

**REPORT ON LARGE TURBINE GENERATOR  
MAINTENANCE PRACTICES**

**Working Group 01  
of  
Study Committee 11  
(Rotating Machines)**

**1987**



# **REPORT ON LARGE TURBINE GENERATOR MAINTENANCE PRACTICES**

**Working Group 01 of Study Committee 11 (Rotating Machines)**

**Edited by J.G. Heard (Convener of WG 01)**

**Report published at the request of J. Dacier (Chairman of SC11)**

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# Report on Large Turbine Generator Maintenance Practices

By J. G. Heard

Convenor Working Group 11.01

Report published at the request of the Chairman of Committee 11  
Mr. J. Dacier

## Introduction

Preventative maintenance of generators is an important contribution to the improvement of their availability. The number and nature of the maintenance tasks as well as the periodicity depend largely upon the machine type, its design and its duty type. These practices are generally agreed between the manufacturer and the user.

The questionnaire considered minor (Type 1) and major (Type 2) outages. These were defined as:

Type 1 - Outage of not more than 3 to 4 weeks in which maintenance is carried out both outside and inside the generator by removing stationary parts but without removing the rotor.

Type 2 - Outage during which the rotor is removed to allow complete access to the stator winding and the bore.

Answers were given for 3 major types of generator; direct gas cooled rotor and stator winding, direct gas cooled rotor winding with a water cooled stator winding and a water cooled rotor and stator winding design.

The questions were intended for generalised answers that could apply to most cases, and in order to obtain comparisons of large amounts of data, basic information was required in tabular form.

The first part of the questionnaire dealt with maintenance policy, its frequency, the intervals between maintenance and how these intervals were influenced, the time normally planned for maintenance and how it is influenced. The components which dictate the intervals between maintenance were investigated and also the incidents which caused any temporary revision of planning activities. The maintenance programme duration and content for major parts of the generator were identified together with the working hours needed for major items. An attempt was made to enumerate the average figures of maintenance hours annually for each class of generator.

The final section of the questionnaire dealt with the tests made to identify the maintenance required and also carried out afterwards to confirm that the objectives had been met.

### Frequency of Maintenance

Five reasons were suggested for the determination of the frequency of generator maintenance: Type of station, nuclear or fossil, unit size, duty, age and system demand. Replies were varied, but in order of importance the frequency and duration were considered to be dependant on the type of station (nuclear or fossil), the age of the machine, its type of duty, in some cases according to a prescribed formula, with some influence from system demand and the unit size. Other reasons put forward were related experience with machines of similar design and the opportunities presented by operational problems on the system or other plant.

It is universal practice to plan a maintenance outage of the generator in the first period of operation, after one or two years or upto 10,000 hours service. In the majority of cases the rotor is removed for this inspection, but sometimes this decision is guided by sample inspections of other machines in a multi-unit station.

### Types of Maintenance

Two types of maintenance were considered, those in which the rotor remains in the stator and those when it is removed. In the first case, when the rotor remains in the machine, the intervals between maintenance vary between six months to three years, with one answer stretching to four years. In the majority of countries the interval lies between one to two years. An even wider variation appears when the fuller maintenance with the rotor removed is considered. In this event most maintenance is carried out over a three to five year cycle, but this can stretch to eight, nine or ten years.

These intervals are mainly chosen to fit in with outages or operations on other plant, usually the boiler statutory outage, or in the case of nuclear units, reactor re-fuelling. A significant number of countries consider that the maintenance interval does not depend upon the generator itself. Where it does the main criteria is the number of hours run and the number of starts. In addition to the influence of the inspections on similar plant in the station, one reply also notes that intermediate diagnosis inspections are becoming a major factor whereby these results are used to postpone or advance the planned overhauls. In summary, three levels of inspection appear to be being operated; time related, time and duty related according to a formula, and condition related, all of which can be influenced by maintenance on an opportunity basis caused by system failures or faults on other plants.

### Duration of Maintenance

As may be expected from the considerations of the major influence of other plant on the generator maintenance, the time allowed for short term maintenance outage with the rotor assembled varies over a wide range from one half to eight weeks, with the majority lying between one to four weeks. Maintenance with the rotor removed usually lasts from four to thirteen weeks with the average around eight weeks. There is no particular correspondence between the intervals for the two types of maintenance, generally a rotor out maintenance is between two and three times the period for a rotor assembled maintenance. Again the time allowed for these maintenance activities is dictated by the times required for the boiler or other major power plant equipment, or reactor re-fuelling. Generally the time allowed for either maintenance does not follow a defined formula, but depends upon the experience of each utility.

When the generator does dictate the maintenance period, the principal reason given is to attend to the stator winding slot wedging and endwinding support. The next most common reasons are bearing, seals and brushgear. In only one case are rotor endrings mentioned (a parallel study has been made on this topic in an associated report).

Even though the generator may not dictate the intervals between maintenance and its duration, and although utilities may follow intervals between well defined strategies, nevertheless instances may occur which give rise to temporary revisions to the planned maintenance. Twenty-nine different instances were reported (see Table 1.4.4). The most common reported incidents are out of phase synchronizing, heavy short circuit, rotor winding earth fault, stator winding water leakage and hydrogen leakage, loss of cooling and hydrogen shaft seal failure. Notably stator winding earth fault was given as a reason by only one country which indicates the reliability of modern stator winding insulation systems. Out of phase synchronizing required an immediate short duration shutdown for inspection (without removing the rotor) but in some cases this could be extended to an inspection with the rotor removed. Stator coil faults, stator earth faults and unbalanced load or short circuit are additional causes for immediate shutdown and removal of the rotor.

There are a variety of reasons reported for bringing short duration maintenance forward to the next shutdown. These are indicated on the table but no clear pattern emerges. Out of phase synchronizing is quoted as a reason for bringing short duration maintenance forward to the near future, but the small number of replies does not give this answer much reliability. Maintenance with rotor removed is advanced to the next shutdown for rotor winding earth faults and faults which give heavy stressing of the machine such as out of phase synchronizing, short circuit and switching in an un-excited unit. Insufficient answers were given for advancing such a maintenance to the near future as any such incidents requiring rotor removal would require either action immediately or as soon as possible.

#### Frequency of Maintenance by Component Identification

Respondents to the questionnaire were asked to indicate how often maintenance is carried out for each component examined or tested. A large number of components were identified and these are shown in Table 2.1. It is difficult to summarise such information. It is a source of information into which the reader may enquire for his own purposes.

If there is excessive delay in the application of maintenance to a generator then faults may occur which could have been avoided. In the experience of the Working Group the major areas in which these faults may show themselves are stator winding insulation damage due to excessive vibration caused by loosened slot wedges, overheating of the stator winding due to corrosion products caused by leaks in gaskets or seals, stator endwinding looseness, damage to stator core ends, rotor wedge cracking and conductor wear, stress corrosion of endrings, bearing and seal damage and slipping flashover. In most cases the faults evolve progressively with the exception of stator bar insulation damage causing sudden failure, and slipping flashover.

#### Maintenance Planning

The Working Group studied the maintenance programme duration and content for eight major parts of the generator. This information is given in detail in Table 3.1.

There is a marked variation between the answers. In the case of rotors the inspection time varies between twenty hours up to five weeks. The usual checks are impedance, insulation resistance, winding resistance, NDT of retaining rings and gas leakage check. Single countries also report high voltage checks, RSO tests for interturn shorts, and NDT of the rotor wedges.

Stator inspections vary between a few days and up to five weeks, although the work content given does not give an indication why there should be such variation. Tests reported are stator core and wedge tightness, endwinding tightness, flow tests of stator bars, core through bolt insulation resistance, winding insulation resistance, in some cases the winding loss tangent and two countries report carrying out partial discharge tests.

Other information on the brushgear, excitation equipment, auxiliary systems, bearings and seals, and shaft insulation is included in the table.

### Work Content of Maintenance Activities

The Working Group tried to identify the working hours needed for the major items of a long term outage involving rotor withdrawal, inspection, and rotor reassembly. Again the answers vary considerably, some were given in elapsed time and others in required man hours. In general it can be stated that rotor withdrawal and assembly may take between 350 to 600 hours, but the interval allowed for inspection varies widely.

In most cases maintenance times are not recorded for the generators separately from other plant, however estimates were made from 100 hours to 800 hours approximately, with a majority lying between 400 and 600 hours.

In service the condition of major components requiring maintenance tasks is identified by the monitoring provided. The reader is directed to the report on operational monitoring published in "Electra" No. 96 October 1984. In general these measurements comprise, in addition to the elapsed time and on-load hours, a vibration survey, temperatures of all major parts, hydrogen consumption and leakage, coolant leakage, slipping and brush wear rate.

### Monitoring to Determine Maintenance Required

Tests made prior to or at shutdown to check the state of plant constitute an evaluation of the operational data together with diagnostic tests such as the rundown vibration signature, impedance/speed characteristic, measurement of insulation resistances, rotor thermal balance, e.g. bearing vibration/MW and MVAR, no-load characteristic, airgap search coil and RSO tests. Partial discharge of the stator winding insulation and high voltage tests are recorded by only one or two countries.

Having carried out the required maintenance it is necessary to confirm that the objectives have been met. These tests for major parts of the generator are shown in Table 3.6. All countries check stator wedge tightness and two specifically mention vibration tests to do this. Stator endwinding tightness is checked by all and two countries (not the same two that vibration check stator wedges) carry out a resonance test on the endwinding. Stator core tightness is checked by the majority, and one country refers to a sound propagation test. Half of the replies indicated that a core ring flux test would be made, some only if a repair had been carried out. Stator insulation tests consist mainly of insulation resistance and loss tangent or partial discharge tests. H.V. tests would only be applied if some maintenance had been carried out and in some cases, for diagnostic purposes. The same philosophy applies to the rotor winding insulation where H.V. tests are made

if the winding insulation is repaired, otherwise the check relies upon the measurement of the insulation resistance. Coolers are checked by air leakage and hydraulic pressure tests, and the stator winding cooling water system by leakage, pressure and flow tests. Shaft insulation is always tested, in one case with a shaft current transformer. The excitation system is checked and operational checks are carried out on the voltage regulation system.

Questionnaire 84/3

Large Turbine Generator Maintenance Practices

1. Maintenance Policy

1.1 Frequency of Maintenance

Is the maintenance frequency and duration dictated by e.g.

- a) Nuclear, coal, oil or gas fired type stations.
- b) Unit size.
- c) Unit duty i.e. base load, two shifting (peaking).
- d) Age of machine.
- e) System demand.
- f) Any other reason.

**Australia** : Coal fired, base load plant. Influenced mainly (f) by service hours. Reports from OEM or other utilities.

**Belgium** : No to all a) - f).

**Canada** : a) Nuclear less maintenance than coal fired, but have more major spares.  
b) Not much effect.  
c) Little effect.  
d) Not much effect.  
e) Yes. Plan to avoid winter peak.  
f) Experience, opportunity, supplier, proven or unproven design.

**Czechoslovakia** : a) Yes  
b) No  
c) Yes in principle.  
d) No  
e) No  
f) Planned reconstruction.

France : a) Yes, to the Table:

	<u>Type 1</u>	<u>Type 2</u>
Fossil	1 year	6 years *
Nuclear	1 year ** or more	5 years *

\* General overhaul dictated by administrative requirements.

\*\* 12 to 18 months according to duration of re-fuelling policy.

Germany : a) Basically no; nuclear, some adaption to the refuelling cycle.  
b) No  
c) No, based on equivalent operating hours, see 1.3.2.  
d) No  
e) Sometimes  
f) Sometimes on request of insurance companies; experience with other machines of identical design.

Hungary : Replies made relate to nuclear units for which a defined maintenance programme exists.

India : These are the majority answers from 20 utilities and 1 manufacturer.  
a) Generally No.  
b) No  
c) Mainly no.  
d) Yes  
e) Generally no.  
f) Minority opinion based on set maintenance frequency or an operational problem.

Italy : f) Hours of operation.

Japan : Maintenance frequency is 2 years for a), b), c). 2 years base load, 1 year 2 shifting, and d).

Answers are for D.D. and D.L.

Poland : c) and d) for D.D. and D.L.

South Africa : b)

Sweden : Answers relate to D.L. and L.L.  
a), e), d) in order of importance.

Switzerland : Answers are for D.L.

a), d), e) most important. f) intermediate inspection may influence programme change.

U.K. : a) Due to statutory inspection requirements differing between nuclear and fossil fired plant.

U.S.A. : a) No

b) No

c) Yes

d) Yes

e) No

f) Occasionally

U.S.S.R. : (a, b, c, d) Maintenance frequency and duration is basically the same for all types of stations (including nuclear) and generators identical in design. Some differences depend on turbogenerator rating and type.

(e, f) Change in frequency allowed due to faults in power system or assemblies and systems of units.

1.2 Is it the usual practice to plan a maintenance outage of the generator after the first period of operation? (e.g. 1 to 2 years).

1.2.1 Is the rotor removed for this inspection?

	<u>1.2</u>	<u>1.2.1</u>
Australia	: Yes	No - but guided by a rotor out sample inspection of 1 machine in a multi unit station.
Belgium	: Yes	Yes
Canada	: Yes	Yes
Czechoslovakia	: Yes, 1 years warranty or nuclear first refuel.	Yes
France	: Yes	Yes
Germany	: Yes between $10^4$ and $2 \times 10^4$ hours. Note 1.	Yes
Hungary	: Yes, 1 year.	Yes
India	: Yes	Generally no.
Italy	: 6000 - 10000 hours	No.
Japan	: Yes, 1 year	Yes
Poland	: Yes	Yes
South Africa	: Yes	Sample inspections on first 2 machines in multi unit station, remainder conditional on sample results.
Sweden	: No if diagnostic test. : Otherwise rotor removed.	Yes
Switzerland	: Yes	No, if diagnosis test made. Otherwise rotor is removed.
U.K.	: Yes	Sometimes
U.S.A.	: Yes, 1-1½ years	Recommended
U.S.S.R.	: Yes, 8000 hours	Yes

Note 1 Equivalent hours quoted, according to "VEDW Recommendations for Intervals Between Generator Inspections".

1.3 What are the planned intervals between maintenance overhauls for:

- a) Type 1 maintenance
- b) Type 2 maintenance

	<u>Type 1</u>	<u>Type 2</u>
Australia	: 1½ to 2 years	8 years
Belgium	: -	4 tending to 6 years
Canada	: 2 - 4 years	5 - 10 years
Czechoslovakia	: 1 year	4 years
France	: See Table to Question 1.1.	
Germany	: Conditional (1-2 years)	Equivalent 40000 to 60000 hours According to VDEW Recommendations
Hungary	: After 10 months, 2 months maintenance.	3 years
India	: ½ year to 2 years	2 - 5 years
Italy	: 3 years or 20000 hours	60000 or 9 years
Japan	: 2 years	4 years
Poland	: 1 year	4 years
South Africa	: 2 years after Type 2	4½ years
Sweden	: Up to 10000 hours	Up to 40000 hours
Switzerland	: Te - 25000 hours	50000 Te hours
U.K.	: 3 - fossil, 2 - nuclear	6 - fossil, 4 - nuclear Conditional on load factor.
U.S.A.	: 12/13 months or as required.	Approximately 5 years
U.S.S.R.	: As required. (Practically 6-12 months).	5 years

1.3.1 Are these dictated by:

Other plant outages or operations, such as boiler maintenance or refuelling outages.

- Australia** : Yes, boiler statutory inspections and outages for other plant such as turbines and boilers.
- Belgium** : No, but scheduled as a function of other operations with a minimum theoretical delay of 4 years.
- Canada** : Frequently boiler maintenance.
- Czechoslovakia** : Generally yes.
- France** : Compulsory administrative boiler visits and refuelling outages.
- Germany** : Try to make inspections during outages of other major components or refuelling.
- Hungary** : Reactor refuelling.
- India** : Nearly always depends on boiler or turbine outage.
- Italy** : Not dictated by, but connected with.
- Japan** : No
- Poland** : No
- South Africa** : Statutory inspections on other plant.
- Sweden** : Yes
- Switzerland** : Yes, and by system demand.
- U.K.** : Boiler statutory inspection interval.
- U.S.A.** : Yes, usually.
- U.S.S.R.** : Yes, whenever possible coincident with major power equipment.

1.3.2 If intervals between maintenance outages are dictated by the generator, how is this evaluated, for example by:

- a) The hours run since last maintenance outage.
- b) Number of starts.
- c) MW hours generated.
- d) Any other criteria.

**Australia** : Planning is based on a) in practice, advantage is taken of outages occurring for other plant especially for Type 1 maintenance and to a lesser extent for Type 2.

**Belgium** : Number of years.

**Canada** : Partly but mostly performance of the 'family' of units to date.

**Czechoslovakia** : a)

**France** : Interval does not depend on generator.

**Germany** : a) and b). Work to VDEW formula or equivalent operating hours. (20 hours per start).  
d) In addition abnormal disturbances necessitate shortening of inspection interval or an immediate check.

**Hungary** : Refer to answer to 1.3 a), Type 1 maintenance.

**India** : 13 utilities feel the maintenance interval does not depend on the generator.

**Italy** : a)

**Japan** : a) and b)

**Poland** : a)

**South Africa** : Not applicable - see 1.3.1

**Sweden** : Interval or duration does not depend on generator.

**Switzerland** : a) and b) - to some extent.  
c) No  
d) Intermediate diagnosis inspections are becoming a major factor. According to these results planned overhauls may be postponed or advanced. The conservative time related practice is being changed towards a condition related practice.

**U.K.** : Virtually never dictated by generator.

**U.S.A.** : In cases where dictated by generator, would be a), b).

**U.S.S.R.** : Turbogenerators do not determine maintenance outage planning in fossil and nuclear power stations.

1.4 How much time is normally planned for:

- a) Type 1 maintenance
- b) Type 2 maintenance

	<u>Type 1</u>	<u>Type 2</u>
Australia	: 4 weeks	8-12 weeks (conditional on work and resources)
Belgium	: -	5 weeks for a 4 years maintenance 8-10 weeks for a 6 years maintenance.
Canada	: 1-2 weeks Nuclear 1-4 weeks Fossil Nuclear = 21 shifts/week, Fossil 10 shifts/week.	4-5 weeks Nuclear 4-8 weeks Fossil
Czechoslovakia:	1 to 3 weeks	8 to 12 weeks
France	: 1 to 2 weeks Duration not dictated by generator.	6 to 7 weeks.
Germany	: 1 to 4 weeks	6 to 9 weeks
Hungary	: 8 weeks	8 weeks
India	: 2 to 6 weeks	4 to 13 weeks
Italy	: 4 weeks	7 weeks
Japan	: 4 to 6 weeks D.L. 4 weeks D.D.	8 to 12 weeks D.L. 6 to 12 weeks D.D.
Poland	: Up to 4 weeks	Over 4 weeks, conditional on generator condition.
South Africa	: 50 hours (Nett inspection time)	500 hours
Sweden	: 2 weeks	3-4 weeks
Switzerland	: 2-4 weeks	6-8 weeks
U.K.	: 5 to 8 weeks	8 to 12 weeks
U.S.A.	: 3 to 6 weeks (But can be usually dictated by other plant maintenance)	8 to 12 weeks
U.S.S.R.	: 3 to 7 weeks	Up to 8 weeks

1.4.1 Are these allowable times dictated by other plant components such as boiler or turbine.

Australia : Usually yes.

Belgium : Yes

Canada : No, although the planned outage time and extent of work is frequently dictated by other plant components.

Czechoslovakia : Mostly yes.

France : Yes.

Germany : Reactor fuelling tries to influence generator inspection.

Hungary : Dictated by reactor.

India : Most consider dictated by boiler or turbine.

Italy : Yes

Japan : Yes

Poland : Yes

South Africa : Yes

Sweden : Yes

Switzerland : Mostly yes.

U.K. : Yes

U.S.A. : Yes, generally.

U.S.S.R. : Scope and duration of turbogenerator overhaul is adjusted to the length of major power equipment repair.

1.4.2 Do the criteria for maintenance times follow any defined formulae?

Australia : No

Belgium : No

Canada : Yes a minimum of 2 to 3 weeks is needed to remove and replace a rotor.  
Outage times improve with staff experience of plant.

Czechoslovakia : Given by experience.

France : No

Germany : No

Hungary : No answer.

India : Generally no.

Italy : No

Japan : Yes

Poland : No

South Africa : Yes - ESCOM plant maintenance strategy.

Sweden : Not really. In nuclear station a practice seems to have been established that every second maintenance overhaul has a long duration.

Switzerland : No. Work to VDEW type formula with own criteria for types of overhaul periods.

U.K. : No

U.S.A. : No

U.S.S.R. : Defined by labour requirements for planned work in accordance with specification.

1.4.3 If the intervals between maintenance outages are dictated by the generator, what are the components of the generator which are important? (e.g. is the risk of incidents increased if the time between overhauls is extended).

Australia : All major components of the generator. Not possible to quantify level of risk for each component.

Belgium : Stator slot wedging. Rotor endrings.

Canada : Rotor exchange 2 weeks - Stator exchange 4 to 8 weeks.

Czechoslovakia : The stator winding.

France : Stator endwindings - (annual Type 1 inspection).  
Stator winding slot part - (wedge check and tightness of slot part every 5 to 6 years).

Germany : All major components of the generator.

Hungary : No answer.

India : Shaft seals. Stator winding cooling system. Tightness of slot wedges. Rotor cooling ducts. Sliprings. Terminal bushings. Rubber gaskets. Winding insulation. Bearing insulation.

Italy : Stator winding wedging.

Japan : Rotor assembly. Stator winding. Bearings. Shaft seals.

Poland : Stator endwinding support. Stator core end portions.  
Stator core suspension.

South Africa : Not applicable.

Sweden : Not applicable.

Switzerland : Endwinding support. Bearings. (Modern diagnostic systems avoid the risk at increased intervals).

U.K. : Not applicable.

U.S.A. : Stator winding, wedging.

U.S.S.R. : Critical assemblies are those subject to mechanical wear (brushgear, bearings, shaft seals etc).

Notation for Questions 1.4.4 and 1.4.5

1. Out of phase synchronising.
2. Heavy short circuit, close up system fault.
3. Unbalanced short circuit.
4. Switchgear fault.
5. Switching in unexcited unit.
6. Asynchronous running with substantial output.
7. Overloading.
8. Rotor winding earth fault.
9. Stator winding earth fault.
10. Stator core fault.
11. Loss of cooling.
12. Stator winding water leakage.
13. Hydrogen leaks.
14. Shaft current damage.
15. Hydrogen shaft seal failure.
16. Slipring vibration and sparking. Brush wear.
17. Critical fastening components.
18. Shaft vibration.
19. Abnormal noise.
20. Bearings (loss of lubrication)
21. Overspeed due to turbine control fault.
22. Mechanical incident.
23. Auxiliary system faults.
24. Hydrogen gas consumption.
25. Vibration on component parts.
26. Fault in thermal monitoring of stator winding.
27. Water in casing.
28. Unbalanced load.
29. Problems or unusual occurrences on similar units.

NOTES TO Q. 2.1

1. Italian answer is in operational hours, where 20000 hours is equivalent to 3 calendar years.  
  
Answers are given for DD and DL and only where these differ the two different figures are shown.
2. Answers were asked for in calendar hours. Where these were given in calendar years they have been converted to hours by 1 year equivalent to a rounded off 8000 hours.
3. Japan answer for DD and DL and only shown where different.
4. Poland. Information for DD and DL. Yearly intervals approximated to 8000 hours.
5. South Africa gave answers related to Type 1 or Type 2 maintenance. These answers have been converted to hours on the basis of answer to Question 1.3 a) and 1.3 b), that is Type 1 is 27 months, equal to 18000 and Type 2 54 months equivalent to 36000 hours.
6. U.S.S.R. gave answers in terms of "maintenance overhauls" (MO) and overhauls (O). It is deduced from previous answers that these occur at 5-12 months (MO) and 5 years (O).
7. U.S.A. gave answers based on 8800 hours/years and these have been left in this form.

2.2 Please indicate the kind of faults which have resulted from excessive delay in application of maintenance.

2.3 Did the faults in 2.2 evolve progressively or suddenly?  
(P = Progressively - S = Suddenly).

	<u>2.2</u>	<u>2.3</u>
Australia	: AVR faults. Excitation excursions. Breaking off resistors connected between stator winding hydrogen cooling tubes and stator windings.	P
Belgium	: None	-
Canada	: Excessive gas in coolant leakage leads to winding failure, excessive temperature or vibration leads to seal or bearing damage.	P
Czechoslovakia	: No convincing example.	-
France	: None. Policy is to provide preventive maintenance.	-
Germany	: Loose slot wedges in older machines, vibration of stator bars caused insulation damage. (Breakdown S) Flashover on sliprings caused by brush dust, total lack of maintenance. Flow restriction of water cooled stator bars. Corrosion products caused by oxygen ingress through leaks at flange gaskets and pump seals or changes of water condition. Loose endwindings.	P S P P
Hungary	: Failure to replace seals caused hydrogen leakage.	P
India	: Damage to shaft seal. Loose slot wedges. High vibration of bearing leading to failure. Leakage of stator winding water path. Increase of stator endwinding vibration.	P
Italy	: None	-
Japan	: Stress corrosion cracking of endwinding retaining ring. Rotor wedge cracking. Rotor conductor wear. (The above answers for both DD and DL).	P
Poland	: Stator endwinding support damage. Stator core end portion damage. Stator core suspension damage. Bearing and seal white metal damage.	P
South Africa	: None.	-
Sweden	: None.	-
Switzerland	: Damaged bearings, brush and sliprings, windings, shaft insulation.	P
U.K.	: Excessive stator endwinding support slackness.	P
U.S.A.	: Endwinding looseness. Damage to core ends.	P
U.S.S.R.	: No answer given.	

3. Maintenance Planning

3.1 Please identify maintenance programme duration and content, and special checks for:

- a) Rotors
- b) Brushgear and Sliprings
- c) Stator
- d) Excitation Equipment
- e) Auxiliary Systems
- f) Bearings
- g) Seals
- h) Shaft Insulation/Shaft Earthing

Notation for Q. 3.1

Rotors	Crack test retaining rings	NDT Ret (dye penetrant, ultra- sonic)
	Crack test wedge	NDT w
	Wedge tightness	WT
	Slipring lead tightness	SR lead
	Winding insulation cleanliness	W clean
	Insulation resistance measurement	I.R.
	Winding impedance measurement	Z
	General inspection	Vis.
	Bearing insulation	B I.R.
	Air or gas leakage check	G
	Fan blade checking	F
	Winding resistance	R
	H.V. test	H.V.
	Runout check	Run
	Recurrent surge oscillograph test of winding turn insulation	R.S.O. or interturn if method not specified
	X-Ray of elastic joints	X-Ray
	Brushgear and Sliprings	Check brush wear
Check current sharing		J
Sparking check		S
Clean		C
Slipring grinding		SG
Changing polarity		P
Brush changing		BC
Brush spring pressure check		BS
Stator	Endwinding tightness	EWT
	Core end iron tightness	CT
	Leak test (stator water system)	L
	Core hot spots or ring flux test	CH
	Core through bolt insulation	T1R
	Partial discharge test	PD
	Check temperature detectors	TC
	Frame/supports	SM
	Terminals/bushings check	T
	White metal check	WM
	Dye penetrant test	DP
	Outboard end shaft voltage	SV

3.2 Please identify working hours needed for the major items in a maintenance outage Type 2 e.g. rotor withdrawal, inspection and reassembly.

**Australia** : Not sufficient data.

**Belgium** : Rotor withdrawal and reassembly.  
 125MW                      250/300MW                      500MW                      1000MW  
 800 m.h.                      1500 m.h.                      4000 m.h.                      6000 m.h.  
 (Calendar time not greater than 5 weeks)                      (Daily working time 2 x 12 hours)

**Canada** : Rotor withdrawal                      150 hours  
 Rotor inspection                      150 hours  
 Stator inspection                      150 hours  
 Reassembly                      150 hours  
 Up to 850 hours to inspect endrings (removed) and rewedge stator windings.

**Czechoslovakia** : Rotor withdrawal and assembly 360 hours (estimated).

**France** : Rotor withdrawal and assembly 6/7 weeks.

**Germany** : Depends on design, manufacturer and special power plant conditions. Varies between 3000 and 15000 m.h. (15000 m.h. in the case of BWR stations).

**Hungary** : Not recorded separately.

**India** : Rotor withdrawal                      36/72 hours  
 Rotor maintenance                      120 hours                      (15 days)  
 Bearing inspection                      128 hours  
 Shaft seal assembly                      48/96 hours                      (25 days)  
 Auxiliary system                      240 hours                      (30 days)

**Italy** : Rotor withdrawal                      150 hours  
 Machine reassembly                      300 hours

**Japan** : Rotor withdrawal                      26 m. days  
 Rotor inspection                      304 m. days  
 Rotor reassembly                      26 m. days

**Poland** : Rotor withdrawal                      4 days  
 Rotor reassembly                      5 days

**South Africa** : Stator                      500 hours

**Sweden** : Stator wedges & core ring flux test. Endring U/S test.  
 Visual inspection airgap surfaces, all with rotor in situ,  
 in 6 calendar days. 1500 m.h (for a BWR)

**Switzerland** : Rotor withdrawal, in-                      1500 hours  
 spection and reassembly

**U.K.** : Rotor withdrawal, in-                      1088 m.h.  
 spection and reassembly.  
 Wedge tightening.                      1562 m.h.

**U.S.A.** : Rotor withdrawal                      2100 m.h.

**U.S.S.R.** : No answer given.

3.3 Are maintenance times recorded separately from other plant items?  
If so could you give the average figures in calendar hours/year for  
each class of generator. If not available can you give estimated,  
(with E after figures)?

Australia : No answer

Belgium : No answer

Canada : Yes. Fossil 140 hours Nuclear 90 hours (E) generator only.

Czechoslovakia : 720 hours (E).

France : Not recorded separately.  
Type 1 1/2 weeks (E)  
Type 2 6/7 weeks (E)

Germany : Data not available.

Hungary : Maintenance times must be within about 400 hours.

India : No separate time recorded. 40 days (E).

Italy : Yes. 400 calendar hours DD(E)  
600 calendar hours DL(E)

Japan : No answer.

Poland : No data available.

South Africa : No data available. 165 hours/year (E).

Sweden : Yes. 500 hours/year (E).

Switzerland : No answer.

U.K. : Yes. 830 m.h. maximum for slipring machine.  
400 m.h. (E) for brushless machines.

U.S.A. : Between 110/500 m.h.

U.S.S.R. : No answer given.

3.4 What measurements are made in operation to identify the state of the major components or need for a maintenance task in table in Question 3.1? e.g. on-load hours, number of starts.

- Australia** : Vibration, temperature surveys. Liquid detection operation, differential pressures. Shaft voltages, brushgear inspection, hydrogen leak rates. AVR performance. Seal oil flows etc.
- Belgium** : See Table 1V to Monitoring Questionnaire.
- Canada** : Elapsed time, alarm and vibration levels, temperature of windings, coolers, bearings, seals, partial discharge measurement.
- Czechoslovakia** : On load hours.
- France** : Shaft vibrations, bearing temperatures, stator winding temperatures and operation data.
- Germany** : a) Data evaluation of the normal monitoring system during operation.  
b) Condition checks for entire equipment e.g. leaks, broken instruments, vibration, noise etc.  
c) Operating hours, number of starts.
- Hungary** : Gas fault analysis twice a year.  
Bearing vibration.
- India** : On load hours. Temperatures of critical components. Hydrogen consumption. Bearing vibration. Filter pressure drops.
- Italy** : On load hours. System fault records.
- Japan** : Shaft vibration, winding temperatures, on load hours, number of starts for both DD and DL.
- Poland** : Bearing and shaft vibrations, winding temperatures. Stator winding water and gas temperatures, water flow and conductivity, gas to water leakage, frame liquid leakage, brushgear temperature, excitation, seal temperatures and pressures. Bearing and seal temperatures. Shaft voltage.
- South Africa** : Vibration, flow and differential pressures and chemical analysis of coolant, temperatures, hydrogen leakage, slipping and brush wear rates, excitation current.
- Sweden** : Temperatures, vibrations, leakage rates.
- Switzerland** : Vibrations, different operating parameters by diagnosis tests (e.g. temperature, shaft voltages/currents).
- U.K.** : None. The generator is expected to operate between planned outages without any maintenance requiring a shutdown.
- U.S.A.** : Rotor vibrations, field temperature. Air gap flux probe. Brushgear arcing by EMI monitor, stator temperatures, end-winding vibration by fibre optics. Core noise level. Operating parameters of bearings, seals, auxiliaries. Shaft insulation.
- U.S.S.R.** : The state of the major components in operation is identified by means of operational monitoring system (see answers to the Questionnaire on Operational Monitoring).

3.5 What tests are made prior to, or at shutdown to identify the state of plant before any disassembly?

- Australia** : Tests as in 3.4. Also RSO, in some cases - electrical tests.
- Belgium** : None.
- Canada** : Note alarm readings, deviation reports, station log. Compare full load readings with reference (base line) readings all instruments. Partial discharge readings of stator windings.
- Czechoslovakia** : Rotor vibrations, sometimes rotor thermal unbalance test (vibration response following sudden change). Rotor impedance sometimes no load characteristic.
- France** : General recording of operational data:- vibrations, temperatures, flow rates, chemical measurements, electrical, leak rates. Run down vibration signature.
- Germany** : Evaluation of data. Operation event history, wear and deterioration of components, deterioration of running behaviour. Frequency of load rejections and associated overspeeds. Rotor earth or interturn faults. Hydrogen water or cooler leaks. Change in coolant flow rates. Shaft insulation deterioration.
- Hungary** : Measurement of insulation resistance.
- India** : Prior to shutdown. Impedance/speed. Run down time, bearing vibration. At shutdown. Stator and rotor winding I.R. and d.c. resistance, rotor interturn faults. Stator tan delta, hydraulic test, leakage test. Slipring wear, ovality.
- Italy** : Prior to or at shutdown - rotor dynamic impedance. After shutdown - stator H.V. d.c. test.
- Japan** : Gas leakage test.
- Poland** : Bearing vibration/MW and MVAR, no load characteristic, heat run, stator winding I.R (DD only), H.V. d.c. resistance, coolant leakage (DL only), rotor winding I.R. impedance, d.c. resistance, excitation system I.R. shaft insulation, gas cooler leakage.
- South Africa** : Answer as for Q. 3.4.
- Sweden** : Temperatures, vibrations, leakage rates.
- Switzerland** : Diagnosis, operating parameters such as temperatures, vibrations, excitation, coolant flows, shaft currents etc.
- U.K.** : Rotor interturn tests. (Air gap search coil and R.S.O.) Rotor I.R. No load characteristic. Bearing vibration.
- U.S.A.** : Generally none, see data in answer to 3.4.
- U.S.S.R.** : Bearing vibration, load and no load. Bearing insulation. Gas leakage. Rotor I.R. at speed. After shutdown stator winding I.R. whilst hot and H.V. test prior to cleaning.

1.4.4. What incidents have caused a temporary revision to the planned maintenance e.g. system faults.

1.4.5 Which of these incidents in 1.4.4 required:-

Incidents	Type 1			Type 2		
	Immediate	Next Shutdown	Near Future	Immediate	Next Shutdown	Near Future
Australia : 1,4,5,8,13,14	1,4,14	13			5	
Belgium : None						
Canada : 1,8,10,15	1,15			10	8	
Czechoslovakia : 1,2,6	Depends on severity of incident and symptoms					
France : 1,2,11	1	1 less severe 23	1 less severe 23	1 severe. After Type 1 inspection		
Germany : Not specified in answer as diversity of circumstances are felt to be beyond scope of Questionnaire						
Hungary : No answer						
India : 8,9,12,14,15,16,17	12,15	14,16		9,17	8	
Italy : 1,2	1,2	According to severity			1.2	
Japan : 1,2,13,16,18,19,24	13,18	19,24		1,2		
Poland : 1,3,7,11,15,20,21,23	11,15,20	7,23	1	3,21		
South Africa : Nil						
Sweden : 12		25		12	25	
Switzerland : 1,3,22	22		1			3
U.K. : Use unplanned non-generator outages to perform generator maintenance ahead of schedule.						
U.S.A. : 2,13,29	1,2,6	29			29	
U.S.S.R. : 1,2,8,9,12,16,20	16,20	-	-	1,2,9	8,12	-

2.1 Frequency of Maintenance by Components

Please indicate in the table below how often maintenance is done for each component examined or tested. Please add any other components which should be included. Answers should show the statistical (or usual, or average) frequency and not any special or single instances.

	Australia	Belgium	Canada	Czech	France		Germany	Hungary	India	Italy
					Nuclear	Fossil		Nuclear Only		Operation Hours
Bearing Inspection	2-4 yrs	4 yrs	50000	24000	8/10000	6/8000	25/60000	8000	8/24000	20000
Bearing Replacement	As Required	Never	100000	48000	As Required		On Condition	On Condition	As Required	> 60000
Insulation Against Shaft Currents	2 yrs	4 yrs	500	24000	8/10000	6/8000	25/60000	170		20000
Hydrogen Seal Insp.	4-6 yrs	4 yrs	50000	24000	"	"	50/60000	8000	7/35000	20000
Hydrogen Seal Rep.	As Required	Rarely	100000	24000	As Required		On Condition	Rarely	As Required	60000
Endwinding Tightness	1½ to 2 yrs	4 yrs	50000	24000	35/40000	45/50000	25000	8000	8/32000	> 20000 DD > 60000 DL
Stator Wedge Tightness	8 yrs	4 yrs	50000	24000	"	"	50/60000	24000	8000 then 30000	60000
Stator Core Insp.	Core Back 2-4 yrs Full 8 yrs	4 yrs	50000	24000	"	"	"	"	"	60000
Stator Core Ring Flux Test	As Required	Never	100000	After repair only	In case of incident		Exceptionally	Not Usual	No or 30/60000	Not Usual
Stator Core Tightness	8 yrs	4 yrs	50000	24000	35/40000	45/50000	50/60000	24000	No or 15/40000	20000
Rotor Withdrawal	8 yrs	4 yrs	50000	24000	"	"	"	"	25/40000	60000
Rotor Trim Balancing at Site	As required	Never	25000 2pole 50000 4pole	As Required	As Required		On Condition	Not Usual	No or as required	Not Usual
Rotor Body/Tooth/Shaft Inspection	8 yrs	4 yrs	100000	24000	35/40000	45/50000	50/60000	24000 and 8000	30000	60000
Rotor Blower or Fan Inspection	8 yrs	4 yrs	100000	"	"	"	"	8000	"	20000
Rotor Endring Examination (Ext)					As Required					
(i) - Rotor In	No	-	Not Yet	No			"	8000	-	20000
(ii) - Rotor Out	8 yrs	4 yrs	50000	24000	35/40000	45/50000	"	24000 U/S & Magnetic	8000 then 30/40000	60000
Rotor Endring Removed for Exam.	Yes	Never	100000	48000	-	-	Only if U/S Indication	50000	30/35000	Not Usual
Stator Frame/Supports/Endshields	4-8yrs usually 2yrs exceptionally.	4 yrs	100000	24000	-	-	50/60000	8000	As Req. or 30/40000	60000
Brushgear & Sliprings	Weekly Annually	-	500	Weekly 6000	3/10000	6/8000	No general answer	700	Monthly 8/10000	20000
Shaft Insulation	Weekly	4 yrs	500	24000	"	"	25/60000	168	300 to 30000	20000
Rotor Insulation Resistance Test	2 yrs	4 yrs	10000	6000	"	"	12000	8000	8/30000	6000

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Q. 2.1

	Australia	Belgium	Canada	Czech	France Nuclear	Fossil	Germany	Hungary Nuclear Only	India	Italy Operation Hours
Rotor Winding H.V. Test	Not Usually	Never	Only after repair 100000	After repair	-	-	) Very rarely	Not Usual	No or 30000	-
Rotor Winding Impedance Test	2 yrs	Never	-	24000	-	-	) in case of abnormal	24000	8/30000	20000
Stator Winding H.V. Test	Not Usually	4 yrs	Only if Problem	"	-	-	) condition	Not Usual	No or 30/40000	20000 DC
Tan Delta	2 to 3 yrs	Never	N/A	"	-	-	Rarely	Not Yet	7.5/40000	Not Usual
Partial Discharge	1 Utility 2 to 3 yrs	Never	50000 10000 in Future	Not Usual	First Outage	Planned Only	No	Not Yet	Generally No	Not Usual
Any Other Tests on Rotor or Stator Winding:										
a)	RSO Rotor 2 yrs	Stator Connections	D.C. Leakage	D.C. Leakage 24000	P.I if Necessary	P.I if Necessary	Damper Wedges 50/60000	Stator IR 8000	Stator Resis. 8000	Rotor Resis. 20000
b)	U/S Stator Winding Infrequent		A.C. H.V. After Repair	Rotor Thermal Balance As Req.	Stator IR	Stator IR	Slot Wedges 50/60000			Stator Resis. 20000
c)	Slot Dis-Charge In-Frequent						Gas Outlets 50/60000			St. Winding $\Delta p$ 60000 DD only
d)							Rotor Body 50/60000			Rotor End-Winding Exam 20000
Hydrogen Cooler:										
(i) Inspection	3-6 yrs	4 yrs	10000 ) )	) )	) )	) )	) Depends on water	8000	)	20000
(ii) Cleaning	As required	-	50000 ) )	24000 ) )	) 35/40000 )	) 45/50000 )	) condition	700	) 7/25000	External 60000
(iii) Hydrostatic Pressure Test	Infrequent	-	Only Repair 75000 )	)	)	)	50/60000	8000	)	60000
Stator Frame Hydrogen Leakage Test After Reassembly	Yes	4 yrs	50000	6000	3/10000	6/8000	"	8000		20000
Stator Winding System:										
i) Leakage Test	Yes, also bubble test	-	20000 )	24000 )	"	8000	"	8000	8/30000	20000 DL
ii) Rep. of seals gaskets etc.	6-12 yrs	-	50000 )	)	If Necessary		"	24000	"	-
iii) Flushing or Cleaning	Not Usually	-	50000	No	In Case of incident		On Condition	Not Usual	7.5/30000	-
Seal Oil System:										
Cleaning	-	4 yrs	50000	24000	-	-	On Condition	8000	8/30000	60000

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	Australia	Belgium	Canada	Czech	France Nuclear	France Fossil	Germany	Hungary Nuclear Only	India	Italy Operation Hours
Gas Supply System:										
Leakage Test	Annual	1 or 2 yrs	50000	60000	8/10000	6/8000	On Condition	8000	8/15000	20000
Gas Dryers	Less than Annually	1-2 yrs	20000	24000	"	"	"	"	"	"
Gas Dryer Blowers	-	1 or 2 yrs	N/A	N/A	"	"	"	N/A	"	-
Rotating Excitation System:										
Exciter Rotor End-Ring or Banding Examination	2-8 yrs U/S & DP	4 yrs	50000	48000	35/40000	45/50000	50/60000	)	8/30000	)
Rectifier System:										
(i) Fuse Check During Operation	Daily	1 Week	1000	Indicated	Indicated		24 hour or Indicated	) No Experience )	8/10000	)
(ii) Fuse Check Stationary	-	4 yrs	20000	6000	8/10000	6/8000	40000 operating hours	)	)	)
Insulation Resistance Check	2 yrs	4 yrs	-	6000	"	"	12000 or On Condition)	)	8000	) Not
H.V. Test	No	Never	(D.C.) 50000	After repair only	-	-	Very Rarely )	)	)	) In
Any Other:	IR 2 yrs		IR 20000		-	-	Inst. Brushes 720 hours	)	)	) Use
	Diode Blocking 2 yrs							)	)	)
	Heat Sink 2 yrs							)	)	)
Static Excitation Equipment:										
Diodes/Thyristors	Annually	-	20000	)	8/10000	6/8000	50/60000	40000	7/10000	20000
Transformers	Annually	-	20000 clean	) 48000	"	"	"	"	8/40000	"
Voltage Reg.	2 yrs	-	1000	)	"	"	"	8000	4/9000	"
Instrumentation & Monitoring Systems	2-4 yrs	1 or 2 yrs	1000	48000	"	"	"	"	7.5/40000	"
								Exciter Gearbox 8000		

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## 2.1 Frequency of Maintenance by Components

Please indicate in the table below how often maintenance is done for each component examined or tested. Please add any other components which should be included. Answers should show the statistical (or usual, or average) frequency and not any special or single instances.

	Japan	Poland	South Africa	Sweden	Switzerland	U.K.	U.S.A.	USSR
Bearing Inspection	> 6000	8000	36000	10000	25000	25000	8/44000	M.O.
Bearing Replacement	> 64000	As Required	As Required	As Required	As Required	As Required	As Required	O.As Required
Insulation Against Shaft Currents	16000	3000		40000	25000	170	170	Monthly
Hydrogen Seal Insp.	"	8000	36000	"	"	25000	44000	M.O.
Hydrogen Seal Rep.	> 64000	As Required	As Required	As Required	As Required	As Required	As Required	O.As Required
Endwinding Tightness	32000	10000 then 30000	36000	10000	25000	25000	8000/40000	M.O.
Stator Wedge Tightness	32000	"	36000	40000	10000 then 50000	50000	26/44000	0
Stator Core Inspection	"	"	"	10000 with rotor in-situ.	" "	25000 back 50000 bore	26/44000	0
Stator Core Ring Flux Test	Not Usual	30000	If Rewedged	As Required	" "	50000	26/44000 or N/A	Commissioning Partial or complete rewinding
Stator Core Tightness	32000	"	36000	40000	" "	"	"	
Rotor Withdrawal	"	10000 then 30000	"	40000	" "	"	"	0
Rotor Trim Balancing At Site	"	"	As Required	As Required	As Required	As Required	As Required	As Required
Rotor Body/Tooth/Shaft Inspection	Body/Tooth 64000 Shaft 120000	"	36000	40000	10000 then 50000	50000	26/44000	0
Rotor Blower or Fan Inspection	32000	"	18000 and 36000	10000	10000 then 25000	"	26/44000	
Rotor Endring Examination (External)								
(i) - Rotor In	-	"		10000	" "	25000	As Needed	) 0
(ii) - Rotor Out	32000	As Required	36000		10000 then 50000	50000	44000	) 0
Rotor Endring Removed for Examination	> 64000	"	During winding repairs	As Required	-	70/90000	As Required	O.As Required
Stator Frame/Supports/Endshields	32000	30000	18000 and 36000	40000	50000	25000	26/44000	0
Brushgear & Sliprings	8000	8000	"	10000	10000 then 25000	85/25000	170/8800	Periodic
Shaft Insulation	16000	750 and start/stop	"	40000	" "	170	44000	0
Rotor Insulation Resistance Test	16/32000	At start and stop	"	10000	" "	25000	Shutdown 8800/44000	Continuous

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Q.2.1

	Japan	Poland	South Africa	Sweden	Switzerland	U.K.	U.S.A.	USSR
Rotor Winding	Not Usual	At repair only	At repair only	-	-	At repair only	26/44000 or after repair	0.If Repaired
H.V. Test								" "
Rotor Winding Impedance Test	16/32000	30000		-	10000 then 50000	25000	8/44000	" "
Stator Winding	-	30000	36000 if repaired	After rewedging	" "	"	26/44000	0.Reduced test voltage
H.V. Test								
Tan Delta	-	30000	36000	40000 diagnostic	" "	"	Not Used )	0.If Repaired or
Partial Discharge	-	"	"	"	-	"	Not Used )	dried out
							Seldom or 26/44000	
Any Other Tests On Rotor or Stator Winding:								
a)		Rotor rests 30000	Rotor interturn insulation	Leak test of rotor winding 10000	Rotor interturn insulation test	Gap search coil 25000	Rotor & stator resistances R.F. monitoring	
b)		Stator resistance 30000	18000 and 36000	Stator winding pressure test 10000	Stator d.c. leakage	RSO 25000 Stator end-winding vib. 170	Stator I.R. Pressure drop (H windings)	
c)								
d)								
Hydrogen Coolers:								
(i) Inspection	16000	8000 )		10000	10000 then 25000	25000	( MO	)
(ii) Cleaning	"	30000 )	18000 and 36000	As Necessary	50000	As Necessary	(26/44000 )	0
(iii) Hydrostatic Pressure Test	"	" )		10000	As Required	25000	( )	)
Stator Frame Hydrogen Leakage Test After Reassembly	"	8000 and 30000		10000	25000	"	Each gassing after cooler removed 26/44000	
Stator Winding System:								
(i) Leakage Test	16000 DL	8000 DL	18000 and 36000	10000	10000 then 50000	25000	As Required )	)
(ii) Replacement of Seals etc.	"	"	36000	As required	As Required	As Required	" )	0
(iii) Flushing or Cleaning	"	DL and DD 30000	"	"	As Required	32/48000	8.8/17500	)
Seal Oil System:								
Cleaning	8/32000	8000	36000	"	As Required	25000	As Required	

Q. 2.1

	Japan	Poland	South Africa	Sweden	Switzerland	U.K.	U.S.A.	USSR
Gas Supply System:								
Leakage Test	8/16000	8000	18000 and 36000	10000	50000	25000	After opening )	MO
Gas Dryers	8000	"	"	-	25000	"	Generally )	
							not req. )	
Gas Dryer Blowers	8/32000	"	"	-	10000 then 25000	"		
Rotating Excitation System:								
Exciter Rotor End-Ring or Banding Exam.	8/32000		36000	40000		80000	8.8/44000 )	0
Rectifier System:								
(i) Fuse Check During Operation	8000		) 18000 and 36000	170	)	N/A	24,170	Continuous by contactless method
			)		)		8800	
			)		)			
(ii) Fuse check Stationary Insulation Resistance Check	"		)	10000	)	25000	8800	MO
	"	8000	"	"	25000	"	8.8/44000	
H.V. Test	Not Usual	No load S/C characteristic 30000	-	-	-	After repair	Only if required or 26/44000	0
Any Other		Heat run before and after Type 2 Outage		U/S test of diode rings 40000	Clean diodes Current balance 50000 Visual inspection			
Static Excitation Equipment:								
Diodes/Thyristors	8000		) 18000 and 36000	-	Cleaning current balance 50000	25000	( 8.8/44000 )	Continuous
			)				( )	0
			)				( )	
Transformers	"		)			N/A	( )	
Voltage Regulators	"		)	40000	) Check function	25000	( )	Continuous
			)		)		( )	
Instrumentation and Monitoring Systems	"		)	"	)	750/25000	( )	

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	Australia	Belgium	Canada	Czech	France	Germany	Hungary	India	Italy
a) Rotors	Not sufficient data.	Programme includes a detailed list of checks the whole of which lasts about 5 weeks	NDT Ret NDT w SR lead W clean 150 hours	Vis. Z NDT Ret W clean 1 week	Type 1. Vis. BlR Endrings Type 2 NDT Ret GF No times given	Lengthy typical check list given. No times stated.	W clean R.Z. IR G NDT Ret 120 hours	H.V. I.R. R.Z. G NDT Ret Run WT 15 days	Vis. F NDT Ret I.R. Z.R. 3 weeks
b) Brushgear & Sliprings	Ditto	Ditto	W.J.S.C. 3 hours	C. I.R. SG 2 days	Type 1 & 2 Vis. Run.W.	Ditto	C. SG I.R. Painting 30 hours	W.P. S.G. B.C. 7 days	Inspect (1day) SG BC (2 weeks)
c) Stator	Ditto	Ditto	WT 48 hours EWT 24 hours CT 24 hours Clean Coolers 72 hours	WT Vis. CT L I.R. Tan Delta 1 week	Type 1 Vis. I.R. Type 2 Vis. I.R. WT EWT CH	Ditto	C. Vis. WT EWT T.I.R. L PD Tan Delta I.R. TC 210 hours	I.R. Tan Delta L CT WT EWT C 15 days	Inspect and Test 1 week Rewedge 5 weeks
d) Excitation Equipment	Ditto	Ditto	C. (3) Current (8) sharing AVR drift 7 hours	Vis. I.R. Fuse check AVR check 1 week	Type 1 I.R. Fuse diode checks Type 2 Also mech- anical checks	Ditto	No answer	P and other checks 15 days	1 week (Not specified)
e) Auxiliary Systems	Ditto	Ditto	C. L Check operation Standbys etc.	Vis. L Sensor check 4 weeks	L for Type 1 and 2	Ditto	C Check op- eration. Sensor check L 250 hours	C and flush 15 days	Inspection and C 1 week
f) Bearings	Ditto	Ditto	WM check Journal I.R. 8 hours	WM (NDT) 1 week	WM check C. I.R. Type 1 and 2	Ditto	C. WM check clearances, T.C. 45 hours	WM check clearances Polish journal 20 days	Inspect and test - 2 days Replace - 1 week
g) Seals	Ditto	Ditto	Same as f) + O rings and seals check	Vis. O rings and seals replace 3 days	Vis. Seals replace	Ditto	C. Insp. and repair surfaces. Gaskets re- placed. T.C 52 hours	WM condition O rings Clearances 10 days	Inspect and test - 2 days Replace - 1 week
h) Shaft Insulation/ Shaft Earthing	Ditto	Ditto	I.R. Current S.V.	I.R. Vis. 1 days	I.R. Vis.	Ditto	C Brushes & holders I.R. 10 hours	I.R. current S.V. 5 days	Inspect and test 1 day

	Japan	Poland	South Africa	Sweden	Switzerland	U.K.	USA	USSR
a) Rotors	Vis. NDT Ret. (May also apply to other parts) 1 week	Answer too general.	Vis. SR lead NDT Ret. W clean I.R. R RSO 20 hours Test time only	I.R. G Vis. NDT 1 week	I.R. Interturn. X-ray elastic joints. Tightness of bolts. 4 days test only	Withdraw 17 days. I.R. Z NDT Ret. 10 days. Rebuild 17 days.	NDT Ret.  Radial stud test I.R. P.I.	I.R. Z Winding resistance
b) Brushgear & Sliprings	Vis. BS  3 days	BC C (Hours) Slipring and replace (days)	BS W C  8 hours	I.R. Vis. W. BS. Clearance  1 week	Run C  2 days	SG BS I.R.  3 days	-	Resistance
c) Stator	WT Vis.  1/2 weeks	Answer too general	EWT, WT CT PD Flow test bars L S.M. T 500 hours	I.R. L Vis. W C. EWT WT etc. 70 parts checked 3 weeks	Vis. WT CT  4 days	EWT - 1 week WT - 4/5 days CT - 2 days CH	I.R. T.I.R. EWT  Wedging	Numerous tests
d) Excitation Equipment	Vis. Character -istic test 1 week	I.R. (mins) to replace components (days)	Exciter as 3.1 a), b), c). C Test and calibrate AVR 60 hours	I.R. Vis. C NDT etc. 1 week	Vis. C  5 days	Strip down. Vis. Press test coolers 250 hours every 3 years	Fuse test	
e) Auxiliary Systems	Not specified  1 week	Vis.	Vis. C Check operation  50 hours	Check operation C.W. cracks.  1 week	Check operation C.  5 days	Stator water strip L Flow pressure test 200 hours Gas system ditto 400 hours Coolers strip C Pressure test and rebuild 380 hours		
f) Bearings	Vis. D.P.  3 days	Vis.	WM check Clearances I.R. 8 hours	I.R. Alignment W. Vis. Clearances WM (NDT) 1/2 week	Clearances  5 days	Vis. Inspect 10/14 days	Inspect Check clearances	Oil flow
g) Seals	Vis. D.P.  3 days	As above	Check condition C 8 hours	As f)  1/2 weeks	Inspect clearances  3 days	Strip - Vis. NDT 4-5 days every 3 years	Inspect Check clearances	Oil flow
h) Shaft In- tation/Shaft Earthing	I.R. 1 day	H.V.	Vis. I.R. 3 hours	As f)  1 day	S.V. C 2 days	Vis. C 1hr/week	Check monthly	

3.6 What tests are made to confirm that maintenance objectives have been met.

	Australia	Belgium	Canada	Czech	France		Germany	Hungary	India	Italy
					Type 1	Type 2				
Stator Wedge Tightness	Hammer test.	Loss of elastic reserve in ripple spring system.	Wedge map.	Yes	No	Yes	Hydraulic test of ripple spring action or vibratory check	Yes	Yes	Yes
Stator End-winding Tightness	Visual, Bolt torque	< 500MW - visual > 500 Eigen frequency measurement.	Bolt torque and p.d. at rated volts.	Yes	Yes	Yes	Yes Visually	Yes	-	-
Core Tightness	Visual, knife test.	Hammer test.	Knife, visual.	Yes	No	Yes	Yes	Yes	Yes	-
Core Ring Flux Test	Thermovision. Thermocouple.	-	Only if repaired.	-	No	No	Not normally performed only in case of doubt	No	Yes	-
Stator Insulation Tests	H.V. if repaired. Diagnostic tests (eg. DLA, PD)	I.R. H.V. I.R.	I.R. H.V. d.c. if winding maintained.	Yes	H.V. if repaired I.R. Yes	I.R. Yes	Yes H.V. (rarely) Tan Delta P.D.	I.R. If repaired	I.R.	Yes I.R. H.V. if maintained
Rotor Winding Insulation Tests	I.R. Z	I.R.	I.R. d.c. resistance. H.V. d.c. if repaired.	Yes	H.V. No I.R. Yes	No Yes	Yes I.R.	Yes	Yes	Yes
Coolers	Pressure test. Temperature checks on RTS.	-	Cleanliness. Leak test.	Leakage test.	No	Yes	Yes	Yes Pressure test.	Yes	Yes
Stator Winding Cooling Water System	Leakage. Temperature & Conductivity RTS	6 bar air press test - only 1000MW units.	Filter cleanliness. Pressure test.	Leakage test.	Yes (DL)	Yes (DL)	Yes Hydraulic tests	Yes	Yes Leakage & flow test (DL)	Yes
Shaft Insulation	I.R. & shaft voltage on RTS.	I.R.	I.R.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Excitation System	In service performance.	Diode and fuse check. Shaft alignment.	Visual for cleanliness. Alarms cleared. Continuity & I.R. check.	Yes	Yes	Yes	Yes	Yes	-	Yes
Regulation System	"	Tests before shutdown.	Run up on manual control, transfer to AVR before synchronising.	Yes	Yes	Yes	Yes	Yes	-	Yes

	Australia	Belgium	Canada	Czech	France		Germany	Hungary	India	Italy
					Type 1	Type 2				
Rotor Endrings	Dye penetrant and U/S. Run out checks.	U/S Condensation. Micrographic examination.	U/S compared to reference. Visual.	-	No	Yes	Yes	Yes U/S Magnetic particle.	U/S and dye penetration.	Yes
Others:		Frame - 6 bar air pressure. Turbine generator alignment.		Frame and H <sub>2</sub> leakage test.					Frame leakage test. Rotor Ventilation. OCC and SCC.	

NOTES TO Q. 3.6

U/S	-	Ultrasonic test
OCC and SCC	-	No load characteristic and short circuit checks.
I.R.	-	Insulation resistance megger test.
P.I.	-	Polarisation Index.
R.S.O.	-	Recurrent surge oscillograph.

3.6 What tests are made to confirm that maintenance objectives have been met.

	Japan	Poland	South Africa	Sweden	Switzerland	U.K.	U.S.A.	USSR
Stator Wedge Tightness	Hammer	Yes	Yes	Hammer/vibration diagnostic test.	Electromagnetic Hammer/vibration test.	-	Tap test	
Stator Endwinding Tightness	Hammer and visual.		Yes	Resonant frequencies and level.	Bolt tightness.		Visual impact Resonance test	
Core Tightness	Sound propagation test.	Yes		Visual, knife	If repaired.		Visual and knife test	
Core Ring Flux Test	No	Yes	Yes	Diagnostic El Cid test	If repaired.	Yes	No, unless rep. Hot spot check	
Stator Insulation Tests	I.R.	( Yes ( H.V. after ( repair.	P.I.	H.V. if re-wedged. IR Tan Delta	Yes	I.R. & P.I. H.V. Tan Delta	I.R. H.V. if repaired	
Rotor Winding Insulation Tests	I.R. & Z	( Yes ( H.V. Z ( after re-pair.	I.R.	I.R.	Yes	Yes	"	
Coolers	Air leakage test.	Leakage	Hydraulic pressure test.	Leakage	Leakage		Pressure test	
Stator Winding Cooling Water System	Air leakage test. Conductivity	Yes Leakage (DL)	Flow test.	Leakage	Leakage Deioniser check.	Flow Yes	Leak test	
Shaft Insulation Test	I.R.	Yes	Yes	I.R. Shaft current Transformer	Voltage and current.		Yes	
Excitation System	Static characteristic test.	I.R. test.	Check operation.	I.R.	Operating checks		Variety of tests as required by system	
Regulation System	"		"		"	Yes	"	

No specific answers. Tests performed according to operation and maintenance instructions.

Q. 3.6

	Japan	Poland	South Africa	Sweden	Switzerland	U.K.	U.S.A.	USSR
Rotor Endrings	U/S	U/S and Dye Penetrant when removed	Dye Penetrant	U/S	Dye check if removed. Sometimes X-ray		Visual D.P. U/S	
Others:		Stator frame and system leakage test		Stator frame and system leakage test		Stator frame leakage test		
		Rotor air gap search coil after re-winding				O.C. curve		
		Bearing vibration		Bearing and shaft vibration		Rotor air gap Search coil and RSO		
		O/C and SCC after rotor repair				Bearing vibration		
		Heat run of the stator or rotor or cooling repair				Alarm and protection checks		

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