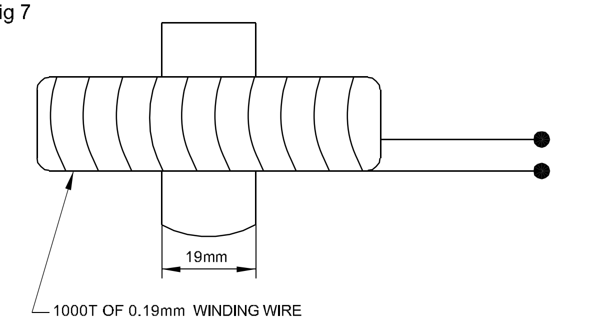


Polarity test by search coil method (Fig 7) : The search coil consists of a coil of 1000 to 2000 -turns. The iron core should have one end rounded. This coil is used for testing the polarity of the poles of the rewound stator.

A more reliable way is to use the search coil in conjunction with a centre-zero milli-voltmeter or galvanometer. (Fig 8) If the search coil is so made that one end of the core projects beyond the windings it can be used to polarise very small stators by placing the projecting end on each pole in turn without the coil itself entering the stator.

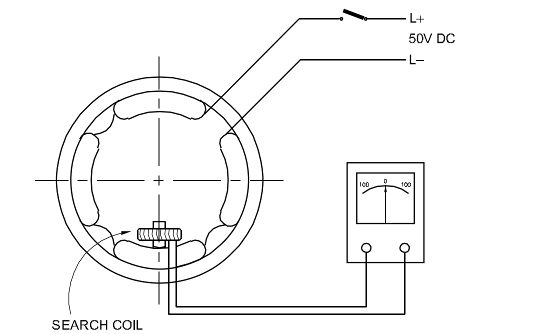
With the search coil core making contact with a pole, the switch is closed (Fig 8) and the galvanometer will give a kick either to the right or the left at the moment, the circuit is made. Mark the pole thus treated either R or L as the case may be with chalk.

Fig 7



SEARCH COIL

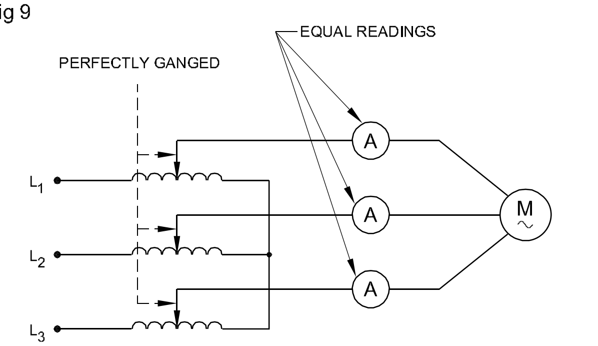
Fig 8



The next pole is marked in the same way according to the direction of the kick. It must be emphasised that all readings must be taken when the switch is made, because a reverse kick is seen when the switch is opened.

Unbalanced current test: In the case of three-phase winding reduced voltage is applied from a 3-phase auto-transformer to get nearly full load current as shown in Fig 9. In this test all the three phase currents measured should be the same. Even if the windings are good, ±3% variation of the current is permissible.

Fig 9



No-load test : After impregnation and assembly of motor, check the rotor for free rotation. Connect the motor to the rated supply voltage. Run the motor at no load and record the no-load voltage, current and speed of the motor. In no case these readings increase beyond name-plate values. Inspect the bearing sound and vibration. Normal sound without vibration is an indication of a good job. However, the perfection of the winding job could be ascertained only through a load test.

Insulating varnish and varnishing process in electric machines

Objectives: At the end of this lesson the you shall be able to
- **state the importance of varnishing the winding of a machine**
- **state the types of varnish, their characteristics and uses**
- **state the use of thinners**
- **explain the methods employed in preheating the winding**
- **explain the process of varnishing a winding.**

Importance of insulating varnish to the electrical machines : The hygroscopic (absorbing moisture) nature of many of the solid insulating materials used for general insulation has to be neutralised by varnish impregnation. Varnish will not allow the ingress of moisture to enter inside the winding layers by forming a cover and in many cases, works against the action of oils, acids, alkalies and heat. Insulating varnish is also necessary to bond conductors together especially in rotating machines. Heat dessipation from the windings is improved by the displacement of air by solid varnish between the conductors.

Types of Varnish: Four types of varnishes are commonly available to use with electrical windings. They are:

1 air-drying varnishes

2 baking varnishes

3 thermosetting varnishes

4 solventless varnishes.

Air drying varnish : This varnish consists of solid particles and a solvent. The varnish is dried by vaporisation of the solvent without heating. In comparison with baking varnishes, air-drying varnishes have low strength and high porosity(having too many small holes) because their films do not flow well enough to seal up the voids (gaps) left by the drying out of the solvent. Furthermore, they tend to deteriorate rather rapidly in the dip tank and during storage. The fastest drying types have a shellac spirit base and may be either clear or black. These can be used for emergency repair jobs or for touch-up work. Black asphalt-base varnishes are available, but these have only fair resistance to oil.

A number of oleoresinous (oil and resin base) varnishes, both black and clear, are available in the market. These varnishes dry by loss of the solvent and by oxidation and are more oil-resistant than the asphalt-base varnishes. Synthetic based air-drying varnishes are also used to some extent.

Baking varnishes - oleoresinous : Baking varnish also consists of solid particles and solvents. Varnishes of this type were more widely used before thermosetting varnishes were developed. They dry partly by polymerization and partly by oxidation, depending upon the drying oils they contain. Linseed oil varnishes dry almost entirely by oxidation; tung-oil varnishes dry both by oxidation and polymerization. Drying by oxidation causes a hard surface to form while the varnish is still wet underneath. This is the disadvantage of this type of varnish particularly in deep coils.

Thermosetting varnishes : These are heat-hardening, clear, synthetic varnishes which represent a vast improvement over ordinary baking varnishes, which depend upon oxidation for hardening. These varnishes are suitable for use either with Class B or Class E insulation.

Solventless varnishes : Recent developments indicate that in a few years satisfactory solventless varnishes (100 percent solids) may be commercially available; and these will be free of the poor shelf life characteristic and tank deterioration of the present solventless varnishes.

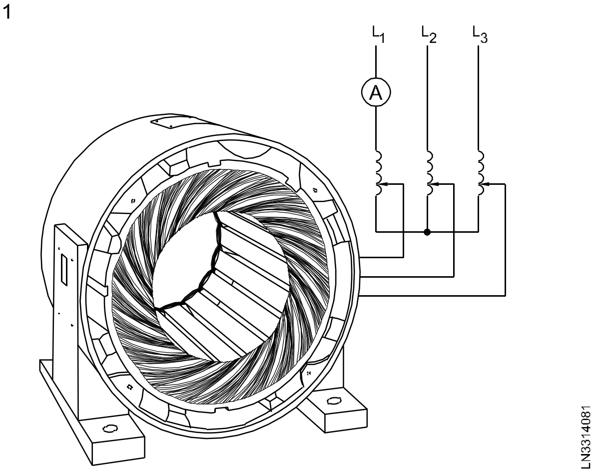
Varnish thinners: Thinners are used to adjust the viscosity and solid content of varnish to the desired amount. Addition of thinners should be done slowly, accompanied with rapid agitation of the varnish to obtain thorough mixing. In selection of thinners - specific recommendations for particular types of varnish should be obtained from the varnish manufacturer. The contents of thinners on the varnish should not exceed 60%.

Preheating : Preheating of winding before varnishing is done mainly to drive out the moisture in between the winding layers.

The winding should be completely dried before applying the varnish by any one of the following methods.

1 By applying a low voltage, about 20% of normal to the stator terminals through a 3-phase auto- transformer as shown in Fig 1 so that a current not greater than full load flows in the winding. The motor may be heated for 8 to 10 hours.

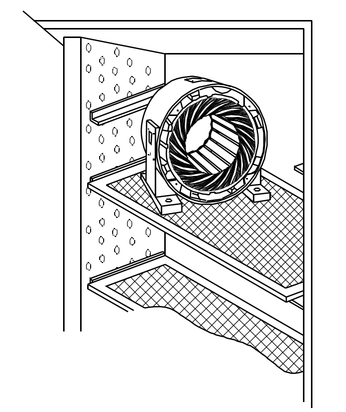
Fig 1



Close supervision is necessary as the heat generated by the winding is not easily dissipated.

2 The motor can be placed in an oven, as shown in Fig 2 but the temperature should not be allowed to exceed 90°C.

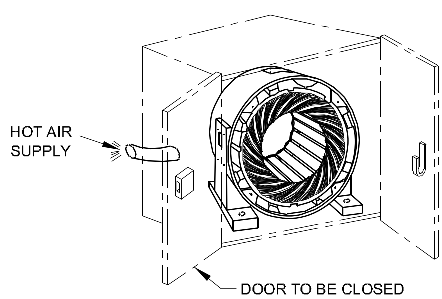
Fig 2



OVEN USED FOR DRYING THE WINDING

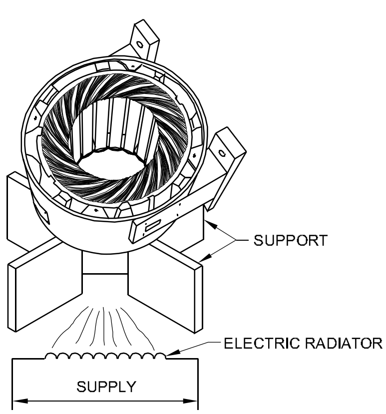
3 Hot air may be blown into the windings which is kept in a closed chamber as shown in Fig 3 but the air should be clean and dry and at a temperature of not more than 90°C.

Fig 3



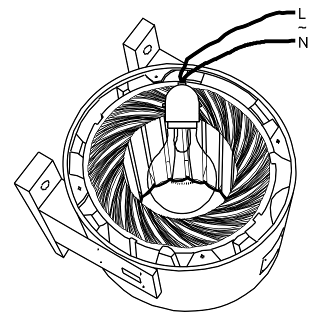
4 Coke braziers or electric radiators may be placed around the machine as shown in Fig 4.

Fig 4



5 Carbon filament lamps, placed inside the machine as shown in Fig 5, may be employed quite satisfactorily, but care should be taken that the hot bulb is not in contact with any part of the windings. If it is not possible to reach a sufficiently high temperature, the ventilation may be reduced by covering the stator with a tarpaulin.

Fig 5



The method of heating employed for drying out should be continuous and the process should be carefully watched to ensure that the windings do not attain a temperature sufficiently high to damage the insulation. The maximum safe temperature of the windings measured by thermometer is 90°C. At the same time the temperature should not be allowed to fall too low as this will cause re-absorption of moisture.

The insulation resistance is found to drop considerably as the motor warms up, the insulation resistance reaches the minimum, and then remain constant for some time, depending upon the dampness of the machine. As the drying process progresses further, the insulation resistance will gradually rise. The drying out should be continued as long as the insulation resistance rises, or until a sufficiently high value, i.e. not less than one megohm per 1000 volts at 75°C has been reached.

During the drying out period, reading of temperature and insulation resistance should be taken at least once an hour, in order to see how the drying out is progressing. The temperature of the motor should be kept constant as far as possible; otherwise the readings may be misleading.

After the winding is preheated, cool the job to a temperature of about 60°C before applying the varnish. This is important because the higher temperature would tend to seal the outer side with the varnish layer.

Varnishing process : Varnish is applied to the windings either by immersing the whole (wound) stator in the varnish tank or by pouring the varnish on the windings. In some cases varnish can also be applied with a painting brush.

Air-dry varnishes are natural drying; so allow the job to set at normal temperature atleast for 6 hours.

Impregnation : For impregnation follow the procedure recommended by the manufacturer of the varnish.

Impregnation process : The following is the impregnation procedure of class E motors. Use Class E impregnation varnish.

1 Preheat the job for eight hours in an oven at 85-100°C and measure the insulation resistance. If the insulation resistance is less than infinity continue the preheating process till the insulation resistance is infinity.

2 After preheating, allow the job to cool down to 60°C and dip it in the varnish tank. Dip the hot winding in vertical position in the varnish for one hour or for sufficient time for all the air bubbles to escape.

3 Drain the varnish from the job by lifting it over the tank in a cradle for about one hour till the varnish drains completely.

4 After draining, heat the job to 120°C for two hours and 140°C for a minimum of ten hours.

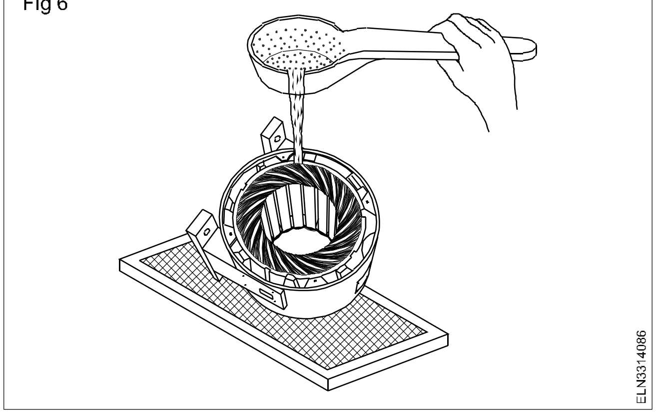
5 Measure the insulation resistance immediately after baking, and the value should not be less than 2 meg-ohms.

6 For second impregnation cool the job to 70°C after baking and repeat steps 2,3 and 4 as above.

In case there is no varnish tank to use, place the stator on a container filled with varnish and pour the varnish on it with a spoon as shown in Fig 6. In this case, pour the varnish sufficiently on it from the connection side and opposite of the connection side alternately by changing the position of the stator.

Varnish stripping : After the winding has been dipped and baked, it is often necessary to remove the excess varnish from such places as air gap surfaces or the end-shield fits, since there are no practical means for preventing the varnish from accumulating there. A rag saturated with the correct solvent for the varnish to be removed can be used to wipe off excess accumulation of the wet varnish. Baked varnish coatings can readily be stripped off from metallic surfaces if these surfaces are treated with a suitable masking compound before dipping. This compound is thinned with acetone for spraying or is maintained at a heavy molasses like consistency if it is to be applied by dipping or by brushing. After the thin coating has been dried for half an hour, the apparatus may be given the normal varnish impregnation and baked. After baking the masking compound will strip cleanly from the bare metal merely by inserting a knife or finer nail under it at one point. Both the varnish and the masking compound can be removed as a single intact film by peeling off the layer.

Fig 6



Method of connecting end connection, group connection, terminal leads, binding and forming the overhangs

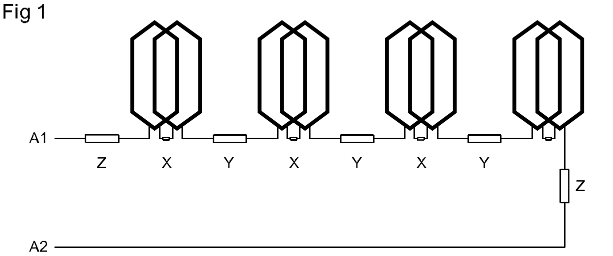
Objectives: At the end of this lesson you shall be able to
- **state the type of connections in winding**
- **explain the method of making coil end connections**
- **explain the method of making group (jumper) connections**
- **explain the method of connecting terminal leads**
- **explain the method of binding the end/terminal/lead connections with the winding**
- **explain the method of forming the overhangs.**

The procedure explained below is common for any winding.

End connections : There are three types of connections to be made in the windings. First for coil connection for coil group as shown by X, second for connecting the coil groups (jumper connection) in one phase as shown by Y and third by connecting the lead wires as shown by Z in Fig 1. Better to proceed one by one in the above stated sequence while winding.

Any connection to be made in winding wires should start with a proper identification of the coil ends. For a beginner, it may be necessary to refer alternatively to the developed diagram, connection diagram as well as the actual winding often to eradicate the confusion. After identifying the coil ends simply twist the ends to be joined temporarily as shown in Fig 2 and recheck the connection with respect to the developed diagram and the connection diagram.

Fig 1



After ascertaining the connections are correct, remove the enamel insulation with the help of sandpaper or a knife or by an electrically operated insulation remover. In all methods see that the wire is not nicked or bent often to avoid damage.

Method of coil connections : Check whether the enamel insulation is completely removed. Twist the wire together to a length of 20-25 mm and insert the PVC or empire sleeve as shown in Fig 3. Bend the joint towards the coil bunch and tie with a twine.

Fig 2

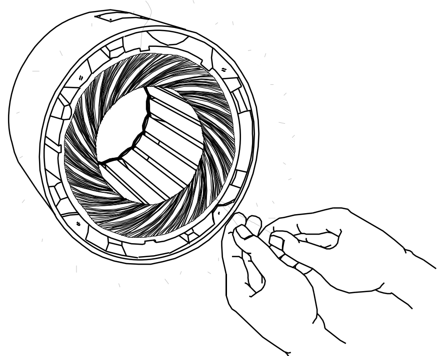


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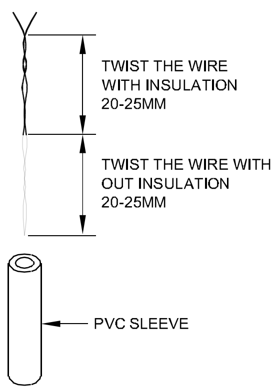
Fig 3



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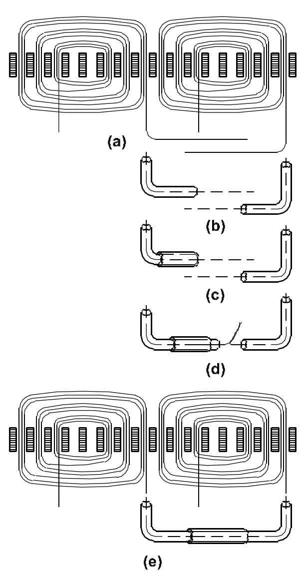
Method of group connections (jumper connections): Place the wire to be joined overlaping each other for 40 mm. Cut the extra length as shown in Fig 4a. Remove the enamel insulation to a length of 40 mm in the winding wires.

Insert a suitable PVC or empire sleeve of sufficient length inside the two wires to be joined as shown in Fig 4b. Over one of the sleeves insert another sleeve of larger size as shown in Fig 4c. Twist the wires together as shown in Fig 4d. Bend the joint on the wires and pull the 2nd sleeve insulation over the joint as shown in Fig 4e.

Fig 4



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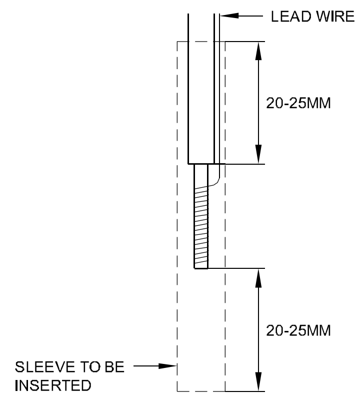
Method of lead connections : To connect the lead wire, strip the insulation of the cable to a length of about 25 mm and also remove the enamel insulation from the winding wire to that length. Clean both the wires and wind atleast 10 times of the winding wire over the lead wire tightly as shown in Fig 5.

Use the PVC or empire sleeve to insulate the joint as shown in Fig 5.

Fig 5



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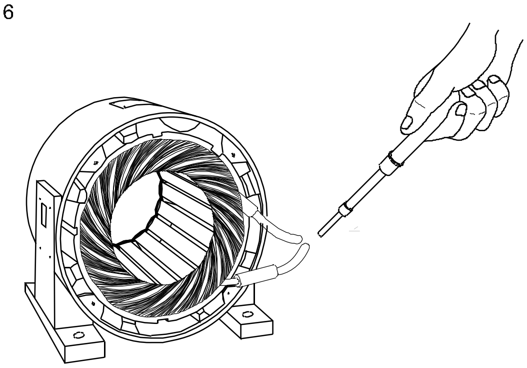
After testing the winding for correctness as outlined earlier in the end all the connections earlier made need to be soldered as shown in Fig 6 and then insulated by the sleeves.

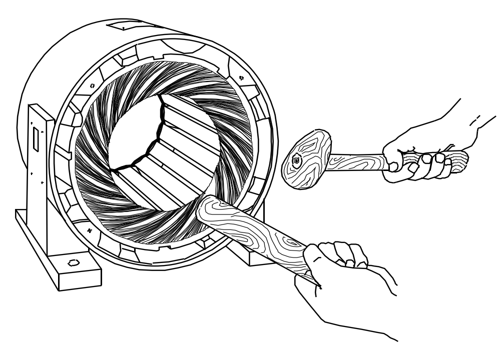
Fig 6



ELN3314096

Shaping and binding the overhangs : After soldering and sleeving all the end connections, lay the jumper wires and lead wires in a symmetrical manner so that uniformity is maintained and the overhang looks neat. By a wooden or nylon mallet, gently tap the coil overhangs on both the sides into concentric ring. Use wooden or fibre roller for this as shown in Fig 7. At intervals check the overhang dimensions with the data taken earlier.

Fig 7



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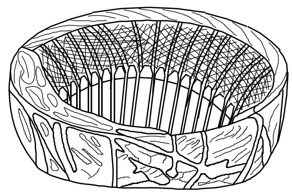
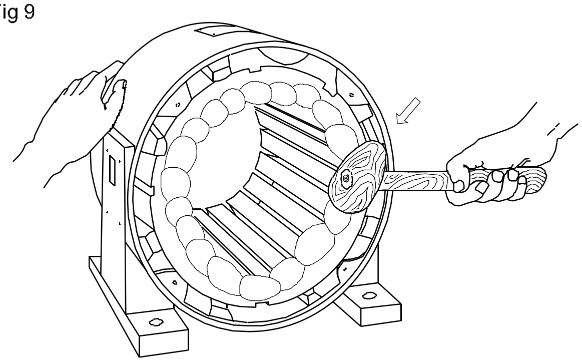
Bind the end connections, jumper and lead connections with the coil tightly with binding thread with suitable tape as in the original. (Fig 8)

Fig 8



After binding the connection leads with the overhangs, once again finally shape both the overhangs into concentric rings, so that they spread uniformly and do not touch the rotor. During the process check often whether sufficient gap is provided between the frame and end covers as in the original. (Fig 9)

Fig 9



Maintenance, service and troubleshooting in AC 3 phase squirrel cage induction motor and starters

Objectives: At the end of this lesson you shall be able to
- **list and state about the maintenance schedule of AC 3 phase motor**
- **list out the possible faults, causes and remedies in 3 phase motors**
- **explain the mechanical problems in motor, bearings and their remedies**
- **state the lubrication techniques on learning**
- **explain the troubleshooting of AC motor starters and maintenance of starters.**

Generally due to the rugged construction of the AC squirrel cage induction motor, it requires less maintenance. However to get trouble-free service and maximum efficiency, this motor needs a scheduled routine maintenance. As found in most of the industries the AC squirrel cage motor is subjected to full load for 24 hours a day and 365 days a year. Therefore the maintenance should be scheduled to have periodic maintenance for a selected area on daily, weekly, monthly, half yearly and yearly periods for increasing the working life of the motor and to reduce the break down time.

Maintenance schedule: Suggested maintenance schedule for the AC squirrel cage induction motor is given below as a guide.

Daily maintenance

- Examine earth connections and motor leads.
- Check motor windings for overheating. (Note that the permissible maximum temperature is above that which can be comfortably felt by hand.)
- Examine the control equipment.

In the case of oil ring lubricated machines

i) examine bearings to see that oil rings are working

ii) note the temperature of the bearings

iii) add oil if necessary

iv) check end play.

Weekly maintenance

- Check belt tension. In a case where this is excessive it should immediately be reduced and in the case of sleeve bearing machines, the air gap betweeen the rotor and stator should be checked.
- Blow out the dust from the windings of protected type motors, situated in dusty locations.
- Examine the starting equipment for burnt contacts where motor is started and stopped frequently.
- Examine oil in the case of oil-ring lubricated bearings for contamination by dust, dirt etc. (This can be roughly ascertained on inspection by the colour of the oil).

Monthly maintenance

- Overhaul the controllers.
- Inspect and clean the oil circuit breakers.
- Renew oil in high speed bearings in damp and dusty locations.
- Wipe brush holders and check the bedding of brushes of slip-ring motors.
- Check the condition of the grease.

Half-yearly maintenance

- Clean the winding of the motors which are subjected to corrosive or other such elements. Also bake and varnish if necessary.
- In the case of slip ring motors check slip rings for grooving or unusual wear.
- Renew grease in ball and roller bearings.
- Drain all oil bearings, wash with kerosene, flush with lubricating oil and refill with clean oil.

Annual maintenance

- Check all high speed bearings and renew if necessary.
- Blow out clean dry air over the windings of the motor thoroughly. Make sure that the pressure is not so high as to damage the insulation.
- Clean and varnish dirty and oily windings.
- Overhaul motors that are subject to severe operating conditions.
- In the case of slip ring motors, check the slip ring for pittings and the brush for wear. Badly pitted slip rings and worn out brushes should be replaced.
- Renew switch and fuse contacts if badly pitted.
- Renew oil in starters that are subjected to damp or corrosive elements.
- Check insulation resistance to earth and between phases of motor windings, control gear and wiring.
- Check resistance of earth connections.
- Check air gaps.

Records : Maintain independent cards or a register (as per specimen shown in trade practical) giving a few pages for each machine and record therein all important inspections and maintenance works carried out from time to time. These records shall show past performance, normal insulation level, gap measurements, nature of repairs and time between previous repairs, and other important information which would be of help for good performance and maintenance.

Faults which occur in AC 3-phase squirrel cage motor can be broadly divided into two groups

They are

1. Electrical faults
2. Mechanical faults.

In most of the cases both the faults may be individually present or both may be present, as one type of fault creates the other fault. The following charts give the cause, the test to be carried out and possible remedy.

Chart 1

Motor fails to start

S.No	Cause	Test	Remedy
1	Overload relay tripped.	Wait for overload coils to cool. Push the reset button if separately provided. In some starters the stop button has to be pushed to reset the overload relay.	If motor could not be started check the motor circuit for other causes as outlined in this chart.
2	Failure of power supply.	Test the power supply at the starter incoming terminals.	If the supply is present in the incoming terminals of the starter, check the starter for fault. If not, check the main switch and fuses. Replace the fuses if necessary or restore power supply.
3	Low voltage.	Measure the voltage at the mains and compare with the name-plate rating.	Restore normal supply or check the cables for underrating.
4	Wrong connection.	Compare the connection with the original diagram of the motor.	Still if motor does not start, reconnect, after disconnecting the connection of the motor.
5	Overload.	Measure the starting torque required by load.	Reduce load, raise tapping on auto-transformer, install a motor of a higher output.
6	Damaged bearings.	Open the motor and check the play of bearings.	Replace if required.
7	Faulty stator winding.	Measure current per phase and they should be equal, if required measure resistance per phase; check insulation resistance between winding and earth.	Repair the fault if possible or rewind stator.
8	Wrong control connections.	Check the control circuit and compare it with the circuit diagram.	Reconnect the control circuit according to the manufacturer's circuit diagram.
9	Loose terminal connections at mains or at starter or at motor.	Check the terminal connection of the main switch, starter and motor for discolouring and loose nuts.	Tighten the terminals.
10	Driven machine is locked.	Disconnect the motor from the load.	If the motor starts satisfactorily check the driven machine and rectify the defect.
11	Open circuit in stator or rotor.	Check visually and then with multimeter/megger.	Rectify the defect or wind.
12	Short circuit in stator winding.	Check the phases and coil groups with the help of an ohmmeter or use internal growler.	Repair the winding or rewind.

S.No	Cause	Test	Remedy
13	Winding is grounded.	Test with a Megger or test lamp.	If the fault is found, repair or rewind.
14	Bearing stiff.	Rotate the rotor by hand.	If the rotor is stalled, dismantle the motor and rectify the defect.
15	Overload.	Check the load and belt tension.	Reduce the load or loosen the tight belts.

Chart 2

Motor starts but does not share load (Runs at low speed when loaded.)

S.No	Cause	Test	Remedy
1	Too low a voltage.	Measure voltage at the motor terminals and verify it with the name-plate.	Renew bad fuses; repair circuit and remove the cause of low voltage, like loose or bad contacts in starter, switches, distribution box,etc.
2	Bad connection.	Check the connection and contact of starter for loose contact.	Remove the fault as required.
3	Too low or high tension on driving belt.	Measure the tension and verify it with the instruction of the manufacturer.	Adjust the belt tension.
4	Open circuit in rotor winding.	Examine the rotor bars and joints.	Re-solder the rotor bars.
5	Faulty stator winding.	Check for continuity, short circuit and leakage.	Repair the circuit if possible or rewind the stator.
6	Defective bearings.	Examine bearings for play.	Replace the bearings.
7	Excessively loaded.	Measure the line current of the motor and compare it with its rated current.	Reduce the mechanical load on the motor.
8	Low frequency.	Measure the line frequency with a frequency meter.	If the line frequency is low inform the supply authorities and get it corrected.

Chart 3

Motor blows off fuses

S.No	Cause	Test	Remedy
1	Incorrect size of fuses	Check the size of the fuse wire (it should be rated for 1½ times its normal current); connect the ammeter in the circuit and test for excess load current.	Replace the fuse wire if necessary; repair the motor if it is due to electrical fault of stator or rotor.
2	Low voltage	Measure the line voltage.	Remove the cause of low voltage.
3	Excessively loaded	Measure the line current and compare it with its rated current.	Rectify the cause of overload or install a motor of higher output rating.
4	Faulty stator winding	Check for open circuit, short circuit or leakage of the stator as explained earlier.	Repair the fault; if not possible then rewind the stator.
5	Loose connection in starter	Check for loose or bad connection in the starter because it may cause unbalancing of current.	Rectify the loose connection; loose all the contact points of the starter with sandpaper and align the contacts.
6	Wrong connection	Check the connection with the original diagram.	Reconnect the motor if it still does not start.

Chart 4

Over Heating of the motor

S.No.	Cause	Test	Remedy
1	Too high or low voltage or frequency.	Check the voltage and frequency at the terminal of the motor.	Rectify the cause of low or high voltage or frequency as the case may be.
2	Wrong connection.	Compare the connection with the given circuit diagram.	Reconnect the connection if required.
3	Open circuit in rotor.	Loose joints of rotor bars causeheat.	Resolder the joints of rotor bars and end rings.
4	Faulty stator winding.	Check for continuity, short circuit and leakage as stated before.	Remove the fault if possible; otherwise rewind the stator winding. Remove dirt and dust from them if any.
5	Dirt in ventilation ducts.	Inspect ventilation ducts for any dust or dirt in them.	Reduce the load or loosen the belt. Rectify the single phasing defect.
6	Overload.	Check the load and the belt.	If the defect is with the driven machine repair it. If the problem is with the bearing, investigate and repair or replace with new one.
7	Unbalanced electrical supply.	Check the voltage for single phasing. Check the connections and fuses. Remove the load and check the rotor for free rotation.	If required replace the motor designed for this purpose.
8	Motor stalled by driven machine or tight bearing.	Check the motor - starter contactor	Loose the machine bearing or grease the bearing or replace the bearing.
9	Motor when used for reversing heats up.	Check the connection	Check the manufacturer's instructions.

Mechanical problems in the motor: In general the squirrel cage induction motor is found to develop more mechanical troubles rather than electrical troubles. A thorough knowledge about the bearing and lubrication is a must for every electrician. As most of the faults which developed later in the squirrel cage motor are due to wrong selection of bearings, improper fittings of bearings and inefficient lubrication, it is essential that the electrician should have some knowledge with respect to the types of bearings, method of fitting or removal of the bearings and type of lubricants available in the market as explained below.

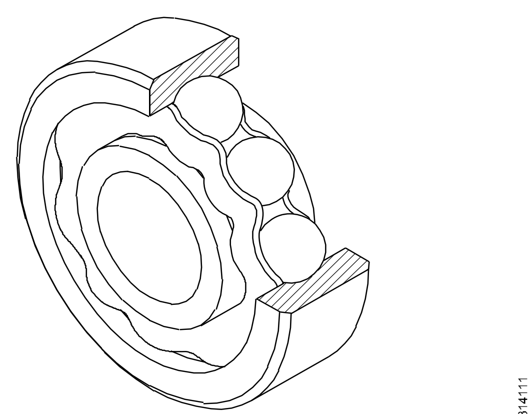
Ball or roller bearings : The electric motor is fitted with either a ball (Fig 1) or roller (Fig 2) bearing for easy rotation of the shaft.

As shown in Figs 1 & 2 these bearings have balls or rollers which prevent sliding friction by rolling between the races.

As bearings are used between stationary and revolving machine parts, such bearings have a stationary and a revolving race.

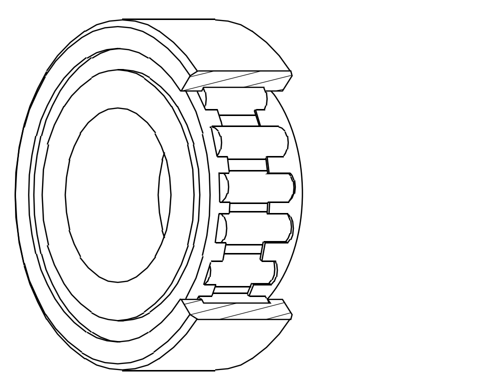
Handling the bearings : Bearings are precision-made of hard, brittle materials. But the working surfaces of bearings are either honed or very soft. If these surfaces are damaged, the bearing is ruined, therefore:

Fig 1



SINGLE ROW SNAP RING BALL BEARING

Fig 2



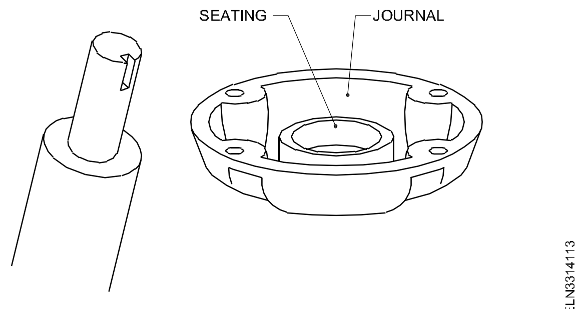
CYLINDRICAL ROLLER BEARING

- handle the bearings carefully to prevent damage
- keep the bearings wrapped until fitted, to keep out dirt
- protect the bearings against corrosion during storage, e.g. steel bearings must be oiled.

Installing bearings : Before any bearing is fitted:

- clean the journal or housing thoroughly and the seatings of the locating devices. (Fig 3)

Fig 3



- inspect the surfaces for damage; do not fit the bearings to damaged surfaces.
- Then coat the journal or housing with clean, light oil.

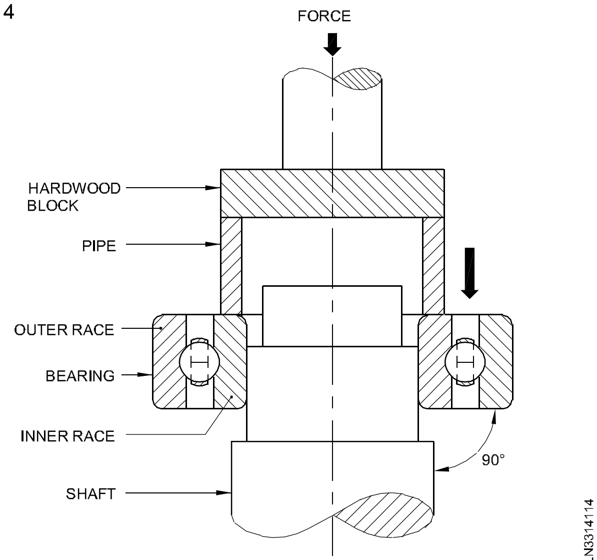
Take care to keep the oil clear of slip rings, brushes and the control gear of a motor.

While fitting the bearings to the shaft sufficient force has to be applied on the bearing. During the process to avoid damage to the bearings follow the procedure given below.

a) Force through arbor press.

Apply force through an arbor press to the inner race which is in contact with the housing as shown in Fig 4 by using a pipe and solid block of wood.

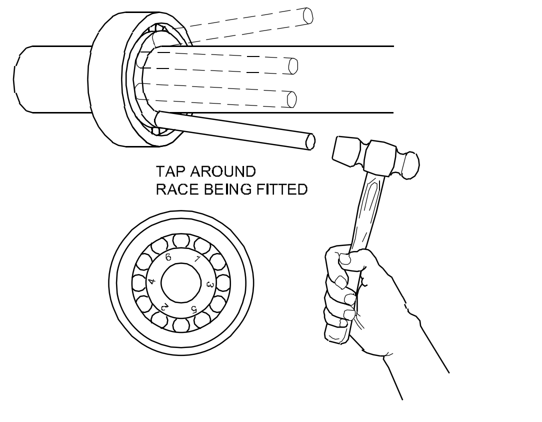
Fig 4



This is the best method, since the bearing can more easily be kept square to its seating.

b) Tapping bearings into place using a drift. (Fig 5)

Fig 5



Bearings should only be tapped into place when they cannot be pressed into position. Decide which is the most appropriate method.

Tap evenly around the race being fitted. Take care to keep the bearing square to seating. The method is useful when the seating is in an awkward situation. Take care to prevent foreign matter from entering the bearing.

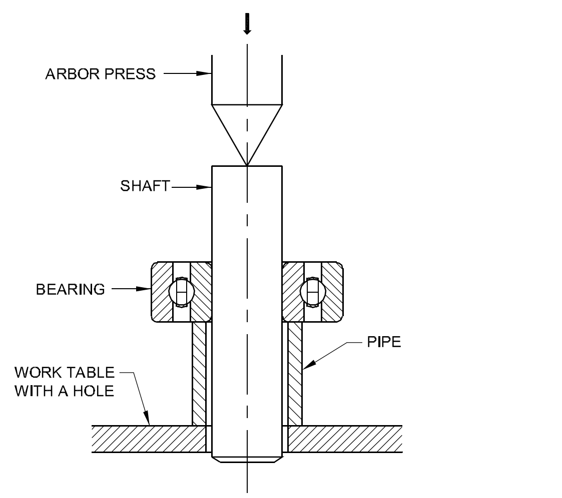
Tap the bearing home gently, stopping frequently to check that it is square.

Bearing removal techniques

a) Using an arbor press. (Fig 6)

Decide which is the best way to set the job up on the press. Apply the force evenly to remove the bearing.

Fig 6

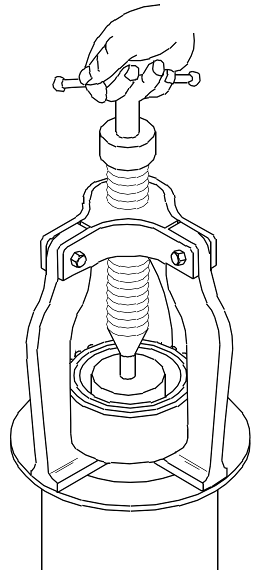


b) Using bearing puller. (Fig 7)

When using bearing pullers take care to keep the bearing square to the shaft. Screw-pullers are suitable for most purposes; take care to keep the puller square when turning the screw.

Locating faults in bearings : For checking any bearing, it should be cleaned well.

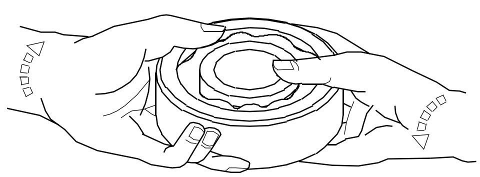
Fig 7



Ball bearings : Normally the ball bearings cannot be readily dismantled for close examination.

Wear : Check the wear of the ball bearing by holding the inner ring between the thumb and fore finger of one hand and holding the outer ring with the other hand . Holding the ball bearing twist the rings to and fro as indicated in Fig 8.

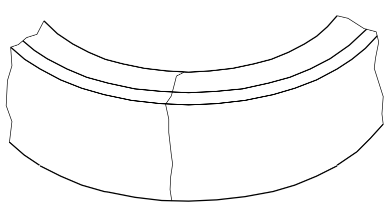
Fig 8



Any sign of movement indicates wear and the bearing needs to be replaced with a ball bearing of the same specification.

Break : Check the bearing for broken inner and outer rings which also indicate poor fitting, excessive load or wrong choice of bearing. (Fig 9)

Fig 9

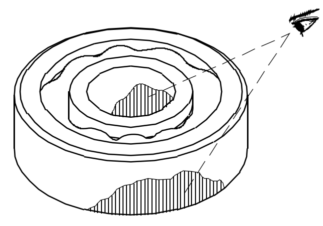


BROKEN RACES

Stains : Check the inner bore and the outer surface for the characteristic brown and black stains on a generally smooth and bright surface. (Fig 10) These marks indicate that movement has been taking place between the bearing, shaft and the housing due to poor fitting.

Roller bearing : After cleaning the bearing remove the inner ring and roller assembly from the outer ring.

Fig 10

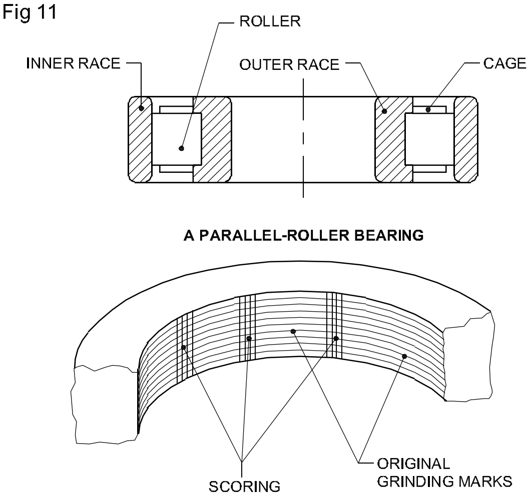


STAINS IN FITTING SURFACES

Check the inner surface of the outer ring. The surface should be smooth and polished with no regular marks of roughness or indentations.

The presence of score marks across the track at intervals corresponding to the pitch of the rollers as shown in Fig 11 indicates faulty initial fitting.

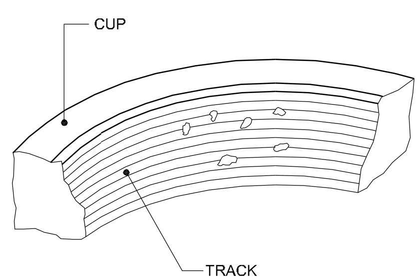
Fig 11



These roller bearings with score mark indicate excessive wear and produce noise.

Rough patches on the track as shown in Fig 12 indicate the wear caused by out-of-balance vibration or fatigue effects. The hard surface flakes off.

Fig 12



Check the general wear of the bearing by using both the hands as described for ball bearings.General wear sometimes causes a loss of brightness of the track, the shine being replaced by a dull surface.

Heavy general wear may produce a distinct groove around the track.

Static electrical discharges may also cause blackened surface pitting of bearing on certain machines. Where this is suspected check the rotor earthing arrangements.

General pitting may be due to rusting caused by inadequate lubrication or damp service conditions.

Examine the cage rings for signs of wear somewhere around the inner circumference. Localized wear of a brass ring may be accompanied by a brassy discolouration of the track, as the minute particles of brass are ground into the surface.

A worn out ring indicates a worn out bearing. Replace it.

Lubrication : Many a time it is detected that the mechanical faults found in the motor is due to imperfect lubrication. A thorough knowledge about lubricatioin is required for the service technician. Most of the motor manufacturers recommend a certain type and grade of lubricant for efficient operation of the motor. It is recommended that the same type and grade should be used to get optimum efficiency of the motor and the specified grade of lubricant should be painted on the motors for guidance.

There are several methods of lubricating motors. Small motors with sleeve bearings have oil holes with spring covers. These motors should be oiled periodically with a good grade of mineral oil as recommended by the manufacturer.

The bearings of larger motors often are provided with an oil ring which fits loosely in a slot in the bearing. The oil ring picks up the oil from a reservoir located directly under the ring. Under normal operating conditions, the oil should be replaced in the motor at least once a year. More frequent oil replacement may be necessary in motors operating under adverse conditions. In all cases, avoid excessive oiling; insufficient oil can ruin a bearing but excessive oil can cause deterioration of the insulation of a winding.

Many motors are lubricated with grease. Periodic replacement of the grease is recommended. In general, the grease should be replaced whenever a general overhaul is indicated, or sooner if the motor is operated under severe operating conditions.

Grease can be removed by using a light mineral oil heated to 165°F or a solvent. Any grease-removing solvent should be used in a well-ventilated work area.

Bearing troubles and the possible remedies are given in Chart 5.The following Do’s and Don’ts instruction is pertaining to ball-bearing. Follow it for avoiding bearing problems.

Do ‘s and Don’ts for ball-bearing assembly, maintenance, inspection and lubrication

Do’s	Don’ts
Do work with clean tools, in clean surroundings.	Don’t work under the handicap of poor tools, rough bench, or dirty surroundings.
Do remove all outside dirt from housing before exposing the bearing.	Don’t use dirty, brittle or chipped tools.
Do treat an used bearing as carefully as a new one.	Don’t handle bearings with dirty, moist hands.
Do use clean solvents and flushing oils.	Don’t spin uncleaned bearing.
Do lay bearings out on clean paper.	Don’t spin any bearings with compressed air.
Do protect disassembled bearings from dirt and rinse of moisture.	Don’t use the same container for cleaning the of bearings.
Do use clean, lint-free rags to wipe the bearings.	Don’t scratch or nick bearing surfaces.
Do keep the bearing lubricants clean when applying and cover containers when not in use.	Don’t remove grease or oil from new bearings.
Do clean outside of housing before replacing bearings.	Don’t use incorrect kind or amount of lubricant.
Do keep bearing lubricants clean when applying and cover containers when not in use.	Don’t use a bearing as a gauge to check either the housing bore or the shaft fit.
Be sure the shaft size is within specified tolerances recommended for the bearing.	Don’t install a bearing on a shaft that shows excessive wear.
Do store the bearing in original unopened cartons	Don’t open the carton until bearing is ready to replace. in dry for installation.
Do use a clean, short-bristle brush with firmly embedded bristles to remove dirt, scale or chips.	Don’t judge the condition of a bearing until after it has been cleaned.
Be certain that, when installed, the bearing is square with and held firmly against the shaft shoulder.	Don’t pound directly on a bearing or ring, when instal-ling,as this may cause damage to the shaft and bearing.

Do's	Don'ts
Do follow lubricating instructions supplied with the machinery. Use only grease where grease is specified. Use only oil where oil is specified. Be sure to use the exact kind of lubricant called for.	Don't overfill when lubricating. Excess greases and oil will ooze out of the over-filled housings past seals and closures, collect dirt and cause trouble. Too much lubricant will also cause over heating, particularly where bearings operate at high speeds.
Do handle grease with clean paddles or grease guns. Store grease in clean containers. Keep the grease containers covered.	Don't permit any machine to stand inoperative for months without running it over periodically. This prevents moisture which may condense in a standing bearing from causing corrosion.

In addition to the bearing faults the motor may develop certain troubles like vibration and noise which may be due to electrical or machancial faults.

Troubleshooting Chart 6 given here illustrates the possible causes, areas of fault and remedies for the faults like vibration and noise.

Chart 6

Vibration and noise in motors

S.No.	Cause	Test	Remedy
1	Loose foundation bolts or nuts.	Inspect nuts and bolts of foundation for loose fittings.	Tighten the foundation nuts.
2	Wrong alignment of coupling.	Check alignment with a spirit level through dial test indicator.	Realign the coupling.
3	Faulty magnetic circuit of stator or rotor.	Measure the current in each phase and they should be equal. Check also per-phase resistance and they should be equal. Check the insulation resistance between the windings and the frame. In a newly wound motor there may be reversed coils in a pole-phase group which can be detected by the compass test.	Repair fault if possible or rewind the motor.
4	Motor running on single phase.	Stop the motor, then try to start. (It will not start on single phase). Check for open in one of the lines or circuits.	Rectify the supply.
5	Noisy ball bearing.	Check the lubrication for correct grade and low noise in the bearing.	If found, replace the lubricant or replace the bearing.
6	Loose punching or loose rotor on shaft.	Check the parts visually.	Tighten all the holding bolts.
7	Rotor rubbing on the stator.	Check for rubbing marks on the stator and rotor.	If found, realign the shaft to centre it or replace the bearings.
8	Improper fitting of end-covers.	Measure the air gap at four different points for uneven position of rotor covers.	Open the screws of the side covers, and then tighten one by one. If trouble still persists, remove the end cover, shift for next position and tighten the screws again.
9	Foreign material in air-gap.	Examine the air-gap.	File or clean out air-gap.
10	Loose fan or bearings.	Check looseness of the fan screw or bearings.	Tighten the fan screws or refit new bearings, if necessary.
11	Slackness in bearing on shaft or in housing.	Remove the bearings and inspect the inner looseness of the race on the shaft and outer race in the housing.	Send the motor to the repair shop for removing the looseness of the shaft and housing, if any.

S.No.	Cause	Test	Remedy
12	Improper fitting of bearings.	Remove the end-covers and examine the assembly of bearings on the shaft or in the housing.	Refit the bearings on the shaft or in the housing.
13	Minor bend in shaft.	Check for alignment on the lathe.	Remove the bend or replace the shaft, if required.

Troubleshooting of motor starters

Objectives : At the end of this lesson you shall be able to
- **state the troubles in the D.O.L. starter, their cause and their remedy**
- **check out the troubles in the mini manual starter, their cause and their remedy.**

Introduction : The D.O.L. starter consists of the fixed contacts, movable contacts, no-volt coil, overload relay and start button which is in green colour and a stop button in red colour with a locking arrangement. Analyse the D.O.L. starter available in the workshop. The main purpose of the contactor is to make and break the motor circuit. These contacts in the contactor suffer maximum wear, due to frequent use and hence these contacts are made of silver alloy material.

A no-volt coil acts as under-voltage release mechanism disconnecting supply to the motor when the supply voltage fails or is lower than the stipulated value. Thus the motor will be disconnected from supply under these conditions. The no-volt coil magnetic system consists of a laminated iron core for minimising the eddy current and hysterisis losses. Shading rings are provided on the pole faces of the magnetic core to reduce the hum level and chattering which is present due to A.C. supply.

A thermal overload relay unit is provided for the protection of the motor. This unit consists of a triple pole, bimetallic relay housed in a sealed bimetallic enclosure. This is provided with a current setting arrangement. After tripping on overload, the relay has to be reset by pressing the stop button. The relay can be reset only after bimetalic strips get cooled sufficiently.

In case the motor does not start even though the start button is pressed, observe whether the stop button is locked with a metallic locking piece provided near the stop button. Release it and press the start button, then observe the functioning of the motor. Even then if the motor does not start check up the 3 phase supply. If the supply is found available at the incoming terminals of the starter, then switch off the supply and rectify the defect in the starter.

Suppose the three phase supply is available and starter NVC is energising but the motor does not start, check for any foreign material in between the contact points. Remove it and test the starter again. Visually observe whether the contacts are closing properly.

If any contact is not closing properly or any burns and pittings are noticed on the contact surface, then remove the contact strips. Dress up properly with zero number sandpaper or with a smooth file or replace it if necessary. Some manufacturers suggest that the contact points made out of silver alloy need to be cleaned with cloth only. It needs no filing or sandpaper rubbing. However, unless the contacts are found to have too much pittings, the filing or dressing with sandpaper is not recommended. Further badly shaped or disfigured contacts need to be replaced with a good ones. See that there is proper spring tension over the contacts. Likewise check all the contact strips of the contactor and clean them with an approved contact cleaner.

When the no-volt coil is activated by the start button, the auxiliary contact of the starter should close to complete the NVC circuit and should remain in the closed position even after the start button is released.

If the overload relay is not functioning properly i.e. not tripping the motor as per setting of the current rating, then replace it with a new one as per with the original specification of the manufacturer.

If a humming and chattering noise is observed in the starter then check for the rated voltage. If the voltage is okay, then check for any gummy material adhered to the pole faces. If found, clean it properly. See whether the shading ring over the pole faces of the NVC is loose. Tighten it properly and also check the spring tension of NVC housing.

Suppose the starter trips often then, check up the load on the motor. (Might be due to overload or over tension of the belt) Reduce the load or tension of the belt. Further check up the motor current in each phase. If the motor takes higher current than specified even though the load is normal, then the fault is with the motor and not with the starter. After attending to the faults and rectifying them, reassemble the starter,connect it to the motor for proper functioning.

Starter check - chart given below could be used to locate trouble in a D.O.L. starter.

Maintenance of DOL starters

Trouble	Cause	Remedy
I Starter check chart		
1 Contacts chatter	Low voltage, coil is not picking up properly. Broken pole shading ring. Poor contact between the pole faces of the magnet. Poor contact between fixed and movable contacts.	Correct the voltage condition. In case there is persistent low voltage, check the supply of the transformer tapping. Replace. Clean the pole faces. Clean contacts and adjust, if necessary.
2 Welding or overheating.	Low voltage preventing magnet from sealing. Abnormal in rush current. Short circuit in the motor. Foreign matter preventing contacts from closing. Rapid inching.	Correct the voltage condition. In case of persistent low voltage, which is accepted normal change the NVC to lower voltage coil. Check excessive load current or use larger contactor. Remove the fault and check to ensure that the fuse rating is correct. Clean contacts with suitable solvent. Install larger device or caution the operator not to operate the inch button too quickly.
3 Short life of contact points	Weak contact pressure.	Adjust or replace contact springs.
4 Noisy magnets	Broken shading coil. Magnet faces not mating. Dirt or rust on magnet faces.	Replace magnet. Align or replace magnet assembly. Clean with suitable solvents.
5 Failure to pick up and seal the contacts.	Low voltage. Coil open or short-circuited. Mechanical obstruction for the moving parts.	Check system voltage. In case persistent low voltage, change to a lower voltage coil. Replace the coil. Clean and check for free movement of contact assembly.
6 Failure of moving mechanism to drop out.	Voltage not removed. Worn or rusted parts causing binding.Residual magnetism due to lack of air gap in magnet path. Gummy substance on pole faces causing binding.	Check wiring in the NVC coil circuit. Replace parts. Replace worn out magnet parts or demagnetise the parts. Clean with suitable solvent.
7 Overheating of coil	Over-voltage. Short circuited turns in coils caused by mechanical damage or corrosion. High ambient temperature. Dirt or rust on pole faces increasing the air gap.	Check and correct terminal voltage. Replace coil. Relocate starter in a more suitable area or use a fan. Clean pole faces.
II Overload relays/ release		
1 Starter is tripping often. Sustained overload.	Incorrect setting of over load relay.	Reset properly. Check for faults/excessive motor currents.
2 Failure to trip (causing motor burn out).	Wrong setting of O.L relay. Mechanical binding due to dirt, corrosion etc.	Check O.L relay ratings and set a proper relay. Clean or replace. Incorrect control wiring. Check the circuit and correct it.

Trouble	Cause	Remedy
III Fuses		
1 Constant blowing of fuses	Short circuit or poor insulation in winding/wiring.	Check the motor and the circuit for insulation resistance.
2 Fuse not blowing under short circuit condition.	Fuse rating too high.	Replace with suitable fuse.
3 Fuse blowing off frequently.	Fuse rating too low. Overloading of feeder.	Replace with suitable fuse. Check for over-current, leakage and short circuit.

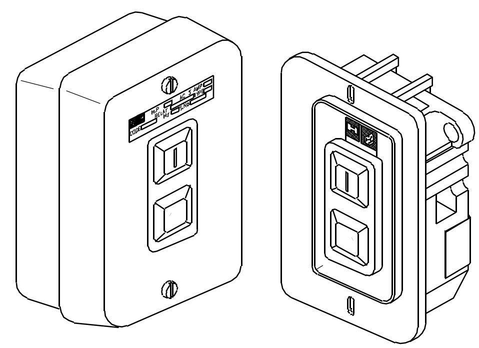
Mini Manual Starter (Refer Fig 1)**:** This starter unit comprises of a double brake 3-pole on load switch operated by means of a toggle mechanism. Adjustable bimetal thermal overload strips are included in it which can be set for the correct load current of the motor.

The stop push-button and overload trips act on the toggle switch mechanism to trip the starter.

The fixed contacts are formed of silver tips on heavy terminal blocks with clamp type terminals. The moving contacts are of copper with silver coating.

In general the manual starters are possessing the toggle switch anchor mechanism. Due to frequent use, the spring tension becomes weak and it will not hold the contacts in the closed position. In such case the lever mechanism should be replaced? If the starter trips often check up the overload thermal strips. If they are defective replace them.

Fig 1



MINI MANUAL STARTER

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