* Classification of Insulating Materials as per I.S. 8504(Part III) 1994

Different insulating materials used in electrical equipments are classified on basis of their thermal stability. The max. operating temp for each class of insulating material is given assuming max. ambient temp of 40°C.

No.	Class	Insulating materials	Uses	Max. operating temp 0°C
1	Y/O	Cotton, Silk, papes vulconized fibess, wood, PVC, VCR etc	Always used with impregnation	90°C
2	A	Cotton, Silk, Papes press, vulcanized fiber wood etc impregnated dielectric oil or varnish also some type of wire enamel.	Leatheroid papes as slot insw cotton covered wires impregnated in shellac varnish slot, wedges	105°C
3	E	Leatheroid papes, polyvinyl acetyl (PVA) enamel for super enamded cond., epoxy resins, cotton fabrics & paper laminates mouldings with cellulose fiber	slot insw, wdg wires insw, insulating moulding with epoxy resin in case of class C.T. etc	120°C
4	B	Glass fibes, asbestos, mica built-up mica, glass fiber, mica laminates etc. with bonding substances like shellac, bitu-minous compounds, epoxy resins	slot liners, phase separators etc insulating tape, binding cord etc etc polyster enamel Cond.	130°C
5	F	Glass fibes, asbestos, mica, varnished glass, fibes textile, built up mica etc with bonding substance like epoxy & silicon alkyl resins.	slot liners, separators, tapes cords etc. polyesterimide enamel or fibes glass braided impregnated with polyurethane wires for coils	155°C

No	class	Insulating materials	Uses	Max operating temp 0°C
6	H	Same material as for class with suitable binding materials i.e. Silicon based glass fabric flexible micanite with suitable resins of polymide films. Glass fabric tape or cord with silicon elastomer cover.	slot liners, insul^n tapes, separators, cond. insul^n, cord for binding sleeves etc	180°C
7	C	Mica, porcelain, ceramics, glass, quartz, asbestos, treated asbestos with inorganic binders such as glass or cement & silicon resins, slate, marble	Same as class H, also insulating materials in forms etc.	Above 180°C

* Factors affecting life of insulating materials :-

1. Temperature :-

The insul^n resi. decreases with temp. The dielectric loss increases with temp. The resistivity of insulating material decreases by increase in temp. The same can be expressed as -

$R_t = R_0 (1 + \alpha_0 t)$

$\rho_t = \rho_0 (1 + \alpha_0 t)$

Where, R_t = Resi. of material at t°C.

R_0 = —— 11 —— 0°C

α_0 = Resi. temp. coeff. at 0°C

ρ_t = Specific resi. at t°C

ρ_0 = —— 11 —— 0°C

2. Absorption of Moisture :-

The absorption of moisture by insulating material decrease it's surface resi. & causes insul^n failure or breakdown when they are exposed to atmosphere. The moisture affects mechanical strength of insulating material.

3. Mechanical Stresses :-

Mechanical stresses are developed in the material due to electromechanical forces, stresses during running cond^n, which is true for rotating electrical machines. It develops very small cracks in the insulating material. Hence reduces the life of insulating material.

4. Thermal Stresses :-

The heat is produced in the insulating material due to dielectric loss, Cu loss in the cond. Heat produced by Cu loss in the cond. is absorbed by nearby insulating material. If sufficient & proper ventilation & cooling is not provided, then insulating material looses it's thermal stability which reduces life of insulating material. Thermal stability means, the heat developed on insulating material should be equal to heat thrown out by insulating material.

5. Electrical Stresses :-

During lightening heavy impulse surge vtgs come across the insulating materials, even switching produces vtg surges. Such transient vtg, when greater than breakdown vtg. of insulating material, punctures or breaks insulating material & insulating material insulating property.

6 Deposition of dust, dirt, oil :-

The surrounding atmosphere contains dust, dirt particles. These are accumulated over the electrical m/c & the dirt, dust reduces the insul^n resi. Thus, the insul^n becomes weak.

7. Impurities :-

Impurities present in insulating material reduces the insul^n resi. as well as the dielectric strength.

* Measurement of Insulation Resistance :-

1) Insulation Resistance Meter (Megger) :-

- Megger is a device which directly indicate the value of insulating material.
- To make a insulation resistance test, disconnect the equipment from supply, & then connect the terminals of megger to the winding and frame & move the handle of generator at normal speed, pointer will moves over the scale to indicate the value of insulation resistance.
- When megger is operated the behaviour of pointer should be carefully observed, we can learn so many things from the movement of pointer.
- The leakage of current along the surface of dirty insulation is generally indicated by slight kicks down scale whereas response of pointer when testing good insulation is downward dip followed by gradual climb to true resistance value.
- Initial dip of the pointer towards zero is caused by capacitance of wdg mainly in large machines, cables & capacitors.

Note :- Draw ckt dig Here from drawing sheet No. 03 of Megger

- **Dielectric absorption Test by using megger :-**
  The insln resi. is measured at regular interval of 30 min. & recorded. Finally a graph is plotted by taking time on x-axis & megger reading in MΩ on y axis. From graph condn of insln is interpreted. Mostly used when previous record is not available.

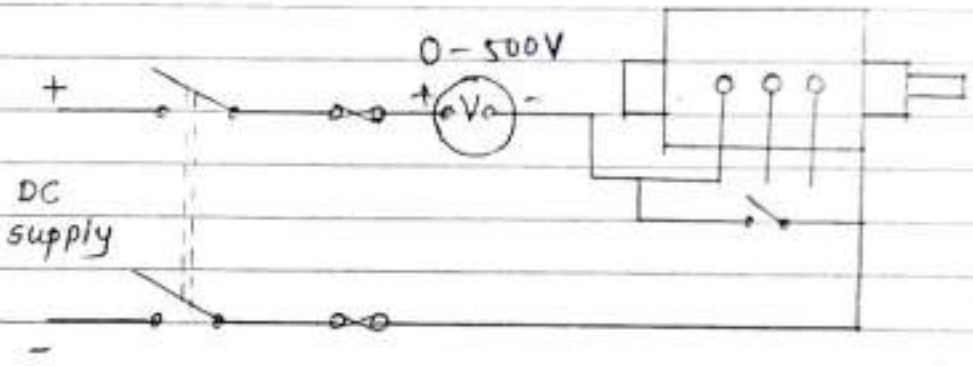
- Polarization index by megger :-

Polarization Index (PI) = $\frac{\text{Insul}^n \text{ resi after 10 min.}}{\text{Insul}^n \text{ resi after 1 min.}}$

PI should be greater than 1.5 for class-A insul^n
—— " —— 2 for class 'B' insul^n

2) Voltmeter Method :-

- This method can be used only when megger is not available. A high resi. dc voltmeter having range 500 to 600V may be used to determine the insulation resistance, provided that sensitivity of the meter is 100 ohm per volt.
- Fig. indicate the ckt connection for the test.



- Voltmeter indications are recorded with single pole switch closed and again with it open. The insulation resistance is calculated by using following relation

$$RI = \frac{R(V_1 - V_2)}{V_2}$$

where,

RI - insulation Resi.
R - resi. of voltmeter
V_1 - Voltmeter reading when switch is close.
V_2 - voltmeter reading when switch is open.

* Interpretation of Condition of insulation :-

From dielectric absorption test by using megger, the graph of insul^n resi. Verses time in min. is plotted as below -

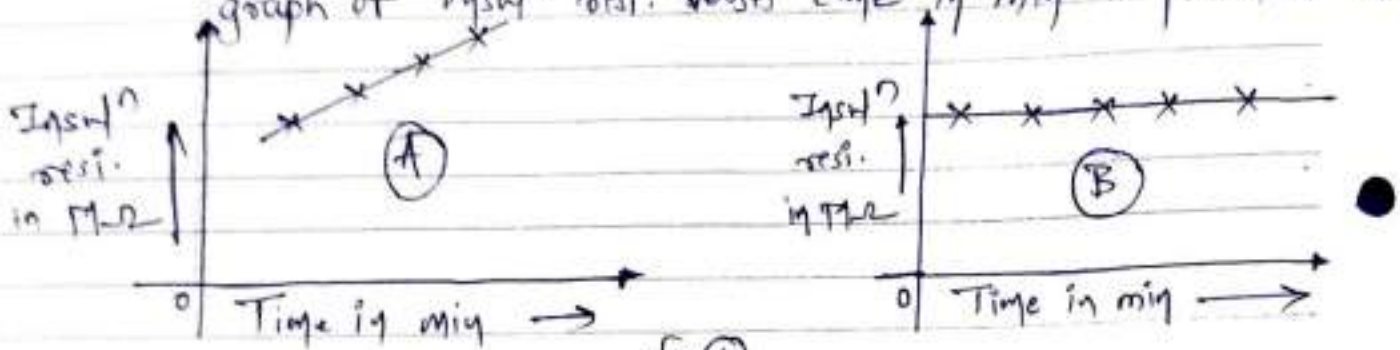


fig (1)

If the graph shows steady increase (A) in resi. then insul^n is clean & dry & if the graph shows steady line or const line (B), then the insul^n is dirty moist. Hence the insul^n should be cleaned & dried.

From polarization index method (for class A insul^n) if the polarization index is greater than 1.5 then the quality of insul^n good.

From readings of insul^n resi. measured by 500volt 2000volt megger separately, plot the graph of insul^n resi. Time in min.

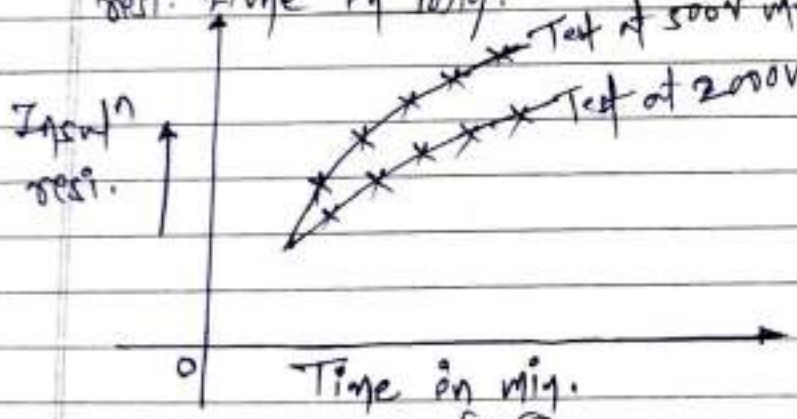


fig (2)

The wide spread of the curves indicate presence of moisture. Greater than 25% difference in resi. with the appl^n of 1 to 4 ratio of test Vtg. is reasonable indication of moisture.

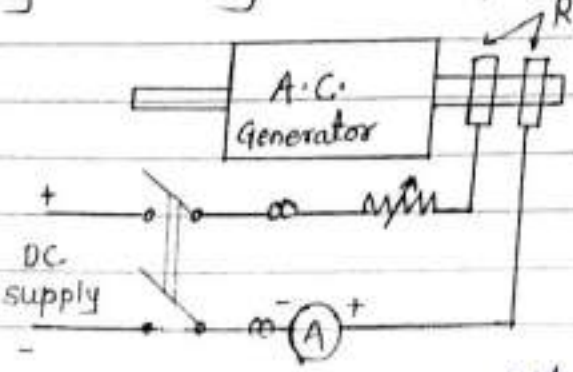
* Different Methods of Measuring Temperatures :-

1) Thermometer Method :-

- This method is mostly used for determining temp. of stator core, bearing, T/F top oil, T/F core etc.
- In this method, thermometer taped to the part of which temperature is to be recorded.
- In case of electrical machines through which current is flowing, mercury thermometer should not be used because its reading is affected. Hence in such cases alcohol bulb thermometers should be used.

2) Resistance Measurement Method :-

- This method of temp. determination may be used on almost any type of wdg.
- It is most suitable for measurement on cylindrical rotor of high speed alternators, because their external & internal temp vary to great extent.
- fig. shows connection for rotor temp. measurement test of an a.c. generator.
- In this method, resistance just before the test is calculated & when temp. becomes steady, the resi. is calculated by the ratio of V/I, then by using following relation,



$$t_2 = \frac{V_2 (234.5 + t_1)}{I_2 R_1} - 234.5$$

or $$t_2 = \frac{R_2 (234.5 + t_1)}{R_1} - 234.5$$

where,

R_1 - initial resi. value.

V_2 - voltmeter indication at the instant of temp. to be determined.

t_1 - reference cold temp.

t_2 - Internal temp. at which V_2 & I_2 are measured.

3) Embedded Detector Method :-

- This type of method is generally used in case of very large machines having rating above 1000 H.P.
- If this method is to be used, then at the time of manufactor of machine, thermo-couple is inserted below the coil & in the HT wdg at maxi. temp. spot.
- The induced emf is developed in the thermo-couple is calibrated directly to record the temp. of wdgs, which is recorded on dial of instrument.

* Correction to the Measured Value of Insulation Resistance :-(Applying correction factor when r.l.c is low):-

- Insulating material have a negative resistance temp. coefficient i.e. resi. of insulation decreases greatly with increase in temperature.
- Hence insulation resi. should be immediately carried out after the machine is stopped.
- If the insulation resistance measured at different temperature are to be compared to a common reference temp generally 75°C, correction factor is used either division or multiplication so that insulation resi at one common temperature can be compared.
- Multiplying or division factor is obtained from curves drawn for obtaining temp. resi. correction data. Following table give approximate correction factor for different values.

Temp °C	Divide by factor	Temp °C	Multiply by factor.
25	10	75	1
30	8	80	1.25
35	6.35	85	1.6
40	5	90	2
45	4	95	2.5
50	3.15	100	3.15
55	2.5	-	-
60	2	-	-
65	1.6	-	-
70	1.25	-	-

• From this if insulation resistance at 75°C is 1 MΩ its value should be 5 MΩ at 40°C if its value should be 0.5 MΩ at 90°C.

* Properties of good T/f oil :-

• Generally mineral oil grade-B is used for transformer and switch gears.

1) Viscosity :- Viscosity indicates fluidity, oil with lower viscosity has more fluidity and gives more cooling effect as it can pass through ~~very small aperature of~~ winding & take heat from it.

2) Insulation & dielectric strength :
The insulation of T/f oil is sufficiently high but dielectric strength greatly reduced by the presence of moisture. The dielectric strength should not be less than 30kV with 2.5 mm standard gap.

3) Flash point :- The temp. at which vapour above oil surface ignites spontaneously is termed as flash point. Its value should not be less than 160°C.

4) Fire point :- The temp. at which oil will ignite and continue burning should be about 200°C

5) Water Content :- The presence of water reduces dielectric strength of oil. Water content should not be more than 5ppm

6) Density :- As per IS the density at 20°c should equal to 0.89 gm/cm³.

7) Purity :- It should not contain impurities such as sulphur and its compounds. It will cause corrosion of metal parts & accelerate the formation of sludge.

8) Sludging :-
- Sludging means the slow formation of semi-solid hydrocarbons which may acidic in nature. They block the passage of cooling oil. This is due to heat and oxidation.
- If bright copper surfaces are exposed to oxygen, the process of sludging accelerates.
- By providing conservator tank contact of copper surface with oxygen is avoided.
- The limiting value is less than 0.1%.

9) Acidity :-
- oxidation of oil gives CO_2, volatile water, soluble organic acids & water.
- They are responsible for corroding iron & other metals. Hence presence of air and water can be reduced by providing conservator tank and breathers.
- The limiting value of acidity after oxidation is 0.4 mg of KOH/g.

* When filtered oil is filled in T/F tank, then.
i) Water contained should not be more than-5 ppm
ii) Acidity neutralization value - 0.03 mg KOH/g.
iii) Loss tangent at working temp - 0.005
iv) Density at 20°C - 0.89 g/cm³.

C.C - Cubic centimeter.

$1g/cm^3$

* Test on insulating oil

1) Acidity Test :- In this test, 10 gm of sample oil is taken in a 250 c.c. conical flask. Then in another flask 50 c.c. of alcohol is taken and 1 C.C. of phenolphthalein solution is added. This combination is heated to 40-50°c and neutralised with a solution of KOH. This neutralised alcohol is added to the oil sample taken in the first flask. This sample is heated to boiling point & boiled at least 5 min. 1 C.C. of phenolphthalein is added & cooled 40-50°c & titrated quickly with KOH solution then acidity or no. of mg of KOH required to neutralize the acidity of 1 gm of sample is 50-1 NV/W

KOH - Potassium hydroxide

where,

V - volume of KOH solution in mm^3

N - Normality of KOH solution

W - Weight of sample in gm.

2) Flash point Test :-

- In this test, T/f oil is continuously heated till a point is reached at which vapour formed on surface of oil fires spontaneously. The temp of oil at this point is noted, it should not be less than 130°c to 140°c

3) Crackle Test:- The aim of this test is to determine presence of water or moisture in the oil.

- In this test, oil sample is taken in test tube and heated on gas burner if water or moisture is present in the oil crackling sound is heard; when oil get heated up.
- Another method is that sample oil is taken in glass beaker of 250 ml & iron rod of 12.5 or 15 mm size is heated to red hot & plugged into oil under test, if a crackling noise is heard, it indicate presence of moisture in oil.

4) Sludge test:- One of the test carried out to determine rate at which sludge is form at 120°C under definite condition of oxidation is known as sludge accumulation test. Copper can be used as catalyst to shorten the time of test. It takes 30 to 40 days in normal course, Copper reduces to 14 days.

→ List the agents which contaminates insulating oil:-

i) Water
ii) Dirt / dust
iii) Carbon deposits
iv) Sulphur
v) Acids
vi) Gases
vii) Alcohols
viii) Grease
ix) Acetones & aldehydes
x) Ketons
xi) Presence of sludge which is mainly an oxidation product, whose formation is accelerated by temp. & contact with air.

* Protection of Electrical Equipments during the period of Inactivity :-

- When electrical equipments are kept idle or inactive for long period, insulation absorb the moisture. Moisture will condense with faster rate if temp. of machine falls below dew point.
- It reduces the dielectric strength of insulation Hence temp. inside the machines is to be kept few degree higher than ambient temp. so that condensation will not takes place.
- It can be achieved by using space heaters or placing electric lamps in the housing of machines.
- The motors and generators are used on ship-boards consisting of built in heaters for above purpose. If the machine is to be left ideal for a long period produces flat spots on metal surface, pitting the commutator. So that brushes should be raised off the commutator.
- Placing electric lamp in the housing of machines to provide heat.
- Cover the m/c with water proof cloth during inactivity.
- The brushes should be raised off the commutator & slip rings which prevents electrolysis bet? them & pitting commutator or producing flat spots on metal surface.
- Pour insul? into wdg. if required.
- Run the m/c during period of inactivity even if not required.

* Methods of cleaning the insulation :

1) Removal of Loose Dust :- The loose dust which is accumulated on the surface of windings, in the ventilating duct etc. can be removed by application of a compressed air at about 2·1 to 2·8 kg/cm^2 from a portable vacuum cleaner. The operator should use safety goggle & dust mask so that he can work close to the job.

2) Sticky Dirt :- Encrusted or sticky dirt which blocks mainly the ventilating ducts can be removed carefully with a hard wood or fibre scaper. A metal scaper may damage the insulation hence should not be used.

3) Oily Viscous Film :- The oily viscous should be wiped down with a piece of cheese cloth or lintless rag dampened with a approved petroleum solvent. Excessive use of solvents will damage the protective covering provided by insulating varnish. Only that much solvent should be used which will remove the oily scum. Then wipe dry with a clean cloth.

Spraying the solvent through a automiser held close to the work is an excellent way of loosing and removing the grime from hard to get at places. Though carbon tetrachloride is excellent cleaning agent, its use should be avoided because it is very toxic.

Prob No: 15, 17, 23, 46, 47, 35

* Drying Electrical Insulation :-

a) External Heat :-

i) Baking in oven :- The most popular method of drying insulation is through the application of external heat. It is conviniently carried by placing the equipment in baking oven in which const. temp. can be maintained with the help of thermostat control

ii) By using boilers :- Small machines are often successfully dried by placing them on the top of a boiler. When external heat is used for baking or drying, it is to be observed that temp. of winding as measured by thermometer attached to coils should not exceed 90°C.

iii) By electric lamps/heaters :- Sometimes electrical heaters arranged surrounding the machine or radiant heat lamped can also be used to heat the varnish. Sometimes heat of 200W, 500W lamp is used to dry insul. The drying takes place through radiation of heat.

b) Internal heat :-

The insul^n of wdg. can be dried with help of heat produced in wdg., by I^2R loss. The D.C. Vtg. can be obtained with the help of rectifier. Low D.C. current is passed through field wdg. & armature is short ckted. For Induction motor apply reduced Vtg to stator & block rotor such that rated current will pass through stator. The Cu losses are converted into heat, which is used to dry the insul^n. Even for TIF secondary is short ckted reduced Vtg is applied to primary. The Cu losses (I^2R) are used to heat the winding.

* Revarnishing Insulation :-

- Varnishing of insulation is carried out by following way :-

a) By brush using air drying varnish.
b) By spraying method using air drying varnish.
c) Hot-dip method using baking varnish.
d) Vacuum impregnation using baking varnish.

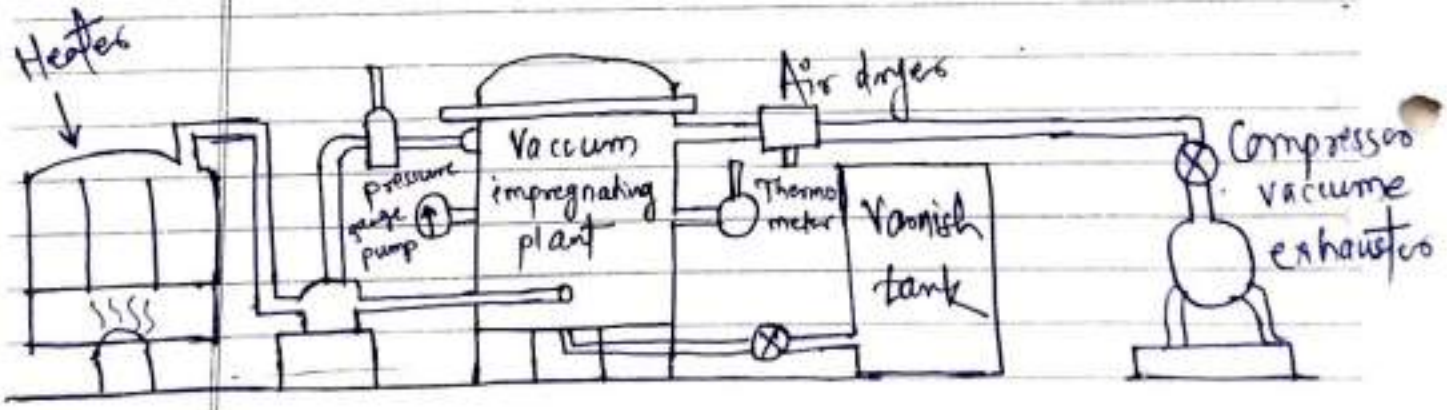
- Out of these @ and ⓑ are methods which are used in small repair shops carrying out rewinding of armatures & stator or rotor etc. They are very simple, cheap and are carried out when baking oven is not available. They will not give good result as compared with © & ⓓ. As @ & ⓑ are very simple so not discussed in detail.

c) Hot - Dip Method :-

- In this method, the wound armature, stator or rotor etc. are first heated in baking oven at about 100°c for atleast one hour so that any moisture present in it will be get evaporated.
- It is then completely immersed in a varnish tank and kept in immersed condition for at least $\frac{1}{2}$ an hour so that any varnish will get filled in all air pockets in winding and slots etc. It is then taken out and kept on iron grill for some the time so that excess varnish get drained out. It is kept in a baking oven at a temp. of 100 to 110°c for about four to eight hours so that the varnish will become bone dry.

d) Vacuum Impregnation :-

- It is carried out in a vacuum impregnating plant which consist of a double jacketed vacuum impregnated chamber which has a removable top cover.
- The chamber can be heated by circulating steam or hot oil through jacket. There is a chamber for storing the baking type of varnish.
- A compressor cum vacuum exhauster which can create a desired pressure or vacuum by using proper valves is connected to chamber.



- First ~~the~~ wound armature, stator or rotor is placed in the chamber by operating the top covers. Then it is tightly closed. The chamber is then heated upto 100°C by circulating steam or hot oil through jacket of chamber & temp. is maintained for nearly four hours.

DATE / /

- During this period, air from the chamber is pumped out by vacuum exhauster and vacuum is maintained which will help in vapourising the moisture present in the coils and removing the same completely.
- Then insulating varnish from varnish tank is allowed to flow into the chamber till the varnish in the chamber comes ~~eon~~ upto a level in which windings are completely immersed.
- Then the valve of varnish tank is closed and a pressure from compressor about 1·4 to 2·1 kg/cm^2 is applied above varnish surface, which will make the varnish to be forced in all the porous (air packets etc) spaces in the interior of coils
- The pressure is maintained for an hour and valve of varnish tank opened and varnish is made to flow back to the tank under air pressure till excess varnish also gets drained out.
- The valve is then closed and armature is then boked in the chamber at 100 to 110°c for nearly 8 hours till varnish is completely dried out till it becomes bone dry.
- The air pressure and circulating steam or oil in the jacket is then stopped and armature or stator is then removed by opening the top cover.