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CENTRAL ELECTRICITY AUTHORITY

CORRESPONDENCE TUITION SCHEME

Course for Turbine House Employees

LESSON SIXTEEN

REVISION PAPER III

STANDARD ANSWERS

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EDUCATION AND TRAINING BRANCH

STANDARD ANSWERS

LESSON 16

REVISION. PAPER III

111. When coal is burned the oxygen from the air unites with the carbon and other elements in the coal, thus producing heat-energy. In a boiler combustion chamber the radiant heat waves are transmitted from the hot fuel and burning gases to the boiler furnace walls, tubes and heating elements. Most of the radiant heat is absorbed and passed to the water by conduction. Convection currents in the water complete the transfer of the heat and the water is converted into steam. The steam then passes through a superheater, which is in the path of the hot boiler gases and as a consequence the temperature of the steam is increased.

From the superheater the steam is piped to a steam turbine to which is coupled an alternator. The high velocity steam gives up its kinetic energy to the turbine rotors, causing them to rotate and drive the alternator rotor. The running speed is either 1,500 or 3,000 R.P.M. and the speed is maintained at this level by the action of the turbine governor.

The windings of the alternator rotor are energised by a direct current supplied by a generator known as an exciter. The electric current generated in the alternator stator windings is conducted from the machine by cables attached to terminal connections usually brought out below the stator.

Heat units are lost in the boiler and turbine houses in the following manner:-

(i) Leaks in boiler casings thus allowing ingress of air.

(ii) Damage to insulation of pipework, valves, air trunking and turbine casings.

(iii) In the final flue gases, where the losses can be excessive if the boiler economiser and air heater surfaces are allowed to become fouled.

(iv) Unburnt carbon in the ash and grits.

(v) The latent heat of the exhaust steam is lost to the circulating water.

(vi) To the cooling medium of the alternator stator and rotor.

(vii) Excessive turbine blading clearances. Worn and dirty turbine blading.

112. The safety devices and alarms fitted to turbo-alternators are comprised of the following:-

Atmospheric Valve. This is fitted between the steam side of the condenser and atmosphere and is a safety valve designed to open should the pressure in the condenser exceed atmospheric pressure due to a loss of the circulating water. It safeguards the L.P. turbine casing and condenser against excessive pressure.

Overspeed Trip. To protect the turbine against overspeeding should the main governing mechanism fail. This is a spring loaded bolt or ring fitted in the end of the shaft and is set to operate a trip lever at a pre-determined shaft speed.

Alternator Protection. Consists of current transformers which compare the currents flowing at the ends of each phase of the alternator winding. Should any out of balance occur due to a fault the current transformers would operate a relay which would trip out the main alternator circuit breaker and the field switch.

A Kenotometer. An instrument to indicate the back pressure. It enables an operator to see at a glance that his correct back pressure is being maintained. A sudden rise in back pressure might be due to faults on the vacuum raising plant or circulating water system.

Turbovisory Gear. Instruments for indicating the shaft eccentricity and differential expansion. They are fitted to all modern turbines and give an accurate and continuous record of the shaft and casing conditions whilst running.

Oxygen Recorder. An instrument which will record the presence of any dissolved oxygen in the condensate. It is extremely undesirable to have any dissolved oxygen in the feed water because of its corrosive effect on boilers and pipework.

High Water Alarm. This is a float operated alarm fitted to the condenser. It indicates by an audible warning that the condensate level is rising.

Dionic Recorder. An instrument which indicates and records the purity of the condensate. It will immediately indicate a rise in the condensate conductivity due to a leak of circulating water or to the addition of any other impurities or chemicals to the condensate.

Alternator Temperature Indicator and Alarm. An instrument which indicates the temperature of the cooling medium in the alternator and is set to give audible warning of any abnormal temperature rise which could be caused by a fault in the cooling system.

Hydrogen Purity Meter. To indicate that the purity of the hydrogen in the alternator is being steadily maintained in the safe zone.

Oil Tank Level Indicator and Alarm. Indicates the level of the lubricating oil in the tank. In some cases an audible alarm is also fitted which operates at a lower level than normal which might be due to a continual loss say through a faulty cooler tube.

113. (i) A turbine having been brought up from cold will tend to vibrate if it is loaded too quickly. This might be indicated by a rise on the shaft eccentricity indicating instrument. The reason for this vibration is that the metal of the machine has not reached its maximum working temperature and the cylinder has not properly expanded on its sliding feet and keyways. The possible remedy would be to reduce load to a figure where vibration ceased and then increase the load more slowly thus giving the turbine a chance to fully expand to its hot running condition.

(ii) If a turbine commences to vibrate whilst on a steady load then a quick glance at the lubricating oil temperature to bearings, gland sealing or steam inlet temperature might provide the answer and any necessary correction of these to normal should enable the machine to return to even running.

(iii) If after a period of running it is noticed a machine will not take full load, or a load approaching full load, without vibration setting in and yet all readings are normal then coupling lock can be suspected. Flexible couplings tend to act as oil centrifuges and in time become dirty with the deposits from the oil. The remedy is to shut the machine down in order that the couplings can be examined and cleaned.

(iv) If a quick look round, whilst having the load reduced, proves all readings normal but still the vibration persists then the machine must be taken off load and shut down because a blading fault is to be suspected. Again if there were a quick rise in the Dionic reading coincident with the start of vibration then it is almost certain the L.P. blading has a fault and condenser tubing has been damaged. If this has occurred steps should be taken immediately to ensure the minimum contamination of the feed system and shut down the machine for examination.

114. The main method of utilising steam in the turbine house is in a turbine, to convert heat energy to mechanical work by driving an alternator rotor and so produce electricity at the alternator terminals.

The other uses of steam in the turbine house are:-

(i) <u>Feed Water Heating</u>. For this purpose steam is 'bled' from a number of points along the turbine casings according to the number of stages of feed heating. By doing this the latent heat is given up to the feed water instead of being lost to the circulating water; the result is a nett gain in heat and therefore of thermal efficiency.

(ii) In Evaporators. Either the Central Type which use live steam or the Bled Steam Type which are supplied by steam extracted from some suitable stage down the turbine. Evaporators are essential to provide the make up distillate for the boilers. The former type have the advantage that they may be worked whilst the turbine plant is shut down.

(iii) Domestic and Heating Calorifiers. For hot water services and heating in the accommodation, workshop and office buildings.

(iv) Auxiliary Lubricating Oil Pumps. Designed to cut in should the main oil pump pressure start falling.

(v) Emergency Steam Feed Pumps. Where installed these pumps are sometimes fitted with a pressure controlled steam valve which opens when the feed line pressure falls to a pre-determined figure.

(vi) Air Ejectors. These are steam operated and are essential to keep the condensers free from air and incondensible gases.

(vii) For Sealing the Turbine Glands. To prevent the ingress of air.

(viii) For Deaerators. It is essential that the make up feed water be free of oxygen and carbon dioxide. To do this in some systems a mechanical deaerator is fitted.

115. When warming up a turbine from cold a procedure is usually laid down according to size and type based on the Manufacturer's recommendations and previous experience with the particular machine.

In a cold machine a proportion of the steam will condense as soon as it strikes the colder metal and so great care must be taken to ensure that the casings are well drained. This also applies to the steam pipes to the set on warming up.

Where H.P. casing joint warming steam is fitted particular care as to its use, in conjunction with the gland steam, must be observed and the casing expansion reading must be regularly checked against the rotor expansion. Also regular observation of the points, where axial and radial expansion is allowed for, must be made to ensure that there is free movement.

Attention to gland steam is essential, too much at the L.P. glands will cause the casing to become hot before vacuum raising commences. When the machine is under vacuum then care must be continually exercised to see that steam is maintained at all glands. A loss of sealing steam at an H.P. or I.P. gland will allow cold air to be drawn in and a consequent risk taken of local damage being caused to the shaft.

116. Demineralisation of raw water is a process which removes almost all of the dissolved solids and gases thus making evaporation unnecessary.

The raw water is first passed through a cylinder of cation exchange material which converts all salts into acids, then through a cylinder containing anion exchange material which absorbs all the acids formed in the first cylinder so that only water, silica and carbon dioxide pass through. The carbon dioxide is then removed by passing the water through a degassing tower in which a stream of compressed air is blown

in the opposite direction; this scrubs out the carbon dioxide. The water is then passed through a mixed bed unit containing special cation and anion exchange materials mixed together. These special materials remove from the water, silica, the last traces of carbon dioxide and other impurities to give water of extreme purity, having a conductivity of less than 0.2 dionic units.

The exchange materials become exhausted after a time and when this occurs, cation exchangers are regenerated with sulphuric acid and anion exchangers with either soda ash or caustic soda.

117. With modern high pressure boilers it is essential that the condensate be kept free of all dissolved solids and gases because it is used for feed water and is returned to the boiler. The circulating water is mainly taken from canals, rivers, estuaries or the sea and so in all cases is contaminated. A leak from the cooling water side of a condenser into the condensate will cause contamination by the addition of the dissolved solids and gases through the cooling water leak. These in turn would be passed into the boiler with the feed water and could start scale forming and corrosion. This would be most undesirable and as soon as a leak is indicated the offending condenser must be isolated.

Cooling water, due to the impurities it contains, is a very good conductor of electricity whereas pure condensate is not. As soon as cooling water starts mixing, due to a leak, with the condensate this occurrence will be indicated by a rise in units on the Dionic Instrument.

To test a condenser for leaks the cooling water side is drained, the inspection doors opened and the tube ends cleared of trash. The jacks are put in under the condenser and the steam side space is filled with town's main water to which a little fluorescein dye is added.

The town's main water will find its way through the leaking tube to the water box and will carry some fluorescein with it. When light from an ultra violet lamp is allowed to fall on the fluorescein it will give off a pale green luminous coloration and in this way, the leaking tube can be readily detected.

118. In a power station boiler feed water is the subject of very close care and study. As there is always a loss due to drainage, leakage, boiler sootblowing and boiler blowdowns, this loss in the feed system has to be made up with what is generally termed make-up water. All raw waters such as town's main, borehole, river or canal are impure to some extent because they contain in solution certain solid substances such as salts and gases such as oxygen, carbon dioxide and ammonia. As this water is totally unfit to be used as make-up, for the modern high pressure boiler, in its raw state it should first be softened and then passed through an evaporator in order to obtain distillate free from all dissolved solids and gases.

In a triple effect evaporator the water to be evaporated is fed to the preheater and after being heated there passes through the feed regulator valves and enters the cone shaped base of the evaporator bodies. Live steam is expanded through a thermo-compressor into the

heating chamber of the first effect. The whole of the vapour generated in the first effect is discharged into the heating chamber of the second effect, whilst the vapour from the latter is discharged into the third effect heating chamber. Vapour pipes connect the third effect ebullition chamber to the thermo-compressor and the preheater. The larger portion of the vapour generated in the third effect is entrained by the thermo-compressor and is discharged, together with the expanded live steam, into the heating chamber of the first effect. The distilled water output is derived from the vapour condensed on the outside of the tubes of the three heating chambers and the preheater.

Provision is made so that incondensible gases are discharged automatically and continuously to a vent condenser.

A continuous blowdown is made from the lower cone of each effect through blowdown traps.

119. Although a modern alternator has a very high efficiency of 96-99% at full output, according to the size and type, it is necessary to have an effective cooling system. This is needed in order to keep the temperature within reasonable limits and to safeguard the insulation.

A 60 MW alternator at 98.5% efficiency on air cooling would have a loss of:-

$$\frac{60 \times 1.5 \times 1000 \text{ kW}}{100} = 900 \text{ kW}$$

This loss when converted into heat is equivalent to 900 - 1 kW electric fires and in order to remove this heat an efficient alternator cooling system must be provided.

The methods in use for cooling alternators are the closed air circuit and the closed hydrogen circuit.

Air Cooling

Air is circulated through the various cooling ducts in the stator and rotor by fans either attached to the rotor or separately driven. It is then exhausted below the stator frame and passes through coolers which lower its temperature before it is returned to the alternator.

Hydrogen Cooling

The hydrogen is contained within the stator and the coolers are fitted in the stator body which is built to withstand a designed pressure and all joints have to be gas tight. Where the rotor shaft leaves the casing special oil sealed glands are fitted.

The advantages of hydrogen cooling over air cooling are:-

(i) The lower density of hydrogen, about one tenth that of air at $\frac{1}{2}$ p.s.i.g. gives a reduced windage loss.

(ii) Its higher specific heat and higher heat transfer coefficient enable a reduction to be made in the actual size of the machine compared with an equivalent air cooled alternator.

(iii) Due to the reduced windage loss the noise level of the alternator is reduced.

(iv) Reduced fire risk, as pure hydrogen does not support combustion.

The disadvantage of hydrogen cooling is that the system is more complicated than for air cooling. For an alternator of 60 MW and over, however, this disadvantage is outweighed by the gain in efficiency and reduction in machine size for a given output.

The advantage of air cooling is its simplicity which makes it suitable and more economic for the smaller size machines. Its disadvantage is that it is not such a good cooling medium as hydrogen for the reasons previously mentioned.