COUNCIL FOR
NUCLEAR SAFETY

RAAD VIR
KERNVEILIGHEID

LICENCE
DOCUMENT

NO	TITLE	REV.
LD-1092	REQUIREMENTS FOR INITIAL OPERATOR LICENSING AT KOEBERG NUCLEAR POWER STATION	1

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APPENDIX 3

1. INTRODUCTION

1.1. PURPOSE

The purpose of this licence document is to define the minimum academic qualifications, experience and training that the CNS deems acceptable for nuclear plant personnel for the following duties:

1. Reactor Operator licence holders.
2. Senior Reactor Operator licence holders.

This document relates to the following:

1. Subjects for examination and procedures for applying for and granting of a generic fundamentals certificate.
2. Minimum qualifications to apply for admission to examinations for obtaining a Reactor Operator or Senior Reactor Operator licence and the training programme and subjects of the examination.
3. Procedures involved in applying for and granting of a Reactor Operator or Senior Reactor Operator licence.

1.2. SCOPE

This licence document is applicable to all persons who apply to the CNS for examination for a generic fundamentals certificate, or Reactor Operator licence or Senior Reactor Operator licence.

2. DEFINITIONS

Abnormal operation:

Performance of tasks in response to a system or component malfunction, following an event less severe than one which would lead to Incident Operation.

Candidate:

A person applying to the CNS for examination to obtain a generic fundamentals certificate, a Reactor Operator licence or Senior Reactor Operator licence.

Certificate:

A generic fundamentals certificate issued by the CNS.

CNS:

Council for Nuclear Safety.

Critical error:

A mistake which is judged to be of such severity that its occurrence alone would indicate a reasonable doubt of the candidate's ability to operate the reactor in a safe and competent manner.

Direct supervision:

A situation in which the licence holder has discussed and understood the intended actions of a trainee and will have positioned himself in such a manner that he may interrupt and correct the trainee's actions which he deems as incorrect or inappropriate.

Gender:

The use of the male gender also means the female gender.

Generic Fundamentals Examination (GFE)

An examination, to test theoretical knowledge, set by the CNS for individuals who are expected to become operator licence holders.

Incident operation:

Performance of tasks in response to a system or component malfunction severe enough to be classified as a "Site Alert" or higher.

Licence:

The current variation of Nuclear Licence No. NL-1.

licence holder:

An operator in possession of a current Reactor Operator licence or Senior Reactor Operator licence issued by the CNS.

licence position:

The following are considered to be licence positions occupied by operator licence holders:

1. Shift Manager, [Senior Reactor Operator licence holder].
2. Senior Shift Supervisor [Senior Reactor Operator licence holder].
3. Shift Supervisor (Control Room) [Reactor Operator licence holder].
4. Assistant Shift Supervisor [Reactor Operator licence holder].

The person who performs the Critical Safety Function monitoring, as required by the Functional Restoration Procedures, must be a Reactor Operator licence holder or Senior Reactor Operator licence holder who does not fill any of the operator licence positions in the "Minimum Shift Composition" as listed in LD-1081.

Licensee:

The holder of the current variation of Nuclear Licence No. NL-1.

NPO 0, 9, 1 & 2:

Nuclear Plant Operators responsible for the safe operation of auxiliary plant outside of the main buildings, in the Nuclear Auxiliary Building and in the Turbine Halls, respectively.

Normal operation:

Performance of tasks in accordance with operating procedures under conditions without malfunctions or unusual system conditions.

RO:

Reactor Operator licence holder.

SRO:

Senior Reactor Operator licence holder.

3. REFERENCES

"Guidebook on Training to establish and maintain the Qualification and Competence of Nuclear Power Plant Personnel" IAEA - TECDOC - 525

"Analysis, Conclusions and Recommendations concerning Operator Licensing" NUREG / CR 1750.

"Control Room Operator, Senior Control Room Operator and Shift Supervisor Qualifications" INPO 82-008.

"Guideline relating to the Proof of Technical Qualification of Nuclear Power Plant Personnel" Gesellschaft für Reaktorsicherheit, Edition 1/84.

"Guideline relating to the Content of the Examination of the Technical Qualification of Responsible Shift Personnel at Nuclear Power Plants" Gesellschaft für Reaktorsicherheit, Edition 7/89.

Guideline for the Requirements for applicants for an operator's or supervisor's licence written by Consejo de Seguridad Nuclear, March 1988.

Operator Licensing Examiner Standards, NUREG-1021.

Knowledges and Abilities catalogue for Nuclear Plant Operators: PWR's, NUREG-1122.

Licence Document on the Requirements for Medical and Psychological Surveillance and Control : LD-1077.

Licence Document on the Requirements for Operator Licence Holders at Koeberg Nuclear Power Station : LD-1081.

4. GENERIC FUNDAMENTALS EXAMINATION

4.1. APPLICATIONS FOR EXAMINATIONS

The application for an examination must contain the full name, home address, postal address, identification document number (or in the case of foreign nationals the passport number), of the candidate. The CNS must receive the application at least thirty days before the examination date.

4.2. FREQUENCY OF EXAMINATIONS

The examination will be held annually on a date determined by the CNS. The Licensee must request an examination schedule from the CNS at least ninety days before the proposed examination date.

4.3. APPLICABILITY OF EXAMINATIONS

This examination must be successfully completed before the candidate being accepted for the CNS Operator Licensing Examinations.

4.4. PASS/FAIL CRITERIA

A pass mark of 70% is required in each section of the examination. If a candidate fails the examination then the candidate must wait until the next examination is scheduled and re-apply for examination.

4.5. EXAMINATION REVIEWS AND REPORTS

The Licensee will be given an opportunity to review the examination prior to the candidates taking the examination.

The Licensee reviewers shall not divulge any information about the examination to any other persons and must not participate in any activity involving the candidates until the examination is administered. If these conditions are not complied with, the CNS may cancel the examination or declare the results invalid.

On completion of the examination, the Licensee will be given the opportunity, within five working days, to provide written comments, together with supporting documentation, to suggest additions or changes to the answer key to the CNS.

4.6. QUALIFICATION VALIDITY

Once a candidate has successfully completed the examination the certificate remains valid indefinitely and the examination will only have to be re-taken if the CNS has a doubt regarding that candidate's ability, as described in LD-1081, Section 7.

4.7. TRAINING

The candidate must be trained and examined by the Licensee in the areas listed in Appendix 1.

5. INITIAL LICENSING REQUIREMENTS

The Licensee must inform the CNS of the names and current positions of the candidates expected to be selected for operator licence examinations, before the candidates commencing their training programme. The Licensee must, at periods of sixty days, maintain records of the candidates' progress.

This progress record must be a brief résumé of the courses that the candidates have attended. The Licensee must have in place administrative controls or other means acceptable to the CNS that ensures adherence to the requirements of this Section.

5.1. MINIMUM PREREQUISITES FOR REACTOR OPERATOR LICENCE CANDIDATES

5.1.1. QUALIFICATIONS

The candidate must have Matric with Maths and Science as the basic level of qualification and hold a CNS Generic Fundamentals Certificate.

The candidate must have successfully completed the following courses presented by the Licensee:-

1. NPO 0.
2. NPO 9.
3. NPO 1 & 2.
4. Authorised Person (High Voltage Regulations).

5.1.2. EXPERIENCE

The candidate must be active in the positions of NPO 0, NPO 1 & 2 and NPO 9.

The candidate must have actively performed NPO duties for a minimum period of one year.

The candidate must have completed a minimum of forty shifts in the active position of NPO 9.

The candidate must have witnessed at least one unit start-up and shutdown in either the NPO 9 or the NPO 1 & 2 positions.

5.1.3. TRAINING

The candidate must be trained and examined by the Licensee in the areas listed in Appendix 2.

5.2. MINIMUM PREREQUISITES FOR SENIOR REACTOR OPERATOR LICENCE CANDIDATES

5.2.1. QUALIFICATIONS

The candidate must have a current Reactor Operator licence, hold a CNS Generic Fundamentals Certificate and have the following Licensee qualifications:-

1. Appointed Person (Plant Safety Regulations).

2. Appointed Operator (High Voltage Regulations).

5.2.2. EXPERIENCE

The candidate must have had at least two years experience in a licence position as a Reactor Operator licence holder and must have witnessed at least one outage in a licence position as a Reactor Operator licence holder.

5.2.3. TRAINING

The candidate must be trained and examined by the Licensee in the areas listed in Appendix 2.

The Licensee must give the candidate training in the areas of teamwork and man management skills to a standard acceptable to the CNS.

5.3. EXAMINATIONS

5.3.1. APPLICATION FOR EXAMINATIONS

An application for an examination must contain the individuals information as listed in Attachment B of LD 1081, "Licence Document on the Requirements for Operator Licence Holders at Koeberg Nuclear Power Station". The application must also contain the following information for each candidate:

- Records and results of all examinations/evaluations.
- Individual records for courses attended.
- Depositions that the requirements of this LD have been met in terms of training and examination.

If the Licensee wishes to submit a candidate who does not meet the above minimum requirements of the CNS, then the Licensee must provide justification, with the candidate's application, of equivalence to the CNS requirements.

The initial individual licence applications must be submitted at least sixty days prior to the proposed examination date.

The final application which includes all of the above information as well as the "Proof of Training" as identified in Attachment B(4) of LD 1081 and the evidence that the candidate satisfies the medical requirements as stated in LD 1077, must be submitted at least two working days prior to the start of the examinations. All of the Licensee examinations/evaluations must be completed before the submission of the final application.

The Licensee must supply, at least two working days prior to the commencement of the walk-through examination, a deposition, signed by a Shift Manager, that the candidate has completed at least five working days acting in a licence position, commensurate with the type of licence applied for, under the direct supervision of an active licence holder and that the candidate is capable of fulfilling the duties of a licence holder.

5.3.2. SCHEDULING OF EXAMINATION

The Licensee must request an examination schedule from the CNS at least ninety days prior to the proposed examination date.

5.3.2.1. REACTOR OPERATOR CANDIDATE

The chronology of the examinations will be as follows:

1. A written examination as described in Section 5.3.3.
2. A simulator examination consisting of normal operations.
3. A simulator examination consisting of normal, abnormal and incident operations.
4. A walkthrough examination in the control room and the plant.

Prior to the last examination, the candidate must have completed at least five shifts acting in a licence position as a Reactor Operator licence holder, under the direct supervision of an active licence holder.

5.3.2.2. SENIOR REACTOR OPERATOR CANDIDATE

The chronology of the examinations will be as follows:-

1. A written examination as described in Section 5.3.3.
2. A simulator examination consisting of normal, abnormal and incident operations.
3. A walkthrough examination in the control room and the plant.

Prior to the last examination, the candidate must have completed at least five shifts acting in a licence position as a Senior Reactor Operator licence holder,

under the direct supervision of an active licence holder.

5.3.3. WRITTEN EXAMINATION

The written paper will contain three sections. These will be:-

SECTION 1: NORMAL OPERATIONS AND PLANT SYSTEMS

SECTION 2: ABNORMAL OPERATIONS

SECTION 3: INCIDENT OPERATIONS AND SAFETY SYSTEMS

The candidates will be examined on all three sections on the same day and the CNS will set a time limit.

The Licensee will be given an opportunity to review the written examination before the candidates taking the examination.

The Licensee reviewers shall not divulge any information about the examination to any other persons and must not participate in any activity involving the candidates until the examination is administered. If these conditions are not complied with the CNS may cancel the examination or declare the results invalid.

On completion of the examination the Licensee will be given the opportunity, within five working days, to provide written comments, together with supporting documentation, to suggest additions or changes to the answer key to the CNS.

5.3.3.1. PASS/FAIL CRITERIA

A pass mark of 70% in each section, with an overall average of 80%, of the written paper is required.

5.3.4. SIMULATOR EXAMINATION

The simulator examination will be divided into scenarios of approximately two hours duration. Each candidate must perform a minimum number of scenarios dependent on

whether a RO or SRO licence is applied for. These are as follows:

5.3.4.1. REACTOR OPERATOR CANDIDATE

Eight normal/abnormal operation exercises, four in the position of Assistant Shift Supervisor and four in the position of Shift Supervisor (Control Room).

Three incident operation exercises, one in the position of Assistant Shift Supervisor, one in the position of Shift Supervisor (Control Room) and one when the candidate monitors the status trees for the Functional Restoration Procedures.

5.3.4.2. SENIOR REACTOR OPERATOR CANDIDATE

Eight normal/abnormal operation exercises in the position of Unit SRO.

Two incident operation exercises in the position of Unit SRO.

Note: SRO candidates are assumed to have the abilities of RO candidates as far as panel manipulations are concerned, therefore, they will not normally be examined in that role, however the CNS may at its discretion examine them in the RO positions.

5.3.4.3. PASS/FAIL CRITERIA

The candidate must pass at least 70% of the normal/abnormal operation exercises and all of the incident exercises.

The candidate must not have made a critical error, in any of the exercises. These are:

1. Actions by the candidate that could cause injury or risk of injury to plant personnel and/or the public because of the implications of the error.

2. Actions by the candidate that could cause damage or risk of damage to major plant items,

[e.g. turbine, alternator, primary pumps], or to engineered safety features.

3. The candidate fails to implement immediate actions as required by the Licensee's optimal recovery procedure package; specifically KWB.E-0, ECA-0.0 and FR-S.1.

4. The candidate fails to timeously recognise that a safety set point has been exceeded or fails to take the appropriate action.

The candidate will fail an exercise if an error is made which prevents the successful completion of the objective of that exercise and the error is judged by the CNS not to fall into any of the categories mentioned above. A number of these errors will cast doubt on the candidate's ability to operate the plant in a safe and competent manner.

The candidate will be required to perform additional exercises if the examination scenario is not taken to completion for any reason.

The criteria for passing the various exercises is listed below:

Normal Operation Exercise

The candidate must:-

1. Identify the applicable procedure(s) relating to the task.

2. Be allowed to use references but not be allowed to ask another individual for information concerning questions asked by the examiners.

3. Identify, locate and apply any Technical Specification limitation.

4. Identify and correctly operate components.

5. Determine that the equipment responds as anticipated.

6. Maintain normal operating parameters within acceptable limits.

7. Be able to change core reactivity without exceeding any procedural or safety limits.

The candidate will, at most, be permitted to make two errors depending on their severity.

Abnormal Operation Exercise

The candidate must:

1. Identify that a Technical Specification or operating limit is applicable and is not exceeded by the candidate's actions.

2. Recognise when a Technical Specification or operating limit is exceeded.

3. Identify the appropriate corrective actions.

4. Identify the applicable procedure(s) relating to the task.

5. Determine when the event has been terminated or that the corrective actions have mitigated the event.

The candidate will be allowed four attempts to mitigate the event as long as the actions performed by the candidate are correct for the symptoms observed and the candidate recognises that the actions were unsuccessful.

Incident Operation Exercise

The candidate must:

1. Identify the appropriate corrective actions.

2. Identify the applicable procedure(s) relating to the task.

3. Determine when the event has been terminated or that the corrective actions have mitigated the event.

4. Determine that the equipment responds as anticipated.

The candidate will be allowed four attempts to mitigate the event as long as the actions performed by the candidate are correct for the symptoms observed and the candidate recognises that the actions were unsuccessful.

5.3.5. WALKTHROUGH EXAMINATION

The scope of the walkthrough examination will be in accordance with Appendix 3.

5.3.5.1.PASS/FAIL CRITERIA

The candidate must perform to the satisfaction of the CNS in each area listed in Appendix 3 to this document.

A candidate who fails more than two sub areas has failed the walkthrough examination and does not qualify for re-examination.

5.4. RE-EXAMINATION

Re-examination in either, the written, simulator or walkthrough section of the examination will be at the discretion of the CNS. If a candidate fails more than one section of the examination then that candidate will be required to re-take the whole examination when next scheduled by the CNS upon re-application by the Licensee.

If a candidate has been permitted a partial re-examination, the Licensee will be informed.

The Licensee must notify the CNS, within seven days of being informed, of the extra training that will be given to the candidate in question and must request a date for the re-examination of the candidate. The re-examination date requested must fall within the period of twenty-one days to forty-two days from the date of the initial notification.

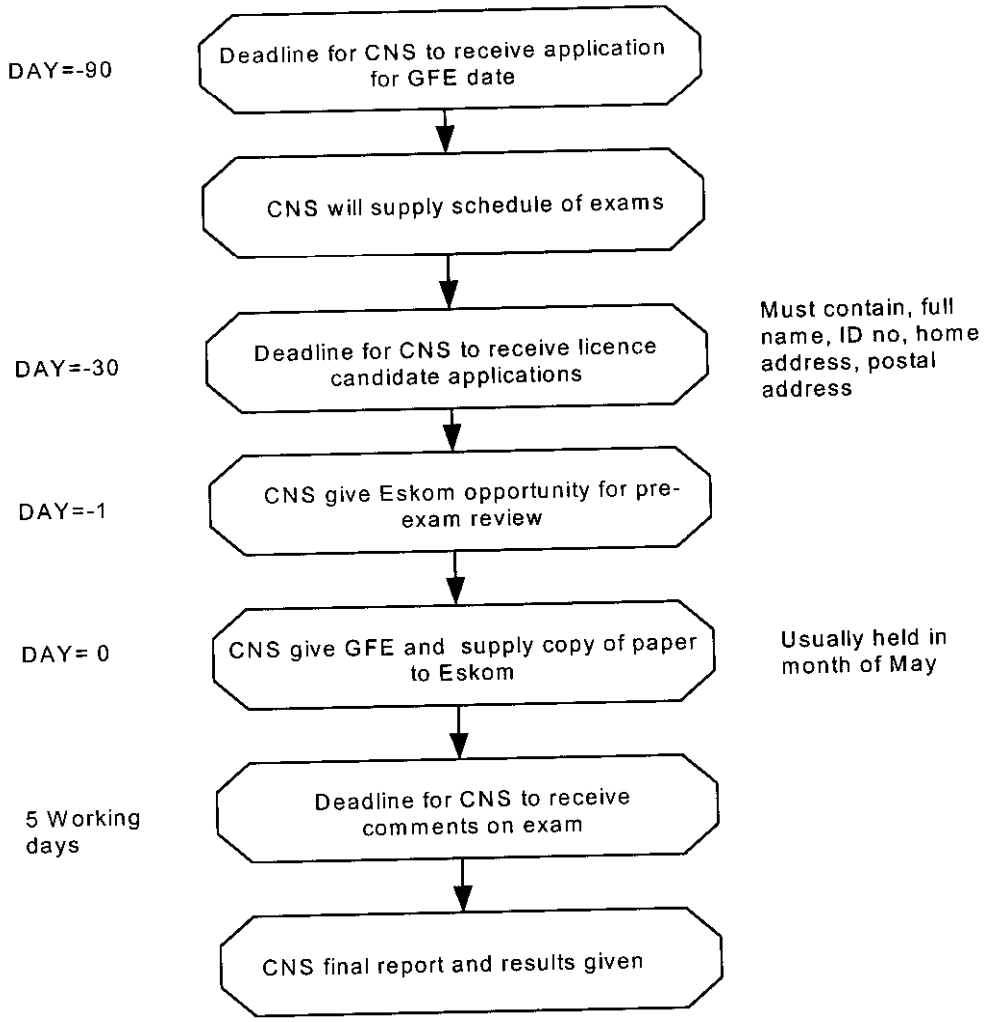
6. RECORDS

All documents that are required as part of this licence document must be maintained by the Licensee to the satisfaction of the CNS for the following retention times:

SECTION	DOCUMENT DESCRIPTION	RETENTION PERIOD
4	Progress reports of licence candidates. Licence candidate examination papers.	Until awarded a licence.
4.3	Application for examination.	Two years.

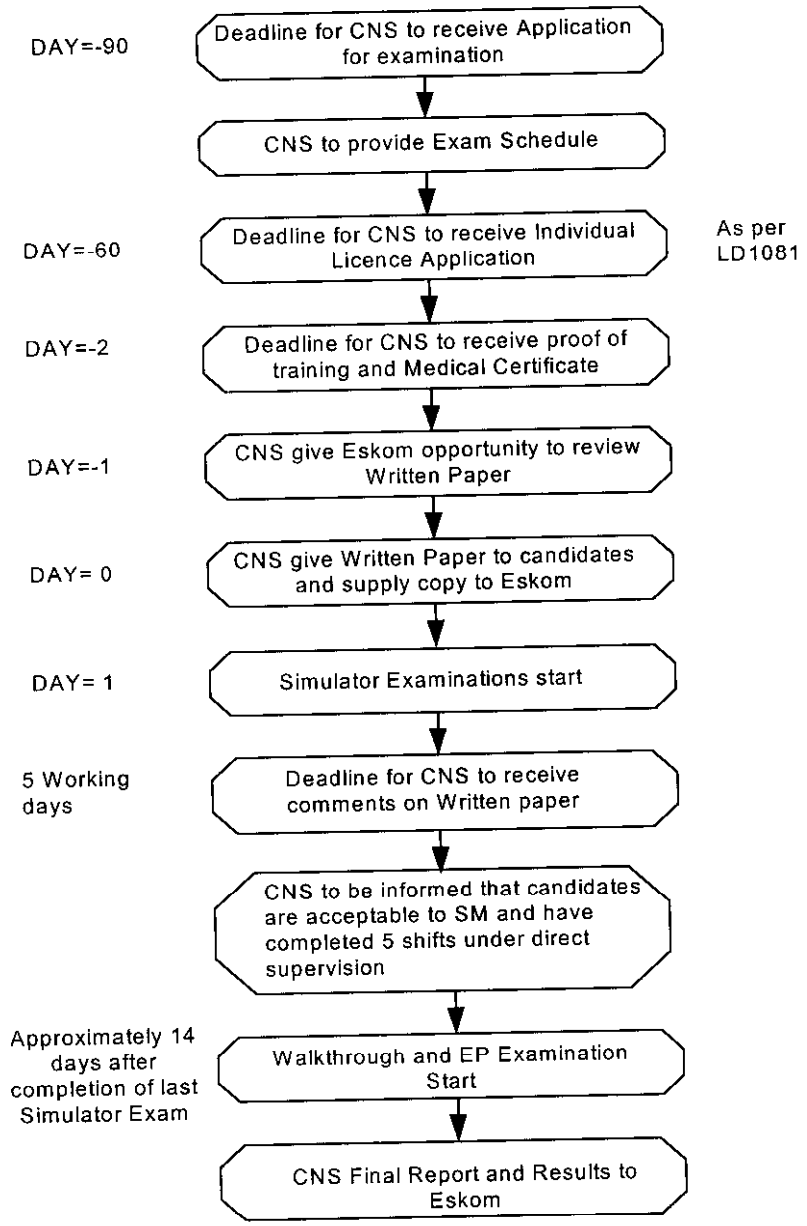
ATTACHMENT 1

FLOWCHART FOR GFE



ATTACHMENT 2

FLOW CHART FOR INITIAL LICENSING



Appendix 1

TOPICS FOR TRAINING AND EXAMINATION FOR GENERIC FUNDAMENTALS CERTIFICATE

1. FUNDAMENTALS OF NUCLEAR PHYSICS

1.1 Quantities, units and symbols

The quantities which are essential in nuclear engineering, including the associated symbols and units.

1.2 Structure of the atom and radioactive decay

Structure of the atom, nuclear charge and mass number.

Terms: isotope, nuclide, neutron, proton, electron, gamma quantum.

Types of radiation, [α, β, γ and n radiation].

Changes in the nucleus and related energy transfer with respect to α, β, γ and n decay.

Representation of the decay laws on the basis of the nuclide chart and decay chains.

1.3 Interaction of radiation with matter

Interactions of α and β radiation with matter.

Qualitative statements concerning shielding against α and β radiation.

Interaction of γ radiation with matter [energy transfer, scattered radiation], or neutrons with matter [scattering, capture fission].

Qualitative statements concerning the shielding against γ radiation.

Neutron Sources.

Qualitative relationship between temperature and kinetic neutron energy.

Process of nuclear fission; binding energy.

Fission cross sections and their dependence on the neutron energy.

Terms: fission product, activation product.

Breeding and conversion processes.

Qualitative statements concerning the shielding against neutrons.

Enumeration of the most important fissile and fertile nuclides.

2. REACTOR PHYSICS

Chain reaction.

Explanation of the relationships described in the 6-factor formula and their extension to the real reactor.

Multiplication factors [type and meaning of].

Reactivity [relation to multiplication factor], moderator, reflector, coolant [effect, materials].

Prompt and delayed neutrons [terms, production, meaning of controllability of the reactor.

Statements concerning the apportionment of delayed neutrons of the most important fissile nuclides.

Terms: critical, prompt critical; changes of neutron flux density at or near the critical or prompt critical state.

Term: Stable period; qualitative statements concerning reactor period or relative rate of flux change.

Terms: stationary, transient; transitional behaviour.

Relationship between the neutron flux density and reactor power.

Neutron flux measuring methods.

Impact of changes in the density of the moderator on the neutron flux.

Qualitative statements concerning the distribution of the neutron flux density over the core and in the proximity of a fuel element and a control rod.

Dependence of reactivity on fuel temperature, coolant or moderator density [steam voids], boron concentration reactor power, moderator temperature and pressure.

Dependence of the co-efficient of reactivity on burnup and boron concentration.

Qualitative statements concerning the operating behaviour above and below the critical state and in various power ranges.

Influence of the poisons [burnable and non-burnable absorbers and the selective way they are used] on the neutron flux density and its distribution.

Xenon poisoning [term, build up process via fission products, dependence on neutron flux density and kind of load change, time behaviour, influence on reactivity], xenon oscillations.

Possibilities of controlling the reactor :-

- burnable poisons.
- control rods, boron concentration.

Methods/techniques of core monitoring of the subcritical or critical reactor.

Neutron start up source [purpose, effect].

Reactivity balance [qualitative], shutdown margin, and shutdown reactivity.

3. ENERGY RELEASES AND THERMOHYDRAULICS

Properties of water, wet steam, saturated steam, superheated steam; identification of these conditions; handling of h-s, T-s diagrams, throttling, expansion.

Circuit process in the thermal power plant. Change of state of boiling water as a result of compression or decompression.

Resistance in pipes and valves. Orifice measurements, operating states of centrifugal pumps, operating limits, cavitation, water hammer.

Mechanisms of heat transfer. Heat transition from metal to water or steam, from water to steam. Condensation. Heat transfer capabilities of heat exchangers.

Bulk Boiling, nucleate boiling, film boiling.

Heat conduction in the fuel and heat transfer from the fuel to the coolant [qualitative].

Terms: critical heat flux, hot spot, minimum critical heat flux ratio, DNB ratio.

Mechanisms and qualitative division of energy release [generation of heat]:-

- in the fuel
- in the moderator
- in the coolant
- in the core internals
- in the shielding

during operation and after shutdown, depending on the type of radiation and as a function of the reactor power during the preceding operating phase.

Natural circulation [one-phase, two-phase], limits of natural circulation, two-phase energy transportation, heat loss from pressurised vessels or systems [cold, hot], single-phase flow [water or steam], two-phase flow [water and steam].

Critical pressure ratio during outflow processes, critical rate, nozzle.

Heat and mass balances in distributed systems [approach].

Physical behaviour of air-steam mixtures [qualitative]. Build up of H_2 concentrations in steam-air mixtures and their ignition limits, methods of prevention of ignition and reduction of H_2.

4. RADIOLOGICAL PROTECTION

Dangers resulting from radiation, objectives of radiological protection.

Explanation of the terms which are essential for radiological protection such as activity, specific activity, activity concentration, half life, effective dose, dose rate, half-value thickness, activation, contamination, incorporation, inhalation, ingestion, submersion.

Understanding of the mode of functioning, handling and scope of application of radiation measuring instruments and equipment [e.g.: ionisation chamber, proportional counter tube, Geiger-Müller tube, scintillation detector, semi-conductor detector, neutron detector, film badge, TLD, and pocket dosimeter], for the measurement of doses in radiation fields, or for the measurement of surface contamination.

Demonstrate an understanding of how the AADQs are derived.

Demonstrate an understanding of the Annual Limit on intake.

Dose limits for occupationally exposed persons in the controlled zone.

Protective measures to be implemented during the handling of unsealed and sealed radioactive sources.

Natural radiation exposure [sources, intensity].

Demonstrate an understanding of dose levels at which deterministic effects manifest.

Dangers of incorporation of radioactive substances [preventive and subsequent measures, measuring methods].

Preventive measures against entrainment of contamination [body, clothing, tools, equipment]. Decontamination measures, in particular obstinate decontamination of the body.

First protective measures until the arrival of the Radiation Protection personnel [control measurements, security measures, decontamination of persons].

Measures and equipment for individual dose monitoring. Time intervals for reviews of individual doses as well as medical radiological protection examinations of persons exposed to radiation.

Protective measures and behaviour for the minimisation of radiation exposure during missions in the restricted access areas during maintenance work [protective effect of distance and working time, shields, protective clothing, respirators].

Co-operation with Radiation Protection staff.

5. VALVES

The function and operation of safety valves.

The function and operation of relief valves.

The relationship of valve position to flow rate and back pressure.

The failed-valve positions for different actuators (open, closed, and as-is positions; spring loaded valves; hydraulic, pneumatically controlled valves; electric motor-drive valves).

Equipment protection concerns in the use of valves (protect valve seals, open slowly).

Manual operation of MOV with motor inoperable.

Principles of operation and purpose of check valves.

Operation of valves and verification of position.

Reason for using globe valves versus gates valves for throttling.

6. SENSORS AND DETECTORS

Flow

Characteristics of venturis and orifices.

Temperature/density compensation requirements.

Effects of gas or steam on liquid flow rate indications (erroneous reading)

Modes of failure.

Operation of a flow D/P cell type flow detector.

Level

Temperature/pressure compensation requirements.

Theory and operation of level detectors.

Effects of operating environment (pressure and temperature)

Modes of failure.

Pressure

Theory and operation of pressure detectors, (bourdon tubes, diaphragms, bellows, forced balance and variable capacitance).

Effects of operating environment (pressure and temperature).

Modes of failure.

Temperature

Theory and operation of T/C RTD, thermostats.

Failure modes of T/C and RTD.

Position Detectors

Failure modes of reed switches, limit switches, and potentiometers.

Application of reed switches, magnets, potentiometers, and limit switches.

Nuclear Instrumentation

Effects of core voiding on neutron detection.

Portable and Personal Radiation Detection

Theory and operation of ion chambers, G-M tube and scintillation detectors.

Use of portable and personal radiation monitoring instruments.

Theory and operation of failed-fuel detectors.

7. CONTROLLERS AND POSITIONERS

Function and operation of flow controller in manual and automatic modes.

Function and operation of a speed controller.

Operation of valve controllers in manual and automatic mode.

Function and operation of pressure and temperature controllers, including pressure and temperature control valves.

Function and characteristics of valve positioners.

Function and characteristics of governors and other mechanical controllers.

Safety precautions with respect to the operation of controllers and positioners.

Theory of operation of the following types of controllers: electronic, electrical, and pneumatic.

Effects on operation of controllers due to proportional, integral (reset), derivative (rate), as well as their combinations.

Function and characteristics of air-operated valves, including failure modes.

Cautions for placing a valve controller in manual mode.

8. PUMPS

Centrifugal

Identification, symptoms, and consequences of cavitation.

Reasons for venting a centrifugal pump.

Consequences of air/steam binding.

Consequences of operating a pump dead headed or for extended times without adequate recirculation.

Relationships between head, flow, and power as related to pump speed.

Need for net positive suction head (NPSH); effects of loss of suction.

Starting current and operating current interpretation.

Purpose of starting a pump with discharge valve closed.

Pressure and flow relationship of pumps in parallel.

Pressure and flow relationship of pumps in series.

Definition of pump shutoff head.

"Runout" of a centrifugal pump (definition, indications, causes, effects, and corrective measures).

Theory of operation of centrifugal pump.

Use of centrifugal pump characteristic curve and a system characteristic curve to illustrate how the system operating point changes due to system changes.

Relationship between flow from a pump and suction heads.

Safety procedures and precautions associated with centrifugal pumps.

Definition of pump efficiency.

Explanation of the difference between ideal and real pumping process.

Positive displacement

Relationship between head, flow, speed and power.

Net positive suction head (NPSH) requirements for a positive displacement pump.

Consequences of operating a positive displacement pump against a closed flow path.

Applications and characteristics of positive displacement pumps.

Reason for starting a positive displacement pump with the discharge valve open.

Safety procedures and precautions associated with positive displacement pumps.

Basic operation of positive displacement pumps.

Theory of operation of positive displacement pumps.

Characteristic curve for a typical positive displacement pump and the reason for its shape.

Jet Pumps

Principles of operation of a worm pump.

9. MOTOR GENERATORS AND TRANSFORMERS

Indication of a locked rotor.

Potential consequences of overheating insulation or bearings.

Causes of excessive current in motors and generators, such as low voltage, overloading, and mechanical binding.

Relationship between pump motor current (ammeter reading) and the following: pump fluid flow, head, speed, and stator temperature.

Difference between starting current and operating (running) current in a motor.

Reason for limiting the number of motor starts in a given time period.

Electrical units: Volts, Amps, VARs, Watts, Hertz, Impedance and Reactance.

Consequences of overexcitation/underexcitation.

Interrelations of the following: VARs, Watts, Amps, Volts, Power factor angle, load angle.

Load sharing with parallel generators.

Motor and generator protective devices.

Transformer types, ratio's and tap changing.

Power Calculations in three phase circuits.

10. HEAT EXCHANGER AND CONDENSERS

Startup/shutdown of a heat exchanger.

Proper filling of a shell-and-tube heat exchanger.

Basic heat transfer in a heat exchanger.

Effects of heat exchanger flow rates that are too high or too low and methods of proper flow adjustment.

Flow paths for the heat exchanger (counterflow and U-types).

Components of a heat exchanger (shells, tubes, plates, etc.)

Control of heat exchanger temperatures.

Relationship between flow rates and temperatures.

Definition of thermal shock.

Principle of operation of condensers.

Relationship between condenser vacuum and back pressure.

Effects of tube fouling and tube failure scaling on heat exchanger operation.

Consequences of heat exchanger tube failure.

Reasons for non-condensable gas removal

11. DEMINERALISERS

Effect of excessive differential pressure on demineraliser performance.

Effects of channelling in a demineraliser.

Reason for sampling inlet and outlet of demineraliser.

Reason for demineraliser temperature and flow limits.

Principles of demineraliser operation.

Demineraliser D/P to determine condition of demineraliser resin bed.

Effects of demineraliser operation on water conductivity.

Demineraliser characteristics that can cause a change in boron concentration.

Reasons for bypassing demineralisers.

Reasons for using mixed-bed demineralisers to process primary water.

Plant evolutions which can cause crud bursts and the effect on demineralisers.

Definition of "boron saturated" as it relates to a demineraliser.

Definition of "lithium saturated" as it relates to a demineraliser.

Effect of temperature on saturated ion exchangers.

12. BREAKERS AND RELAYS

Purpose of racking out breakers (de-energise components and associated control and indication circuits).

Local indication that breaker is open, closed or tripped.

Loss of control power supply, circuit breaker indicator lights and capability to remotely open and close.

Operation of various push buttons, switches and handles and the resulting action on breakers.

Function of thermal overload protection device.

Interpretation of symbols for breakers, relays and disconnects in a one-line diagram.

Safety procedures and precautions associated with breakers, including high, medium and low voltage breakers, relays and disconnects.

Effects of closing breakers with current out of phase, different frequencies, high voltage differential, low current, or too much load.

Effect of racking out breakers on control and indicating circuits and removal of control power for breaker operation.

Function, control and precautions associated with disconnects.

Control room indication of a breaker status.

Trip indicators for circuit breakers and protective relays.

Appendix 2

TOPICS FOR TRAINING AND EXAMINATION FOR REACTOR OPERATOR LICENCE

1. FUNDAMENTALS OF REACTOR ENGINEERING AND REACTOR SAFETY

Basic layout of a pressurised water reactor.

Hazards involved in the use of nuclear energy [fissile product inventory, uncontrolled criticality]; risk.

Terms: normal operation, abnormal operation, incidents.

Safety concept; single and multiple failure concept, quality assurance.

Residual heat removal (RHR) during normal operation, RHR following the failure of the main heat sink, RHR during the loss of coolant.

Basic layout and the function of the barriers against the release of radioactive substances into the plant and the environment.

Terms: inherent safety, diversity redundancy, fail-safe principle, energise and de-energise to trip, active fault, passive fault, self reporting fault [examples].

Survey of the tasks and of typical modes of functioning of important active and passive safety systems in the pressurised water reactor plant.

Knowledge of the physical measuring principles of instrumentation.

Knowledge of the behaviour of measured data indications in the case of faults in the measuring system.

Basic aspects with which reactor protection measures become necessary.

Anticipated typical event sequences which may cause danger to:-

- the personnel in the plant
- the plant, including damage to the reactor core
- the environment

during normal, abnormal or incident operations.

2. OCCUPATIONAL SAFETY

The following shall be addressed in so far as they apply to nuclear safety:

Behaviour in conformance with accepted occupational safety.

Statutory bases for job related occupational safety and provisions and rules of importance to occupational safety.

Characteristic dangers and measures for the prevention of accidents.

Basic measures and procedures for maintenance work [permit to work procedure].

Measures in the case of personal injuries, particularly those resulting from radiation accidents.

Fundamentals of fire prevention and fire fighting in a nuclear power plant; behaviour during fires; basic features of fire alarms.

3. STATUTORY BASES

3.1. Nuclear Energy Act

Basic aims of protection.

Licensing prerequisites.

Changes to the plant or of its operation which require a licence change.

Access and authority of inspectors of the Council.

Basic requirements of Licence Documents.

Requirements of Licence Documents with respect to the responsibilities and authorities of operator licence holders.

3.2. Radiological Protection Standard, OPS 7000

Major provisions of the standard and their relationship to provisions such as:-

- principles of radiological protection.

- the Senior Authorised Person (RP) and the persons responsible for radiological protection, as well as their positions and duties.
- ventilation and plant radiation monitoring systems.
- measures to be taken with events that affect nuclear safety.
- arrangements for mitigating the consequences of accidents or incidents.
- instructions.
- the display of radiological protection ordinance [e.g.: RPC's, zones].
- the protection of air, water and soil.
- occupational radiation exposure.
- environment surveillance.
- other radiation exposures taken into account.
- work prohibitions and restrictions.
- the delimitation of controlled zones.
- local doses measurement in radiological areas.
- radiological protection supervision.

4. PLANT ENGINEERING

4.1. Buildings and building equipment

Layout and functions of buildings, access, location of systems and components with particular consideration to emergency cooling and residual heat removal; location and function of systems and components operated from the control room.

Functions to be performed and different modes of functioning of building equipment important to safety [e.g.: airlocks, escape doors, fire protection doors, fire alarms and fire fighting equipment, smoke exhausts and equipment at the entrance to the controlled zone.

Arrangements of escape routes, assembly points, fences and surveillance equipment.

Accessibility of plant areas during all modes of reactor operation.

Local position of fire fighting equipment.

4.2. Reactor Pressure vessel and internals

Functions to be performed, different modes of functioning, arrangement and layout of the major components [e.g.: fuel elements, neutron sources, in-core instrumentation, control rods including drives, vessel head, seals and leakage monitoring].

4.3. Reactor Coolant Circuit

Functions to be performed, different modes of functioning, arrangement and layout of the pressuriser, pressuriser relief tank, steam generators, reactor coolant pumps, safety valves, relief valves, isolation valves; design and operating data.

Energy sources and heat sinks, energy transportation during power operation, during forced circulation with the reactor shut down, or in natural circulation.

Interpretation of the measured data for the identification of the operating state, mode of operation, influence of the mode of operation on the reactor coolant circuit and adjacent systems, initiation of corrective actions in the case of malfunctions.

4.4. Reactor control

Principle and mode of functioning [control rod control, pressure control, level control, coolant temperature control, power distribution control, power level control].

Impact of control on the various systems.

Modes of operation [manual, automatic] and functions [limitation of control, maximum values, interlocks], overriding control functions between reactor control and control of the water/steam circuit [e.g.: rated values of power and secondary pressure].

4.5. Limitations of any system

Functions to be performed, different modes of functioning, checking for operability, activation criteria.

4.6. Control Rod Drive Mechanism

Functions to be performed, and different modes of functioning of control rod drives and the reactor trip mechanism. Arrangement of components inside the buildings, checking for operability, initiation of corrective actions in the case of malfunctions, criteria for the initiation of the emergency boration system.

Rates of motion and the drop times of the control rods.

4.7. Reactor Protection System

Functions to be performed, layout, different modes of functioning and logic, monitoring for operability and functionality, identification of malfunctions.

Activation criteria of various reactor protection system signals, interpretation of the state of the plant.

In-service inspections according to technical specifications.

4.8. Containment

Functions to be performed and different modes of functioning including containment isolation, arrangement of components and systems in the containment, initiation of corrective actions in the case of malfunctions, containment design limits.

Maintenance of negative pressure, heat removal from containment, H_2 control.

Arrangement of the containment isolation valves in the individual systems.

Influence of isolation of penetration, and/or penetration of containment shell, on the reactor auxiliaries.

4.9. Instrumentation and Alarm System

Functions to be performed by the instrumentation of the active and passive safety systems and the associated alarm annunciatiors. Incident instrumentation. Measuring methods.

Design limits of the measuring system.

4.10. Reactor Auxiliaries

Functions to be performed and different modes of functioning, arrangement of the components in the buildings, integration of the measured data for the identification of the operating state, possible modes of operation, influence of the respective mode of operation on adjacent systems, initiation of corrective actions in the case of malfunctions with respect to the following systems:-

- chilled water system.
- ventilation systems.
- containment spray system.
- containment ventilation systems.
- reactor cavity and spent fuel pool cooling and purification system.
- chemical and volume control system.
- reactor boron and water make up systems.
- nuclear sampling and plant radiation monitoring systems.
- safety injection system.
- nuclear vents and drains systems.
- residual heat removal system.
- component cooling system.
- essential service water system.
- air supply systems.
- effluent treatment systems.

Activation criteria and prerequisites for commissioning and manual interventions with respect to the following systems:-

- containment spray system.
- safety injection system.
- residual heat removal system.
- component cooling system.
- essential service water system.
- air supply systems.
- ventilation systems.

4.11. Conventional Service Systems

Functions to be performed, different modes of functioning and arrangement of the components in the buildings. Functions to be performed by the instrumentation of the following systems:-

- service water systems, fire extinguishing systems.
- air-conditioning systems and ventilation systems.
- fire and gas protection equipment.

4.12. Water-steam Circuit

Functions to be performed, different mode of functioning, arrangement of the components in the buildings, design limits and operating data, tasks of the controls, interpretation of the measured data for the identification of the operating state, possible modes of operation and influence of the respective mode of operation on the connected systems. Initiation of corrective actions in the case of malfunctions with respect to the following systems and units:-

- turbine and condenser.
- turbine bypass system.
- condensate system.
- feedwater systems.

- auxiliary feedwater system.
- safety valves and blowdown systems.

4.13. Cooling Water Systems

Functions to be performed, different modes of functioning, arrangement of the components in the buildings, interpretation of the measured data for the identification of the operating state, possible modes of operation, influence of the respective mode of operation on adjacent systems and initiation of corrective actions in the case of malfunctions with respect to the following systems:-

- closed cooling systems.
- residual heat removal systems.
- reactor coolant systems.

4.14. Electrical Systems

Functions to be performed, different modes of functioning, arrangement of the components in the buildings and activation criteria for placing into operation the various systems for the generation of emergency power to the essential busbars. Survey of the emergency power loads important to safety and initiation of corrective actions in the case of malfunctions.

Functions to be performed, different modes of functioning, arrangement of the components in the buildings, possible modes of operation for the auxiliary power system, survey of the auxiliary power supply and its most important loads as well as the mains connection and manual actions for establishing the auxiliary power supply.

5. CONTROL ROOM

5.1. Control room and auxiliary control panels

Physical arrangement of the control room including the allocation of systems and equipment.

Operation and scope of application of the information, communication and documentation equipment accommodated in the control rooms and ancillary rooms.

Explanation of the identification system of the plant.

Functions to be performed, and meaning of the actuation and display fields of the panels.

Diagnosis of the state of plant including normal instrument displays, incident instrumentation and reactor protection panel.

Functions to be performed and location of the auxiliary control panels, including emergency shutdown panels.

5.2. Control Room Engineering

Meaning of codings; display, signal and actuation equipment; allocation to the respective systems or components; meaning, handling and operating conditions of the key operated switches.

Malfunction in control room engineering and corrective actions.

Mode of functioning and operation of the alarm systems.

5.3. Computer Systems

Functions to be performed, different modes of functioning, arrangement of the components in the buildings, design limits and operating data, tasks of the controls, interpretation of the measured data, possible modes of operation, influence of the respective mode of operation on the systems connected and initiation of corrective actions in the case of malfunctions with respect to the computer system or with the data received from the system.

6. PLANT OPERATION

Explanation of the startup and shutdown of the reactor from various states of operation, as well as its power operation, in compliance with procedures and Operating Technical Specifications.

Operating transients and behaviour of the plant.

Characteristic development of the essential operating data during startup and shutdown.

Effects of secondary side operating parameters on the primary side operating parameters.

Admissible maximum temperatures and differences during startup and shutdown regarding thermal shock and brittle fracture.

Thermohydraulic processes during heat transport in the reactor pressure vessel.

Explanation of the operating processes of individual systems on the basis of Operating Technical Specifications, including in-service inspections and periodic testing.

Interpretation of the measured data and changes in measured data which are necessary for the identification of the state of plant, including identification of malfunctions of individual systems.

Interpretation of signals which are indicative of malfunctions and incidents. Explanation of the necessary automatic actions and of the possible manual interventions in the case of individual systems.

Explanation of the in-service inspections of safety systems [scope and date of inspection] in compliance with operating technical specifications and procedures.

Operation and monitoring of airlocks.

Operation of fire extinguishing equipment and respirators as well as other fire fighting measures.

Operation of the fire protection panel in the control room.

Functions to be performed by shift personnel when fuel handling is in progress.

Tests of the emergency systems from the emergency shutdown panel.

Prescribed measures with respect to the discharge of liquid and gaseous effluent.

7. ABNORMAL OPERATING EVENTS

7.1. Malfunctions of Important Systems.

Identification, consequences and measures to be taken in the case of malfunction of the following systems:-

- reactor coolant circuit, reactor coolant pumps, pressuriser.

- reactor control systems, scram operation.
- instrumentation.
- containment.
- the following systems, [with a view to radiological protection]: sampling systems in the nuclear island, vents and drains on the nuclear island, plant release pathways.
- reactor auxiliaries.
- systems of the water-steam circuit, as well as the feedwater pumps, the condensate pumps, the circulating water pumps.
- the conventional service systems.
- the cooling water systems.
- electrical power supplies and boards.

7.2. Abnormal operation and incidents.

Identification of the respective states of plant, in particular of subcriticality and removal of residual heat from the reactor core on the basis of the status tree monitoring and others; checking the safety systems for conforming function on the basis of the incident; required measures for assuring long term subcriticality and the removal of residual heat from the reactor core. Interaction of the various safety systems during various states of the plant and the possibilities of manual intervention in accordance with operating procedures and background documentation.

Identification and development of the malfunctions and incidents including, but not limited to, those listed below; explanation of the malfunction effects on reactor operation, the plant and the environment; methods used for the determination of the cause of incidents; interpretation of annunciators and other systems for the clarification of the causes; measures for the elimination of the incident; cause and possibilities for the minimisation of the activity discharge; application of the incident related operating rules.

1) Loss of instrument air to various headers, affecting plant performance.

2) Loss or degraded electrical power to the station including :-

   a) Loss of offsite power, with successful house load.

   b) Loss of emergency power, failure of emergency diesel generators.

   c) Loss of power to electrical distribution boards.

   d) Loss of power to the individual instrumentation boards (AC as well as DC) that provide power to control room indications or plant control functions affecting plant response.

3) Malfunctions affecting the reactor coolant pumps, including vibrations and seal failures.

4) Loss of forced reactor coolant flow due to single or multiple pump failure.

5) Loss of condenser vacuum.

6) Loss of service water (SEC) or cooling to individual components.

7) Loss of component cooling (RRI) system or cooling to individual components; leaks on the component heat exchangers inside and outside of containment.

8) Loss of normal feedwater; failures of pumps, valves affecting the feedwater system.

9) Failure of a train of the protection system.

10) Control rod failures.

11) Inability to drive the control rods.

12) Fuel cladding failure.

13) Turbine and generator malfunctions.

14) Turbine trip; generator trip.

15) Failure of the following automatic control systems:

a) Rod control systems.

b) Chemical and volume control system.

c) Steam dump system.

d) Feedwater control system.

16) Failure of the pressuriser pressure and level control system.

17) Reactor trip.

18) Failure of any nuclear instrumentation channel.

19) Failure of any process instrumentation channel, alarm, control system, related to:-

a) Rod control systems.

b) Chemical and volume control system.

c) Steam dump system.

d) Feedwater pump and feedwater control system.

e) Pressuriser pressure and level control system.

f) Turbine control system.

Also any channel that has an input into the protection system.

20) Leaks on chemical volume control system.

21) Leaks on condensate, feedwater and steam system.

22) Passive failures in systems such as the engineered safety features and the emergency feedwater system.

23) Malfunction of any major component of the important systems.

24) Loss of coolant.

a) Significant SG tube leaks; single and multiple SG tube ruptures.

b) Inside and outside containment (loss of recirculation).

c) Small break LOCA.

d) Large LOCA.

e) Failure of safety and relief valves.

25) Total loss of all AC power (offsite and onsite).

26) Complete loss of feedwater (normal and emergency).

27) Main steamline break as well as main feedline break, inside and outside containment.

28) Failure of the automatic reactor trip system (ATWS).

29) Accidents causing a serious threat to the plant critical safety functions, such as:

a) Inadvertent return to criticality after a reactor trip.

b) Failure of emergency core cooling systems during a LOCA which results in core exit thermocouple temperatures in excess of 650 °C.

c) Accidents inside containment that result in containment pressures in excess of the design values and hence to containment failure.

d) SG tube rupture, combined with a secondary side leak (stuck open safety valve), or combined with a loss of AC power.

e) loss of coolant accidents combined with instrumentation failure or drift.

30) Natural circulation cooldown with the formation of a steam bubble in the reactor vessel head.

31) Loss of natural circulation in one or more loops.

7.3. Unforeseen event sequences

Design limits :-

- Design limits of the components and systems important to plant safety such as the reactor pressure vessel, containment, steam

generators, emergency core cooling and the residual heat removal system.

Aims of protection :-

- The aims of protection which determine the safety of the plant such as :-

  a) subcriticality,

  b) long term core cooling,

  c) heat removal from the reactor coolant,

  d) power supply,

  e) activity confinement.

Safety parameters :-

- the plant-specific measured data which determine the aims of protection and their admissible ranges.

Safety functions :-

- the functions which assure compliance with the aims of protection and their effectiveness, such as reactor scram, safety injection, containment isolation.

Core damage:-

- possibilities of the identification of precursors to core damage, [such as high core outlet temperature, high primary circuit activity].

Identification of critical states :-

- measured data which, when exceeded, endanger the aims of the protection and are indicative of failures or ineffectiveness of safety functions, [such as neutron flux measurement, reactor coolant level, reactor coolant temperature, fuel element temperatures, main steam pressures, air activity, busbar voltages].

8. ADDITIONAL MONITORING REQUIREMENTS

8.1. Environmental Monitoring

Measuring instruments for environmental monitoring [e.g.: liquid wastes, stack, metrological data, steam releases], with display or alarm in the control room.

Countermeasures in the case of increasing activity discharges in a release pathway.

Monitoring of activity discharges through the stack.

8.2. Chemistry Monitoring

Monitoring of the chemistry of the various circuits.

8.3. Access Control

Control of access to the individual buildings or compartments.

8.4. Radiological Protection Monitoring

Must be familiar with the type of instrumentation and their mode of functioning for the following purposes:

personnel monitoring.

area monitoring.

9. ADMINISTRATIVE REQUIREMENTS

9.1. Control Room and Shift Duties

Scope of duties of persons on shift.

Responsibilities and authorities within a shift.

Responsibilities and authorities of top management, other management personnel and Radiation Protection staff with respect to shift personnel.

9.2. Control Room Response to Emergencies

Alarm equipment in the nuclear power plant.

Signals, behaviour and measures taken at various stages.

Preconditions and responsibilities for the initiation of the emergency plan.

Notifications.

Duties and responsibilities of shift staff during a nuclear emergency.

9.3. Operating Documentation

Structure, contents and handling of documentation including the safety specifications as well as any additional plans, drawings and descriptions that may be required.

9.4. Conditions imposed and documents issued by the CNS

Reporting requirements with respect to non-conformance with the CNS requirements.

Survey of the conditions imposed and the documents issued by the CNS with respect to operations.

9.5. Other Operating Rules

Important details for shift operation as part of the duties and responsibilities of the shift staff.

Appendix 3

SCOPE OF WALKTHROUGH EXAMINATION KNOWLEDGE REQUIREMENTS

A candidate will be examined on his degree of knowledge in the following areas.

1. CONTROL ROOM

1.1 Shift Handover

Verbal exchange; Shift change-over sheet; Emergency Duty Roster; Control Room Log; Review of Limiting Condition of Operation, Temporary Operating Instruction, Specific Instructions, Temporary Alterations and Out of Normal boards.

1.2 Administrative Procedure/Controls

Periodic Tests; Permits to Work; Specific Instructions; Interface with Interconnected Power System; Mechanical Drawings; Instrumentation drawings; Defects (PERMAC); Admin Lockouts; Use of Inhibit Keys.

1.3 Control Room Equipment

Communication equipment, PAX, PABX, Intercom, PA System, Alarms, Ringmaster, Sound power phones, In-plant cameras, Emergency telephones, KIT, JDT (Fire) Panel, Common panel, RPN cabinets, KRT sheet, Control Room leak rate sheets.

1.4 Control Room Tasks

Control room tasks which the candidate as a licence holder will have to perform during normal, abnormal or incident operations.

2. 15m and 11m Levels of Electrical Building

The tasks which the candidate as a licence holder will have to perform during normal, abnormal or incident operations.

3. Electrical Distribution

All of the following voltage supplies:- 230, 125, 48 & 30DC; 6,6kV; 380V (Non-essential & Essential); 220V (Essential & Continuous).

4. Emergency Shutdown Panel

Panel operation and communications

5. Nuclear Auxiliary Building

All systems and components of the NAB including the diesels. A candidate must be able to:-

1. Locate a component
2. Explain its function
3. Explain the impact on plant operation if the component fails.

6. Reactor Building

All systems and components of the reactor building. A candidate must be able to:-

1. Locate a component
2. Explain its function
3. Explain the impact on plant operation if the component fails.

7. Turbine Hall

All systems and components of the Turbine Hall of which the ASG and Outside Plant are considered to be part. A candidate must be able to:-

1. Locate a component
2. Explain its function
3. Explain the impact on plant operation if the component fails.

8. Additional Duties and Responsibilities

The candidates must identify the additional duties and responsibilities expected of a licence holder when on shift.

Radiological Controls

Personal monitoring; Personnel monitoring equipment and its use; Radiation Protection Certificates.

Plant Safety

Fire Protection; Hazardous Area Entry; Hazardous Material; Security.

Emergency Plan Duties

Duties of shift staff in emergency conditions.