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Internal Assessment Test 1 –SEP 2016

Sub:	Testing and Commissioning of Electrical Equipments							Code:	10EE756
Date:	07-09-2016	Duration:	90 mins	Max Marks:	50	Sem:	7	Branch:	EEE

Note: **Answer any five full questions. Sketch figures wherever necessary.**

1. a)Enumerate standards and specification of power transformer [5M]
   b) Explain the working of buchholz relay. [5M]
2. Explain the procedure of drying of power transformer. [10M]
3. Explain various commissioning test conducted on transformer. [10M]
4. Explain the civil work associated with power transformer [10M]
5. State various types of test performed on HV circuit breaker [10M]
6. Explain the standards and specification of circuit breaker [10M]
7. Explain the working of metal clad switchgear with neat sketch [10M]

1 a. What are the standard specifications of power transformers? (10 Marks)

TRANSFORMER RATINGS

Q. 532. State the various essential Rated Quantities of a Power Transformer.

Rated Quantities. These include :

- — Rated voltages of each winding
- — Rated insulation level of each windings
- — Rated frequency
- — Rated apparent power (kVA or MVA)
- — Rated current of each winding
- — Rated short circuit withstand ability
- — Impedance voltage
- — Rated voltage ratio, etc.
- — Bushing and Tap-changers have respective ratings.

Q. 533. What is the significance of 'Standards' ? What is a typical coverage of a standard for Power Transformer.

Standard Specifications for Power Transformers. The international standards published by IEC (International Electrotechnical Commission) are accepted universally. However, each Nation has its own National Standards which are based on particular requirements and practices of that nation. Indian Standards Institution (Indian Bureau of Standards) publishes IS Standards. The Manufacturers and Users in India recognise IS Standards and IEC Standards.

The standards for *Power Transformers* are applicable to three phase transformers rated above 5 kVA. The *Special Transformers* and transformers below 5 kVA are covered by separate standards.

A *typical standard* on power transformer covers the following data :

- — Service conditions
- — Definitions
- — Ratings
- — Tappings
- — Cooling system identification
- — Limits of Temperature Rise
- — Ability to withstand short-circuits and corresponding tests for short-circuit withstand ability.
- — Information to be given on the Rating Plate and Diagram Plate.
- — Terminal Markings
- — Vector Diagrams, Connection, Method of connections, procedure and interpretation
- — Tolerances
- — *Tests.* Acceptance tests, type tests, routine tests, special tests.
- — Fitments
- — Insulation Levels
- — Information for Tenders
- — Practice for Maintenance

The standards are published in several parts. They are revised/amended at times.

b. Explain the procurement procedure of transformer.

◆ 2.3 Procurement of induction motor

Information to be given with enquiry and order: IS 325-1978.

When enquiring for and placing an order for induction motor the following particulars should be supplied.

1) Site and operating conditions
2) Reference to this standard i.e. IS code number
3) Type of enclosure
4) Type of duty
5) Method of cooling
6) Type of construction
7) Frequency in Hz
8) No. of phases
9) Mechanical output in KW
10) Rated voltage and permitted variation
11) Class of insulation
12) Speed in revolutions per minute, approximate at the rated output
13) Direction of rotation, looking from the driving end.
14) Uni or bidirection of rotation required.
15) The maximum temperature of air and water used for cooling.
16) Maximum permissible temperature rise
17) The height at which the motor is intended to work
18) Variation of voltage, current, frequency and speed
19) Particulars of tests required and where the tests are to be carried out

20) Any information regarding the associated machine.
21) Rotor, squirrel cage or slip ring
22) System of earthing if any, to be adopted
23) Details of shaft extension required
24) Methods of starting employed
25) Breakaway torque
26) Nature of load
27) For hv motors, fault capacity, duration of fault along with the details of protective devices.
28) Methods of drive
29) Any specific requirements

The induction motor can be purchased by proper procedure. Once the quotations are received from different manufacturers, a comparative statement is to be prepared. A request can be made to the manufacturers to supply the list of users. Before finalizing the quotations, feed back about the performance of the equipment and service after sales can be had from the users. Based on the parameters, performance, provisions, brand name an order can be placed to the company. The induction motor is dispatched to the site by the manufacture with a suitable packing. On arrival at the site, is to be inspected in presence of representative of supplier for damages in transit. The machine is stored preferably indoor in case of delayed installation. At the time of installation necessary preparations are to be done before energizing the motor.

◆ 2.4 Rating plate of induction motor

Rating plate giving the following details should be supplied with each motor

- Reference to the standard i.e. Ref. IS: 325
- Induction motor
- Name of the manufacturer
- Manufacturer's number and frame reference

- Type of duty
- Class of insulation
- Frequency in Hz
- Number of phases
- Speed in rpm
- Rated output in KW
- Rated voltage and winding connections
- Current in amperes at rated output
- Rotor (secondary) voltage and winding connections
- Rotor (secondary) current in amperes at rated output and
- Ambient temperature when above 40°C.

The schedule of tolerances for various parameters is given in the following table.

Table 2.3 Schedule of Tolerances
IS 325 – 1978

Sl.No.	Item	Tolerance
i)	Efficiency	
	a) By summation of losses:	
	Motors up to 50 KW	-15 percent of $(1 - \eta)$
	Motors above 50 KW	-10 percent of $(1 - \eta)$
	b) By input – output test	-15 percent of $(1 - \eta)$
ii)	Total losses applicable to motors above 50 KW	+10 percent of the total losses
iii)	Power factor	-1/6 of $(1-\cos\phi)$; min 0.02 and max 0.07
iv)	Slip at full load and at working temperature	±20 percent of the guaranteed slip
v)	Breakaway starting current of squirrel cage induction motors with short-circuited rotor and with any specified starting apparatus	+20 percent of the guaranteed starting current (no lower limit)
vi)	Breakaway torque	-15 percent to +25 percent of the guaranteed torque (+25 percent may be exceeded by agreement)
vii)	Pullout torque	-10 percent of the guaranteed torque except that after allowing for this tolerance, the torque shall be not less than 1.6 or 1.5 times the rated torque
viii)	Moment of inertia or stored energy constant applicable to motors of frame sizes above 315	±10 percent of the guaranteed value

2 a. Discuss the procedure of filling the oil in a transformer tank.

Q. 552. Explain the procedure of filling the oil in a transformer tank.

Filling the Oil in Transformer. If the oil is despatched separately in drums and the drying-out of transformer is carried out without oil, the oil is filled in the tank after the following steps :

— drying out of the transformer tank ; core and coils.

— filling of oil by means of oil-filtering plant.

Before filling with oil, transformer should be fitted with all accessories including valves, gauges, thermometers and plugs and made oil-tight. Oil samples should be taken and tested before filling the transformer tank. It should be ensured in oil filling operation that no air pockets are left in the tank and no dust or moisture enters the oil and that it is as warm as the surrounding air. All air vent should be opened. Oil should be filled or then oil filtering plant and metal hoses through. Rubber hoses should not be used since the sulphur in the rubber would dissolve in oil, causing dielectric strength of the oil to be lowered and also, the dissolved sulphur would attack the copper in the windings. To prevent aeration of the oil, the transformer tank should be filled through the bottom drain valve. In a conservator type of transformer, the rate of oil flow should be reduced when the level is almost upto the bottom of the main cover to prevent internal pressure from rupturing the relief-pipe diaphragm. Enough time should be allowed (16 to 24 hours) for the oil to permeate the transformer and also the bubbles to escape. Any air accumulated in the Buchholtz relay should be released. The sides of the transformer tank may be tapped with a hammer on all sides to release trapped-up air. An alternate method for removing the trapped air from large transformers is to keep the transformer energized at no load for about 6 to 12 hours at the end of which the air cocks on the transformer are opened to allow the released air to escape.

Vacuum filling may be used for large transformer with tanks designed to withstand vacuum. A vacuum pump may be connected to the top value of the transformer and the oil hose to the top filter press value. The tank shall be tightly sealed and evacuated to approximately 6 mm of mercury and the vacuum maintained for 3 hours or longer depending on the size end voltage of the transformer. The oil value may then be opened and the oil allowed to flow slowly into the tank. The vacuum should be maintained for a short time after the tank is full.

Oil Filling

Before filling the oil in the transformer tank or reactor tank, it shall be heated to 50° to 70°C and filtered through vacuum filter with pore diameter of 5 µm maxm. The air, moisture, solid impurities are removed till gas content is less than 0.2%, moisture content less than 10 ppm, dielectric strength more than 50 kV (tested as per IEC 156) : electrodes $R = 25$ mm spaced at 2.5 mm).

The oil is circulated through the filter a few times before it is filled in the transformer. The procedures to handle dry oil can be :

1. Don't fill oil from mobile *tank-trailer* into the transformer tank directly. Fill the dry oil from mobile tank-trailer into transformer tank *via* the vacuum filter.

2. Don't fill oil from storage-tank into the transformer directly. Fill dry oil from storage tank *via* the vacuum filter in the transformer tank.

3. Take oil from 200 kg drums into storage tank or mobile tank-trailer and dry the oil by circulation through the vacuum pump and then filled into the transformer tank as per 1 or 2 above.

Evacuation

Transformer tank is evacuated to vacuum till pressure is below 0.15 kPa, *i.e.* < 1.0 m bar (Torr) Evacuation is held in the range below 0.3 kPa and 0.15 kPa for 12 to 36 Hrs.

Oil filling and Circulation

Oil is filled through vacuum filter plant and is circulated through filter plant till desired moisture, gases, dielectric strength readings are obtained.

Oil is circulated at least twice at 20°C ambient and twice at 0°C ambient.

Standing Time after Circulation

Before application of voltage, certain standing time is necessary before application of voltage :

Rated Voltage, kV	220	400	765
Evacuation, Hours	12 to 24	24	36
Standing Time, Hours	12 to 48	48	120

b. List out the various commissioning tests on a power transformer and explain any two of them. **(14 Marks)**

— Energizing and operation under observation — Loading and observation.

Q. 559. State the various commissioning tests on a Power Transformers.

Commissioning Tests on Power Transformer. After the above preparations, several commissioning tests are conducted on the transformer and tap-changer. The test to be carried out at site before commissioning the transformer will depend upon the voltage and kVA rating of the transformer, facilities available at site and conditions of the control list of typical tests are given below :

(A)	*General observation*	— Complete Transformer — Control and relay panels, etc. — Junction boxes and marshalling kiosks.
(B)	*Secondary injection Tests*	— Of all the protection relays.
(C)	*Primary injection Tests*	— Tests on operation and stability of earth fault relays on side h.v. — Tests on line directional elements of high-voltage line relays — Tests on high speed neutral circuit breaker — Tests on overcurrent relays on l.v. side — Tests on operation and stability of earthfault relays on l.v. side — Tests on operation of standby earth fault relay l.v. side. — Tests on overcurrent relay on h.v. side (when current transformers are not in transformer) bushings. — Voltage Compensation.
(D)	*Ratio Tests*	— With 415 V applied on high voltage side, measure the voltage between all phases on the low-voltage side for every tap position. — To check phasing, measure volts : A to a, b and c B to a, b and c C to a, b and c Where A, B and C are the terminals of three phases on high-voltage side and a, b and c are the corresponding terminals on low voltage side.
(E)	*Tripping Tests*	— High voltage side breaker — Low voltage side breaker — Intertripping tests — Winding temperature trips.
(F)	*Calibrate earthing resistance*	
(G)	*Buchholtz relays*	— Tests for angle air injection, etc. — Check that there is no air in protector before commissioning — When energizing, close in on 'Trip', etc. — Check for stability when oil pumps are started : 1. at ambient temperature 2. at a winding temperature of 80°C or above.

Contd.

(H)	*Alarm Circuits*	— Buchholtz relay — Oil and winding temperature thermometer set at 85°C and 100°C respectively — Cooling gear failure.
(J)	*Fans and Pumps*	— Check that the oil valves are open in cooling circuit — Check the rotation of pumps, automatic starting overload devices, etc. — Check stability of Buchholtz relay.
(K)	*Tap changing tests to check mechanism, indication, buzzer, lamp, etc.*	
(L)	*Phasing tests*	— At 415 V — Between transformers in a three phase bank — To prove internal and external connections for parallel operation — On auxiliary supplied and voltage transformers.
(M)	*Insulation tests (reduced voltage)*	— On high and low voltage windings — On current and voltage transformer circuit, etc.
(N)	*Check oil levels*	
(O)	*Voltage Compensation test (if compensating transformers are fitted)*	— Primary injection — Load tests — If necessary, switch-in with relays connected to correctly compensated voltages from the other transformer
(P)	*Insulation Resistance*	— Main Circuits — Auxiliary Circuits.
(Q)	Partial Discharge	— Main circuits for record.

3 a. What do you mean by cooling? Explain the different methods of cooling of turbogenerators.
(10 Marks)

Q. 809. Define Cooling. Explain the need of cooling system for electrical machines. Explain the principle of cooling systems.

Definition of Cooling Process. A process by means of which heat resulting from losses occurring in a machine is given up first to a primary coolant, by increasing its temperature. The heated primary coolant may be replaced by a new coolant at a lower temperature or may be cooled by a secondary coolant in some form of heat exchanger.

*Theory of cooling** (Dissipation of heat)

The I^2R losses and other losses in electrical machines appear as heat, the temperature of each internal part is raised above the ambient temperature of the surrounding air. The temperature-rise above ambient is related (*i*) to the rate of heat production, (*ii*) the rate of cooling and (*iii*) the thermal capacity. The *temperature rise* is significant in determining the *plant rating* as it affects the life of the winding insulation, and has specified operating limits.

Heat is removed by a combination of *conduction, convection,* and by *radiation* from outer surfaces. A cool fluid is passed through passages in a machine to remove the heat by *forced convection,* whereas air-current dissipation from the outside surfaces is *normal convection* which may be is augmented by fans.

Convection by random air flow is mainly used in a small machines and is usually aided by rotor fans. For bigger machines the core volume is large and : radial and axial ducts must be provided to increase cooling effect, with means should be provided for directing the coolant through the labyrinth. The cooling system for the largest machines is complicated, but it is important in view of the very large loss-rates.

(10 Marks)

b. Enumerate the requirements of type tests and routine tests on synchronous machines.
(06 Marks)

Q. 1024. State the requirements of type-tests and routine tests on synchronous machines.

The synchronous machines include the following three types :

1. Synchronous generator. 2. Synchronous motors. 3. Synchronous compensators.

The tests performed include factory tests and field tests. The tests are conducted to demonstrate that the machine gives the required performance.

The following tests may be conducted :

1. Open-circuit test (no load test) 2. Short circuit test.

3. Zero-power-factor characteristic and loss measurement.

4. Temperature-rise (*i*) by full load z.p.f. over-excited run, or (*ii*) by equivalent heat run. The latter comprises a rise measurements on the stator with excitation but no stator current, followed by a test with rated stator current but minimum excitation. The total temperature rise is then obtained by combining the results.

5. Overspeed test *e.g.* 2.5 p.u. for turbo and 1.0 p.u. for hydro-generators, the latter in an enclosure ; as the windings loss varies as the cube of the speed, considerable drive power may be demanded.

6. High voltage tests.

7. Insulation-resistance tests, made before and after (6).

8. Waveforms, interference, gap, length, balance, vibration, bearing currents, magnetic symmetry, etc.

All the above test may not be necessarily on each machine. For small machines the testing is much simpler, and may be confined to (1), (2), (3), (4), (6), (7) apart from general machine construction verification. Excitation and control systems are subject to full testing schedules before assembly with the machine itself.

(06 Marks)

c. What is the essential difference between the sustained 3 phase short circuit test and sudden 3 phase short circuit test? **(04 Marks)**

Oscillographic record is not essential during the sustained s.c. current test.

Q. 1032. What is the essential difference between the sustained three-phase s.c. test and sudden three phase s.c. test ?

The *sustained s.c. test* is for steady state characteristics, field current and s.c. current are varied gradually. The measurement is by means of indicating instruments like ammeter and voltmeter. The values of I_f and I_a are r.m.s. steady state values. The sudden s.c. test is an oscillographic test and it gives the oscillographic record of armature current, field current and other quantities under sub-transient, transient and steady state condition. The total duration of such test is of the order of a few tens of cycles to one second. One cycle in 50 Hz system is 0.02 Second Quantities are recorded an ultra-violet recorder and not by indicating instruments.

4 a. Describe the procedure of low slip test and method of calculation of $x_\alpha x_q$ from the same. **(10 Marks)**

for transient phenomena studies along the direct axis, two reactances.

Q. 1040. Explain the procedure of low slip test and method of calculation of X_q from the same.

Low slip test

During the low slip test, subnormal symmetrical three-phase voltage $(0.01 - 0.2\,U_n)$ is appl' to the armature terminals of the machine under test. The voltage should be such that the mac

does not pull in. The excitation winding should be open-circuited the rotor should be driven by a prime mover at a slip less than 0.01 p.u. and for solid rotor machines much less then 0.01 p.u., There by the currents induced in the damper circuits during synchronous operation will have negligible influence on the measurements. During switching on and off of the supply, the excitation winding should be closed (short-circuited or through a discharge resistance) to avoid possible damage. Armature current and voltage and the slip-ring voltage and slip are measured by indicating instruments or recorded by oscillograph. If the residual voltage measured before the test is larger than 0.3 of the supply test voltage, the rotor should be demagnetized. Demagnetizing might be done, for example, by connecting the field winding to a low-frequency source with current about 0.5 of the no-load rated voltage excitation current of the tested machine and gradually decreasing its amplitude and frequency (the latter if possible).

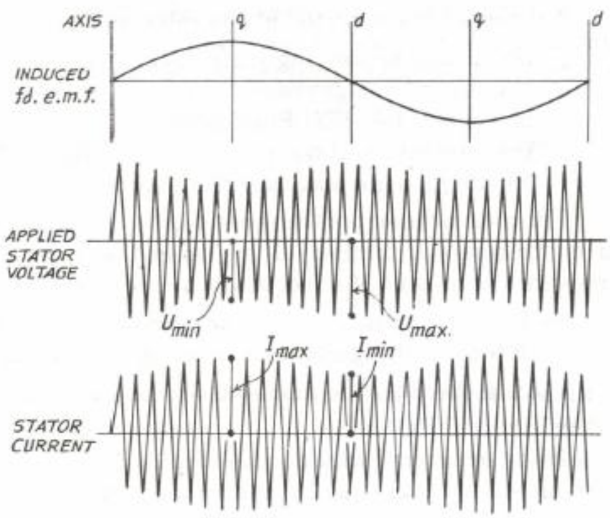

Fig. Q. 1040. Record of Slip-Test.
(The oscillograms of stator current and stator voltage indicate periodic variation due to the slip)

Determination of X_q from low slip test

To determine X_q from the low slip test, armature current and voltage are measured to maximum excitation winding voltage (U_{fo}), and X_q is calculated using the following formula :

$$X_q = \frac{U_{\min}}{\sqrt{3}\, I_{\max}}\,\Omega\,;\left[x_q = \frac{u_{\min}}{i_{\max}}\right]$$

Note. If I_{max} does not coincide with U_{min}, use in calculations I_{max} as a base and its corresponding voltage. Small letters are for p.u. values.

If during the test, the residual voltage of the machine (U_{res}) is in the limits of 0.1 – 0.3 of the supply test voltage, the value of the current is determined using the formula :

$$I_{max} = \sqrt{I_{av}^2 - \left(\frac{U_{res}}{\sqrt{3}\,X_d}\right)^2}\;\Omega\,;\;\left[i_{max} = \sqrt{i_{av}^2 - \left(\frac{u_{res}}{x_d}\right)^2}\right]$$

where I_{av} is the half sum of the two consecutive maxima of the current envelope curve (Fig. Q. 1042).

A check of the measured value may be made by calculating X_d from the same test, using the results of the voltage and current measurements at the time when the voltage of the open-circuit excitation winding is equal to zero comparing it with its real value. Then,

$$X_d = \frac{U_{max}}{\sqrt{3}\, I_{min}}\,\Omega\,;\;\left[X_q = \frac{u_{min}}{i_{max}}\right]$$

(10 Marks)

b. Describe the different methods of measuring DC winding resistance of synchronous machines. **(10 Marks)**

Q. 1038. Explain the procedure of measurement of d.c. resistance of windings.

Measurement of d.c. resistance of windings by the voltmeter and ammeter method and by bridge method.

Any d.c. supply (battery, generator, etc.) of required output rating with stable voltage may be used for measuring d.c. resistance by the voltmeter and ammeter method and bridge method.

The resistance should be measured directly at the winding terminals with the rotor at rest.

Armature winding resistance should be measured for each phase separately. If, for some reason, phase resistance cannot be measured directly, the measurements are made between each pair of the line terminals of the armature winding.

The current value during the d.c. resistance measurements should be such that the winding temperature rise during the test is not more than 1 deg C assuming adiabatic heating. To calculate adiabatic heating use formula

$$\Delta \theta = \frac{j^2}{c} \text{ degrees per second}$$

where j = current density during test A/mm^2

c = constant, equal to 200 for copper and 86 for aluminium.

If the winding heating is unknown, the current should not be more than 0.1 of the rated winding current and should be supplied for not longer than 1 min.

The time of the measurements should be such that, at the instant of the taking instrument readings, their pointers are steady (*i.e.*, transients have disappeared both in the instruments themselves and in the circuits, the resistances of which are being measured).

The winding temperature during the measurement should be determined by means of built-in or embedded temperature detectors where fitted.

The thermometers and thermocouples used for measuring the winding temperature should have been in place for not less than 15 min, and should be protected from any outside influence.

Determination d.c. resistance of field winding

To measure the d.c. resistance of the armature or of the excitation winding by the voltmeter and ammeter method, it is recommended to take three to five readings at various steady values of the current.

The winding resistances are calculated from the formula.

$$R = \frac{U}{I} \Omega$$

where U = voltage applied to the winding, in volts

I = winding current, in amperes

The average value is taken for the resistance. In determining the average value, resistances which differ by more than ± 0.01 from the average per unit value should be disregarded.

D.C. Resistance from line terminals

If resistance measurements are made in turn between each pair of the line terminals of the armature winding ; the resistance R_1 phase 1 is calculated from the formula (in per unit of physical values).

— for star connected winding : $R_1 = \frac{R_{12} + R_{31} - R_{23}}{2} \Omega$

— for delta connected winding : $R_1 = \frac{2R_{12} . R_{23}}{R_{12} + R_{23} - R_{31}} - \frac{R_{12} + R_{23} - R_{31}}{2} \Omega$

where R_{12} . R_{23} and R_{31} are the resistances measured between terminals 1-2, 1-3 and 2-3.

5 a. Explain the foundation details used for induction motors.

Q. 864. Explain the procedure of foundation of electric machines. [Ref. Q. 855]

The static load and dynamic load of running machine is transmitted to the groun ia the machine foundation.

Three basic requirements of the machine foundation are :

— Horizontal level. — Rigidity. — Freedom from vibrations.

The foundation plan is usually recommended by the manufacturer.

The total installation comprises the following essential features :

— Foundation made of cement-concrete.

— Bed-plate ; — Foundation bolts.

The machine is bolted to the 'Bed-plate.' The bed-plate is fixed on levelled foundation. The foundation bolts are used for securing the bed-plate to the concrete foundation. Rolled I-sections are placed in concrete on which the bed plate rests.

Concrete Foundation

The machine with or without bed-plate should be securely bolted to solid, firm, level foundation. The foundation may be common for motor-generator or motor and the driven machine. Alternatively, a separate foundation may be provided for motor and driven machine. The design of foundation depends on the size and speed of machine.

The qualities of a good foundation are rigidity and freedom from vibration.

The depth of concrete foundation should be enough. For this excavation should be of enough depth. The depth depends on the bearing capacity of the soil.

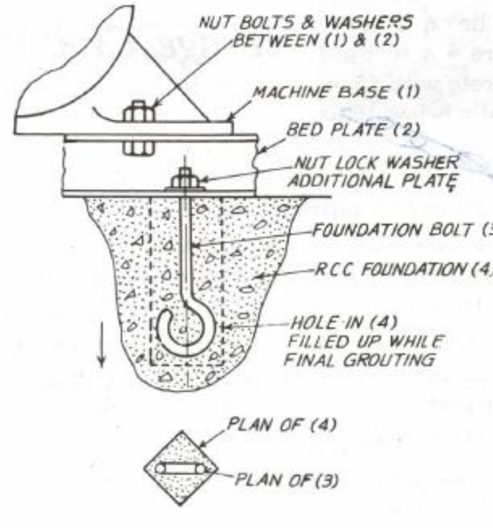

Fig. Q. 864 (*a*). Foundation Bolt Assembly.

Place wooden formers around the edges of the excavation at the floor-level. Also, place I-shaped rolled steel sections in horizontal formation to provide reinforcement to the concrete. This has been described in a subsequent paragraph.

The wooden formers give shape to the concrete plinth of the foundation. The cable ducts or pipe line should be provided by suitable patterns inserted at desired location. Plugs should also be provided for holes for inserting foundation bolts (and their grouting with concrete finally). The plugs should be removed after setting of the concrete.

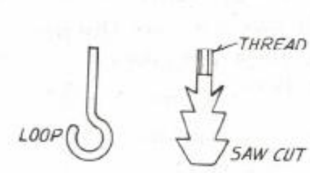

Fig. Q. 864 (*b*). Common Shapes of Foundation Bolts.

The composition of the concrete used for machine foundation is as follows :

Cement : 1 parts ; Broken Stone : 4 parts ; Sharp sand : 2 parts.

The parts should be thoroughly mixed when dry. Water is then added slowly until the mixture is just-sufficiently wet to pass freely in the cavity of the foundation. When the concrete has set, remove the wooden former and plugs and patch off the defects in the concrete foundation. The foundation surface should be levelled. *Allow the concrete to set properly by leaving it for several days.*

Bed-plate

Medium and large rotating machines are installed on bed-plates

— in one piece, or ; sectionalised, or separate for motor/generator.

The bed-plates are secured to the concrete foundation by means of foundation bolts. The machine are bolted to the bed-plate securely. The bed-plates for large machines are fabricated from thick sheet steel or rolled. I-section, large beams. The bed-plate has necessary stiffeners and ribs provided in its structure. The holes are drilled on the top and bottom faces of the bed plate according to the drawing. For bolting the machine and for foundation bolt.

The fabricated bed-plate is generally of rectangular shape (in plan view).

Mounting of Bed-plates for Large Machines

In case of large machines weighing above 20 tons of rolled steel are placed in concrete foundation to provide reinforcement and to distribute the load of the machine uniformly over the concrete foundation. It is preferable to sint the I-sections in the concrete. The number of I-sections depends upon size and load of the machine. Some of these I-sections in the concrete are positioned such that they lie under the heavy load points of the bed-plate. The I-sections may be placed completely in the concrete with the bed-plate surface above the ground level or the I-sections shall be placed in concrete with their upper surface slightly above the ground level. The height of the I-sections is usually below 160 mm for machines above 20 tons.

Pads for Mounting Bed Plate

The *packing plates* are placed on the surface of-section at regular intervals particularly at each side of the foundation bolt. These packing plates are also called *metal pads.* Bed-plates are placed on the surface of these pads. Thus the bed-plates are not directly placed on the I-sections, but on the pads placed on I sections. Metal pads help in uniform distribution of load over the foundation after tightening of the foundation bolts. Sizes of the pads are as follows :

Material	*Height mm*	*Width mm*	*Length*
Steel plate strip	5 to 40	40 to 100	L
Steel strip for Adjustment	0.5 to 5	40 to 100	L
Cast Iron plates	50 to 100	100	L

L = Length of Bed plate + 50 mm.

In case of large machine (> 20 tonnes) the configuration of foundation is as follows.

(*a*) Concrete foundation

(*b*) I-sections placed in *a*.

(*c*) Metal pads placed on *b* at regular intervals.

(*d*) Bed-plate placed on *c*.

(*e*) Bed-plate securely fixed onto the *a* by means of

(*f*) Foundation bolts.

[*For small machines item (b) is deleted*]

Foundation Bolts

The foundation bolts fix-up the bed-plate onto the concrete foundation. The lower portion of foundation-bolts has an eye-shape (book type) or saw-tooth shape to provide grip in the foundation.

The size of foundation bolts are ás follows :

Sizes of Hook Type Foundation Bolts*

Machine Size	*Diameter of cross section D, mm*	*Length L, mm*	*L/D*
Small power machine with light duty	20 mm	400 mm	20
Small power machine with heavy duty	25 mm	600 mm	24
Light duty Medium Machine	30 mm	900 mm	30
Heavy Duty Medium Machine	50 mm	2000 mm	40
Large Machine 5, Heavy Duty	75 mm	3000 mm	40

The foundation bolt is inserted in the holes of bed plate with the spring washer and plane acking washer between the nut and the bed-plate flange. The foundation-bolt should be located rith the bed-plate hole before lowering the bed-plate.

Use crane and slings for lifting bed plate vertically. Position it such that the foundation bolts ome exactly above the corresponding holes in the foundation, and

Make a good "Grouting Mixture" consisting of

Cement	:	1 part
Sharp Sand	:	2 parts.

Make a good mixture of above parts then add water slowly to make *thin* paste. Fill the space round foundation bolts by the cement paste upto the surface level of the foundation. Fill-up the vities by using suitable rod for ramming the grouting. The *grouting* is then allowed to set hard.

b. What modifications are necessary for an induction motor when it is used for hazardous location? **(06 Marks)**

Q. 1179. What is Hazardous Location ? What is Explosion Proof Equipment ? What are its design Specialities ?

'Explosion-Proof' or 'Flame-Proof' Machines. The term 'Explosion-proof' is used in USA and 'Flame-proof' is used in UK and India, 'Pressure-proof type' in Germany. These three terms are synonymous.

Flame-proof Enclosures are specially designed and built for installation in hazardous location. The *hazardous locations include those which have*

— Highly inflammable gases/vapours or liquids.

— Combustible dust. — Combustible fibers floating in air.

— Highly inflammable liquids like petrol, naptha, benzene, ether, acetone, etc. These explosive mixtures of air and inflammable gas can explode in presence of electric arc or electric spark.

The primary consideration in the design of flame-proof enclosures is to prevent such explosion. The flame-proof switchgear should be built such that

— the construction should be strong enough to withstand the high pressure from within, caused by explosion of gas which enters the enclosure.

— the design should be such that the flame-or-spark within the enclosure should not be carried out of the enclosure.

— The enclosure should be gas-tight.

— The flame-proof motors and switchgear should be installed, as far as possible away from hazardous location, (rooms where explosive gas is present). The motors and switchgear should be 'flame-proof' or 'explosion-proof' and should satisfy the codes and standards specified for such switchgear.

All the equipment such, as circuit-breakers, switches, *motors* starters have movable parts, which have relative movement with respect to frame. Hence hermetical sealing is not possible. Further, for the purpose of maintenance, de-assembly is a must. Hence, hermetic sealing is not practicable. The problem also arises due to conduits, cable ducts etc. entering the enclosure. These cannot be made absolutely gas-tight. Apparatus 'breaths', *i.e.* let out air with change in temperature due to load cycle. Due to such breathing outside gas slowly creeps in. In short, hermetic sealing (complete sealing) is not practicable.

When gas or mixture of air and gas explodes inside the enclosure, the flame of burning mixture should be confined entirely within the enclosure and should not be communicated to outside atmosphere, so that the ignition of inflammable gas is prevented.

It is, therefore, necessary to make the enclosure strong enough to withstand high pressures generated within the enclosure due to internal explosions. The enclosures are built ruggedly. The sizes are also relatively ample.

Some motors have to work in a hazardous atmosphere. Simple cage motors are relatively resistant to such as ambient medium, but machines with carbon brushes and sliding contacts depend upon the maintenance of an oxide film on the sliding surface for satisfactory current collection. *Totally enclosed machine or brushgear and cooling by pressurized clean air are necessary. Operation in hazardous atmosphere of a inflammable type may call for nonsparking cage motors with modification in the enclosure for minimizing risk.* For mines, certified flash proof motors are essential, the basis of acceptance *being that if inflammable gases ignite within the machines the explosion is contained in such a way that gases external to the machine are not ignited.* The spark from inside the motor is not communicated to external atmosphere. The motor body is strong enough to withstand the forces of internal explosions without bursting.

c. Write a brief note on 'shaft alignment' of induction motor drive.

Q. 866. What are permissible tolerances of shaft alignment ?

The radial and axial clearance are measured after alignment. The rotor turned through 0°, 90°, 180°, 270°, and 360° shall not differ by following valves :

0.03 mm for 300 mm dia-coupling 0.5 mm for 500 mm dia-coupling.

Q. 867. Explain the procedure of alignment of shaft of electrical machines.

The shafts of driven and driving machine are aligned by various method. Here, the alignment of flexible couplings has been described. There are three steps in the alignment of the shafts.

1. Axial positioning of the shafts.
2. Paralleling of shaft axis.
3. Centering of shaft axis.

Procedure :

1. Align the motor and the driven machine on bed-plates in their final position with shims under their feet.

2. Mark both half coupling by means of chalk line. Make accurate measurement between the gaps between the faces of the vertical surfaces. Turn the motor shaft through 90°, 180°, 270° and 360° and not the readings of the gap.

3. The excess difference is reduced below 0.05 mm by adjusting the shims.

4. Likewise the difference in the heights of axis of drive coupling and driven coupling is gauged by suitable method. One of the method of gauging the gap between vertical surfaces of couplings and the difference in heights is by using Single Point Turn Point Runover Gauge.

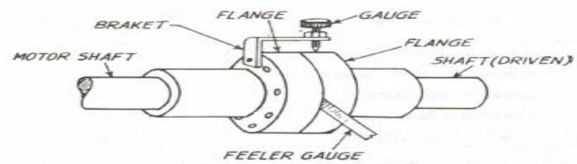

Fig. Q. 867(a). Checking shaft alignment.

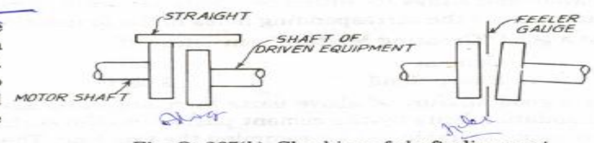

Fig. Q. 867(b). Checking of shaft alignment.

6 a. Give the procedure of high voltage test setup for induction motor.

Q. 914. Explain the procedure of high voltage tests on rotating machine.

The tests circuit are conducting a.c. high voltage tests is illustrated in Fig. Q. 914. This test is conducted to check the insulation of windings. The test voltage is of power frequency (50 Hz) and sine waveform. The test voltages for commissioning test is only 75% of the routine test voltage.

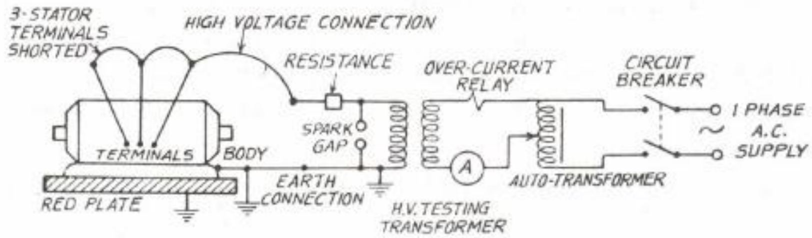

Fig. Q. 914. Circuit for H.V. Power Frequency voltage withstand Test on Stator Windings of 3 phase AC Machines.

$V_{test} \simeq [2\ V_{rated} + 1]$ kV for Routine Test.

$V_{site} \simeq [0.75\ V_{test}]$ for site tests.

The value of Maximum Test Voltage for site tests given by the expressions

$$V_{a.c.} = 75\%\ [2 \times \text{Rated Voltage} + 1000] \text{ Volts}$$

$$V_{a.c.} = 1.5 \text{ Rated Line-to-line voltage.}$$

The connections are shown in the Fig. The three terminals of the motor are connected together and to the high voltage terminal of test supply. The body is earthed and is connected to the earth terminal of single phase test-supply.

In high voltage a.c. tests, the test voltage is raised quickly to the maximum test voltage. It is kept at that value for 1 minute and then reduced slowly to zero. The circuit is discharged by connecting it to ground. *The test is conducted on 'go/not go' basis.* If breakdown occurs, the test supply is automatically tripped. If the machine fails in the test, it cannot be commissioned without rectification.

b. What are the different methods of drying out of an induction motor? Explain in Brief.

Precautions while Drying out

1. Chamber should have thermal insulation to prevent heat loss.

2. The machine body should be covered with canvas to prevent heat loss.

3. Temperature of air shall be controlled by turning off the heater from time-to-time.

4. Local temperature should not exceed 75°C. There should be proper circulation of air in the chamber.

5. The temperature should be raised gradually. Not faster than 10°C per hour. Higher rate of heating results in damage due to differential expansion of metals and insulation.

6. Heating should be continuous and steady temperature shall be maintained continuously during the entire drying period.

Q. 882. Explain the drying out of a motor by radiating lamps. (Infrared Lamps).

This is a most convenient and simple method used for medium and small motors. The infrared lamps are used. The lamps are located in the chamber opposite to the motor winding. (The rotor is removed). This method is applicable to dismantled motor for drying the stator winding and rotor winding separately.

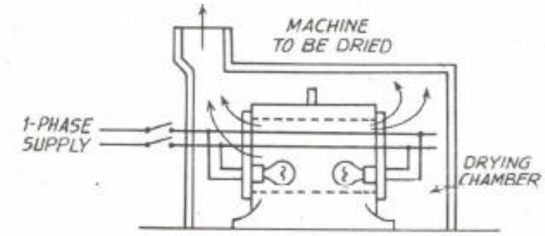

Fig. Q. 882. Drying by radiating lamps.

Q. 883. Explain the procedure of drying electrical machines by circulating short-circuit currents.

This is most convenient method of drying any electrical machine such as generator, slip-ring motor, synchronous motor, d.c. motor, field windings etc.

The machine is connected to low voltage source.

The input voltage, current, power, the temperature of winding, temperature of body, temperature of air are periodically measured. The end shields of the machine are removed. The machine body is covered with trapaulin. No cool air blow shall come over hot winding.

The increase in temperature should be very gradual. The cooling down also be gradual.

Connections for Synchronous machine for drying

There are three alternatives as shown in Fig. Q. 882.

Method 1. D.C. source, stator windings in series with field winding.

The current is adjusted to about 50% of rated field current.

The d.c. current should never be switched off as this would give over voltage and failure of insulation. The current should be reduced by means of rheostat.

Method 2. *D.C. source, current through rotor only.*

The current is adjusted to about 50% of rotor rated current. Stator winding gets heat from the rotor. There should not be switching off rotor current. Rheostat should be used to reduced rotor-current switching off of rotor current gives high over voltage.

Method 3. Single phase a.c. source, current through stator windings connected in series.

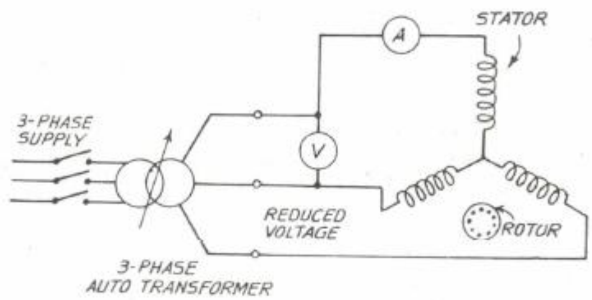

Fig. Q. 883(*a*).

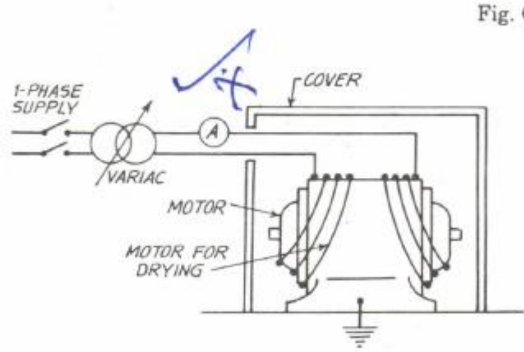

Fig. Q. 883(*b*).

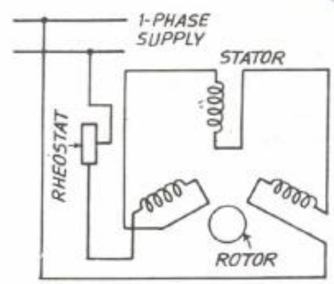

Fig. Q. 883(*c*).

7 a. How can you measure the slip of an induction motor? Write the various methods of measurement of slip. **(10 Marks)**

b. Briefly explain the methods of measuring temperature rise in an induction motor.

motors in laboratory.

Q. 1188. Explain the temperature rise test on a 3-phase induction motor.

Temperature Test is a type test. The machine is directly *loaded*, either mechanically through a d.c. or a.c. generator. Readings of the winding temperatures are taken periodically t the steady temperature is reached. Temperature rise in windings is measured by resistance metho When steady temperatures are reached, the temperature rise of various parts are recorded. The should be below specified limits for the particular class of insulation. Higher temperature are caus by various conditions.

Q. 1189. How can you measure the slip of an induction motor ?

Measurement of slip. There are three methods of measuring the slip.

1. By measurement of synchronous and actual speeds (tachometer).
2. By measurement of the rotor frequency.
3. By the stroboscopic method.

1. **Speed Measurement.** In the first method speed is measured by tachometer. The slip i calculated. This method is very approximate since it depends upon the difference of two relativel large and nearly equal quantities.

$$\% S = \left(\frac{N_s - N_a}{N_s} \right) - 100$$

N_s = Syn. speed ; N_a = Actual speed

2. **Oscillation Measurement.** The measurement of the rotor frequency can be made by inserting a moving-coil ammeter, (with a central zero) in the rotor circuit. The rotor frequency can be determined by counting the oscillations of the pointer. If a central zero instrument is used, the number of complete to and fro swings must be counted, but in the non-centre zero type ammeter the reverse half of the wave produces no effect since the pointer is pressing against the zero stop. The percentage slip is given

$$\%S = \frac{\text{Rotor Frequency}}{\text{Stator Frequency}} \times 100$$

This method must be modified for squirrel-cage rotor, as there are no slip-rings. There is usually a small portion of the magnetic flux going right through the centre of the rotor and cutting the shaft, which has a small e.m.f. induced in it. This can be detected by passing a lead against each end of the shaft, the other ends to be connected to a sensitive moving-coil millivoltmeter. The measurement is then made in the same way as that mentioned above.

3. **Stroboscopic Method.** In the Stroboscopic method a disc with alternate black and white sectors (painted) is attached to the end of the motor shaft. This disc is illuminated by means of a neon lamp operated supply from Stroboscope. The complete apparent revolution of the disc corresponds to the slip per pair of poles. The apparent revolution of the disc per minute are counted, the frequency of slip is obtained from

$$\text{Slip} = \frac{\text{Apparent r.p.m.}}{60} \times \text{Pairs of pole}$$

The percentage slip is then calculated. For testing motor with different numbers of poles, separate disc having different numbers of sectors (painted) is required.

When a Stroboscope is available, the measurement of slip is simpler. The frequency of flashes given by the Stroboscope can be varied. The frequency of flashes is adjusted till the disc appears to be stationary. *All that time the frequency of the Stroboscope* corresponds to *slip frequency*. The slip is noted from the calibrated dial of the *Stroboscope*.

8 a. List the different tests to be conducted on circuit breaker.

Q. 644. State the various types of tests performed on high voltage a.c. circuit-breakers. State the difference between the Type Tests, Routine Tests and Commissioning Tests.

Classification of the Tests

Development Tests. These are carried on components, sub-assemblies and complete circuit-breaker during and after the development of the circuit-breaker. The designers and research scientists verify the effect of various parameters on the behaviour of circuit-breakers, by conducting development tests. Development tests are not specified in the standards.

Type Tests. These are conducted on first few prototype circuit-breakers of each type to prove the capabilities and to confirm the rated characteristics of the circuit-breaker of that design. Type tests are not conducted on every circuit-breaker. Type tests are conducted in specially built testing laboratories. Type tests are performed as per recommendations of standards (IEC) or (IS).

Breaker is not used again after short-circuit type test unless overhauled.

Routine Tests. Routine tests are also performed as per recommendations of the standards (IEC/IS).

Routine tests are conducted on each circuit-breaker. These are performed in the manufacturers premises. Routine tests confirm the proper functioning of the circuit-breaker.

Commissioning Tests. These are conducted on the circuit-breaker after installation on site to verify the readiness and proper functioning.

TESTS ON H.V A.C. CIRCUIT-BREAKERS

Q. 645. State the various type tests performed on high voltage a.c. circuit breakers.

Summary of Type Tests on High Voltage A.C. C.B.

	Test	*Remarks*
1.	No load mechanical operation tests.	No load operations to verify speed of travel, opening time, closing time. Carried out at 85% and 110% rated voltage of shunt trip release.
2.	Mechanical performance tests (Endurance tests).	1000 close-open operations or more.
3.	Temperature rise tests	Steady temperature of conducting part and insulating parts measured for rated continuous alternating current.
4.	Dielectric tests — 1.2/50 μs lighting impulse withstand — 1 min. power-frequency voltage withstand	Five consecutive shots of positive and then negative polarity as recommended in relevant standard, for different test connections.
	— 250/2500 μs switching impulse withstand	For CB rated 275 kV and above.
5.	Short-time current test	Rated short-circuit current passed through closed breaker for 1 sec. or 3 sec.
6.	Short-circuit breaking and making Basic Short-circuit tests	At 10%, 30%, 60% and 100% rated short-circuit breaking current with specified operating, sequence and specified TRV.
7.	Line charging current breaking tests	Applicable for circuit-breakers rated 72.5 kV and above to be used for overhead lines.
8.	Cable charging current breaking tests	Applicable to circuit-breakers intended for long cable network.
9.	Single Capacitor-Bank Breaking tests	Applicable for circuit-breakers to be used for capacitor switching.
10.	Small inductive current breaking tests	Applicable for circuit-breakers with shunt reactors, transformers, reactors, motors.
11.	Out-of-phase switching	Applicable to circuit-breaker which may connect two parts under out-of-phase conditions.
12.	Short-line fault tests	Applicable to circuit-breakers rated above 52 kV and for overhead lines.

b. Write a note on maintenance of circuit breaker.

Q. 684. Explain the various steps in maintenance of circuit-breakers.

Maintenance of oil Circuit-breakers. The discussion pertains to oil circuit-breaker, but some features are common with the other types. The description only gives a general guidance, not for specialists.

1. **Period of Inspection**

(*a*) *Under Normal Conditions.* (1) Once in 6 months or 12 months for c.b. operating in-frequently.

(2) Once in 1 month or 3 months for c.b. operating repeatedly or *according to the manufacturer's recommendation.*

(*b*) *On clearing a fault.* As soon as the circuit-breaker can be isolated from the service.

(*c*) *Overhead.* Once in three years or as recommended by the manufacturer.

(*d*) *Replacement.* When the life period expires. This is a matter of economics and technical considerations.

2. During the periodic check-up the following check should be made :

(*a*) Check the level and condition of oil.

(*b*) Clean the insulators with fine fabric cloth that will not leave fibres. Do not use cotton waste in any case. For removing oil, grease, carbon deposite use trichloroethylene or other chemical recommended by the manufacturer.

(*c*) Check contacts.

(*d*) Check operating mechanism.

(*e*) Check indicating devices.

(*f*) Check auxiliary switches.

(*g*) Tighten nuts, bolts etc.

(*h*) Test insulation resistance by means of high voltage (1000 V.D.C.) megger in case of high voltage circuits and by 500 V meggar in 220 V control circuits.

(*i*) Carry out tests according to the specifications.

(*j*) Take the steps as mentioned in the subsequent paragraphs.

3. When the breaker operates on fault, the internal and external inspection should be carried out as soon as the operating schedule permits.

(*a*) *Examine the Oil.* If badly deteriorated, change it.

(*b*) *Check Arcing Contacts.* Clean with smooth file. If badly damaged, replace them.

(*c*) Inspect the insulation, carefully check the surface.

(*d*) Check the arc control device. If damaged, replace the plates.

(*e*) Check the tripping circuit and operating mechanism.

(*f*) Be sure than no tools are left in the tank.

Some further details are given below :

Contacts. Contact pressure is important. In medium voltage circuit-breaker it is about 5 kg. The pressure is tested as follows.

A feeler gauge of 0.002 inch inserted between the contacts, is pulled by a spring balance, until the feeler is freed. The pressure indicated on the balance is recorded. This method is however, not very reliable. Springs should be adjusted or replaced if, contact pressure is insufficient. Another way is to measure contact resistance. The contact resistance is of the order of 20 micro-ohms for 1200. A normal current rating, the resistance between the ends of pole gives the measure of the contact resistance.

If contacts are badly burned, they should be replaced.

If highly burned or pitted or metal globules are present of the surface is slightly uneven, they are cleaned by fine glass paper of fine file. Original contour should be preserved. While cleaning the contacts, minimum material should be removed. On any account the contacts of the circuit-breaker should not be oiled or greased.

Arc Control Device. Slight blackening is harmful. The condition of plates is important. If badly burned or deformed, the entire are control device may need replacement. But normally only the plates which have burned need replacement. All vents and openings should be cleaned.

Insulators. Porcelain insulators should be inspected for any sign of cracks or defects. They should be cleaned with trichloroethylene. Carry out tests recommended by the specifications.

Opening Mechanisms. Check opening and closing operation by manual signal and tripping by means of relay. Clean all moving parts. Lubricate the sliding parts and surfaces. Avoid excessive lubrication. Check the tightness of nuts, bolts, pins, etc. Check the springs. Check the terminal blocks and the wiring. Check the auxiliary switch.

Relays. It is advisable not to adjust the relay mechanism. The faulty relay should be sent to the manufacturer since relay repair is a specialized job.

Contacts of relays should be inspected for any sign of burning where necessary, glass paper should be used for cleaning. All the terminals of the relays should be checked for thickness. The wiring should be checked security.

c. Explain briefly the commissioning tests on circuit breaker.

Q. 694. Explain the various commissioning tests on high voltage a.c. circuit-breakers.

Commissioning Tests. After the installation, the circuit-breakers and protective gear are subjected to commissioning tests are conducted on site to ensure proper assembly and operational readiness of the equipment. High accuracy is generally not expected in such tests. The tests facility available on site is also a deciding factor.

The commissioning include

— mechanical operation tests
— measurement of travel, simultaneous touching of contacts
— measurement of insulation resistance, resistance between terminals of the p
— pre-commissioning checks
— operation open and close
— checking of operation by energising the manual operating signal
— checking the operation by energising of relays, etc.