(The Ghana Nuclear Power Programme Organization (GNPPO) is mandated with the task of coordinating, overseeing and administering the phase-to-phase implementation of the Nuclear Power Programme in Ghana until the commissioning of Ghana's first nuclear power plant.)

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Nuclear Safety

BACKGROUND

The decision to develop a nuclear power programme requires a long term commitment (over 100+ years) to the peaceful, safe and secure use of nuclear technology. This is explained in the 5 Phases of safety under the next heading *"Scope of the necessary infrastruture for nuclear safety and time frame for its development"* in this newsletter.

The Ghana Nuclear Power Programme Organsation (GNPPO) appreciates the fact that reliance on robust design and engineered safety systems alone are insufficient to ensure nuclear safety. Safety must also consider qualified managerial and operating personnel with the appropriately embedded safety culture.

The GNPPO, at the early phase of Ghana's nuclear power programme, is putting in place robust integrated management system, with strong emphasis on safety culture, which will be transferred to the future owner/operator and the regulatory body. Although Ghana has considerable experience in the construction and operation of huge infrastructure projects like thermal power plants, mining industries, Valco, Hydro power plants etc, such projects are not comparable with the unique requirements of nuclear power. Thus, the establishment of a robust nuclear safety infrastructure and commitment to the Global Nuclear Safety Regime is very critical and important.

The International Atomic Energy Agency (IAEA) publication INSAG-22 (2008), a major resource for this newsletter, ***"defines nuclear safety infrastructure as a set of institutional, organizational and technical elements and conditions that a country's Nuclear Energy Programme Implementing Organization establishes to provide a sound basis and foundation for ensuring a sustainable high level nuclear safety throughout the stages of the programme development".***

Ghana is already a contracting party to the *"Convention on Nuclear Safety (CNS)"* (the CNS sets international safety benchmarks for states operating land-based nuclear power plants) and has signed on to the "Convention on Early Notification of a Nuclear Accident" and the "Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency", although the country is awaiting a confirmation from the IAEA.

SCOPE OF THE NECESSARY INFRASTRUCTURE FOR NUCLEAR SAFETY AND TIME FRAME FOR ITS DEVELOPMENT

Ghana has been operating a 30 kW research reactor since 1995. The country has also been successful over the years in handling and managing various levels of nuclear, medical and industrial radioactive sources.

There is, however, the need to further develop and upgrade existing infrastructure in order to handle the safety challenges associated with a nuclear power programme. This requires commitment by government, the owner/operator, the regulatory body, nuclear technology and equipment suppliers and other organizations to ensure safety in all aspects of the nuclear power programme.

Nuclear safety covers the actions taken to prevent people and the environment from nuclear and radiation accident and to limit or mitigate their consequence. It covers nuclear power plants as well as all other nuclear facilities, the transportation of nuclear materials, and the use and storage of nuclear materials for medical, power, industry, and military purposes. Safety improvements at nuclear power plants have, over the years, been made by identifying and applying lessons learned from nuclear accidents, improving the effectiveness of defence-in-depth, strengthening emergency preparedness and response capabilities, enhancing capacity building ,and protecting people and the environment from ionizing radiation

From nuclear safety standpoint, the lifetime of a nuclear power plant is divided into five Phases with indicative average durations for each Phase.

- **Phase 1**: Safety infrastructure before deciding to launch a nuclear power programme (average duration: 1–3 years);
- **Phase 2**: Safety infrastructure preparatory work for construction of a nuclear power plant after a policy decision has been taken (average duration: 3–7 years);
- **Phase 3**: Safety infrastructure during implementation of the first nuclear power plant (average duration: 7–10 years);
- **Phase 4**: Safety infrastructure during the operation phase of a nuclear power plant (average duration: 40–60 years);
- **Phase 5**: Safety infrastructure during the decommissioning and waste management phases of a nuclear power plant (average duration: 20 to more than 100 years).

The main phases of safety infrastructure development over the lifetime of a nuclear power plant ,based on INSAG-22, are shown in the Figure below. In this edition of the GNPPO newsletter, only phase 1 and 2 are presented which reflect the current Phase of Ghana's nuclear programme.

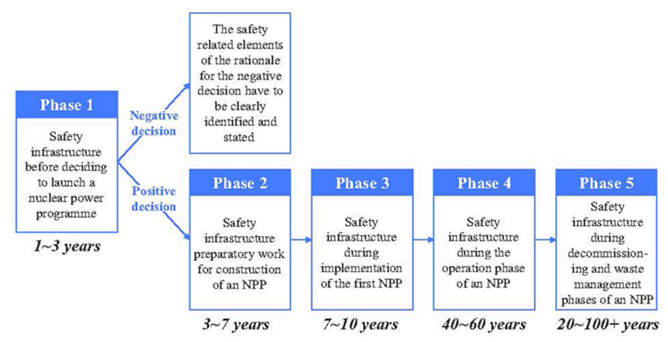
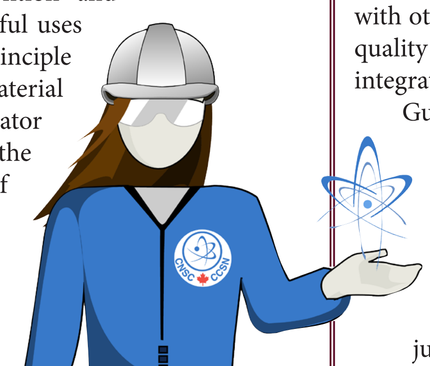


FIG 1. Main phases of safety infrastructure development over the lifetime of a nuclear power plant (based on INSAG-22 [4]). NPP: nuclear power plant.

PHASE 1: SAFETY INFRASTRUCTURE CONSIDERATIONS BEFORE A DECISION TO LAUNCH A NUCLEAR POWER PROGRAMME IS TAKEN

The enactment and/or amendment of nuclear legislation to identify nuclear activities and facilities that require a specific license for safety, security and safeguards is an activity that must be taken in phase 1 of nuclear safety infrastructure development. The nuclear legislation should be detailed and comprehensive and should address the safety principle (prevention and protection); security principle (peaceful uses of nuclear power); the safeguard principle (need to know where radioactive material is);the responsibility principle (operator or licensee responsible for safety); the independence principle (separation of nuclear regulator from implementer); the polluter pays principle (waste management is responsibility of the operator/generator); the radiation protection principles; third party civil nuclear liability; fuel cycle activities, transport of nuclear substances and radioactive material; decommissioning, radioactive waste and spent fuel management.



The phase 1 also considers the establishment of a body that would develop and promulgate detailed safety regulations and safety evaluation, while taking oversight responsibilities over defined nuclear activities.

Ghana has made significant progress in phase 1 safety infrastructure development by passing a comprehensive nuclear law. Ghana also has an independent regulatory body, Ghana Nuclear Regulatory Authority (NRA), with the mandate to develop national policies on the regulation and management of activities with respect to nuclear safety, security and safeguards.

PHASE 2: SAFETY INFRASTRUCTURE PREPARATORY WORK FOR THE CONSTRUCTION OF A NUCLEAR POWER PLANT AFTER A POLICY DECISION HAS BEEN TAKEN

Once the decision to embark on the nuclear power programme is taken, the principal actors; the owner/operator and the regulator-focused actions would need to build the national safety infrastructure.

For the NRA, priority task focuses on human resources and competences and this would continue through phase 3 of the safety infrastructure development. Aside from the above mentioned activities, the NRA would also:

- propose and promulgate safety regulations and guides that properly cover all foreseen nuclear activities in the country;
- verify compliance with applicable legislation and regulations and to assess the safety of installations and activities through analysis, evaluations and inspections; and
- enforce the application of such regulations in case of unanticipated departures or deviations.

Similarly, the owner/operator would develop its work processes, human resources and competences and safety infrastructure, paying attention to recruitment, training and training requirements, as well as technology transfer in phase 2.

FUNDAMENTAL SAFETY PRINCIPLES

The IAEA safety standards, comprising Safety Fundamentals, Safety Requirements and Safety Guides together with other related safety document from the IAEA and other States' practices constitute the basis for which safety requirements of the Ghana nuclear power programme are being developed. The Fundamental Safety Principles provide a coherent set of ten safety principles required in order to achieve the fundamental safety objective of protecting people (individually and collectively) and the environment from harmful effects of ionizing radiation.

The Principles are: 1. Responsibility for safety 2. Role of government 3. Leadership and management for safety 4. Justification of facilities and activities 5. Optimization of protection 6. Limitation of risks to individuals 7. Protection of present and future generations 8. Prevention of accidents 9. Emergency preparedness and response 10. Protective actions to reduce existing or unregulated radiation risks.

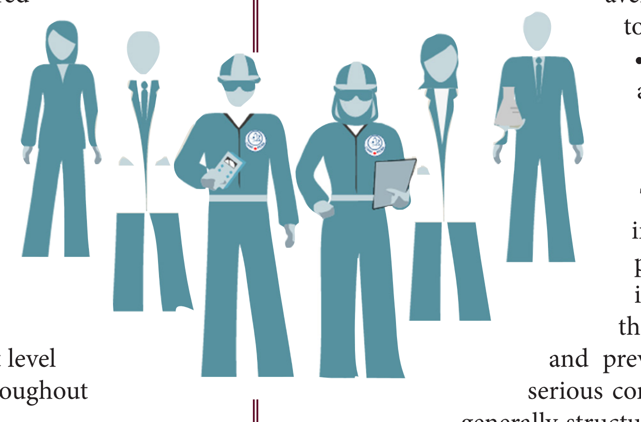
Principle 1: Responsibility for safety: The principle states that the prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks (licensee). This principle is well promulgated in the comprehensive nuclear law and the NRA is mandated to ensure its compliance by making sure the licensee:

- Establish and maintain the necessary competences;
- Provide adequate training and information;
- Establish procedures and arrangements to maintain safety under all conditions;
- Verify appropriatedesign and quality of facilities, activities and their associated equipment;
- Ensure the safe control of all radioactive material that is used, produced, stored or transported;
- Ensure the safe control of all radioactive waste that is generated.

Principle 2: Role of government: To ensure safe regulation of facilities and activities that give rise to radiation risks and for the clear assignment of responsibilities, *an effective legal and governmental framework for safety, including an independent regulatory body, must be established and sustained.* Ghana has advanced in this area with the passage of the NRA Act 2015, (Act 895) and establishment of an independent nuclear regulatory authority. The next step is for government authorities and the NRA to ensure programmes of action to reduce radiation risks, including actions in emergencies.

Principle 3: Leadership and management for safety: Safety has to be achieved and maintained by means of an effective management system which integrates all elements of management so that requirements for safety are established and applied coherently with other requirements, including those for human performance, quality and security. The GNPPO recognises the critical need of integrated management systems and has, therefore, developed Guideline for its Management System, considering safety requirements contained in IAEA document GS-R-3 and some of the requirements in ASME NQA-1-2008. The GNPPO has also drafted a guide to enable its personnel identify key processes for their operations.

Principle 4: Justification of facilities and activities: For facilities and activities to be considered justified, the benefits that they yield must outweigh the radiation risks to which they give rise. Undoubtedly, nuclear power will present enormous benefit to our country: sustainable, secure and affordable energy, sustained job creation (direct and indirect), environmental benefit among others.



Principle 5: Optimization of protection: To ensure that facilities and activities that give rise to radiation risks provide the highest level of safety that can reasonably be achieved throughout the lifetime of the facility or activity.

Principle 6: Limitation of risks to individuals: The purpose of this principle is to ensure that doses and radiation risks are controlled within specified limits. This would be achieved through measures to control radiation risk such that no individual bears an unacceptable risk of harm.

Principle 7: Protection of present and future generations: Radiation risks may transcend national borders and may persist for long periods of time. Therefore people and the environment, present and future, must be protected against radiation risks.

Principle 8: Prevention of accidents: The objective of this principle is that all practicable efforts are made to prevent and mitigate nuclear or radiation accidents. The primary means of preventing and mitigating the consequences of nuclear accidents is 'defence in depth'.

Principle 9: Emergency preparedness and response: The primary goals of preparedness and response for a nuclear or radiation emergency are:

- To ensure that arrangements are in place for an effective response to a nuclear or radiation emergency at the scene and, at the local, regional, national and international levels, ;
- To ensure that, for reasonably foreseeable incidents, radiation risks would be minor;
- For any incidents that do occur, to take practical measures to mitigate any consequences for human life, health and the environment.

Principle 10: Protective actions to reduce existing or unregulated radiation risks: Radiation risks may arise in situations other than in facilities and activities that are in compliance with regulatory control. In such situations, protective actions must be in place to reduce such existing or unregulated radiation risks and must be justified and optimized.

CONCEPT OF DEFENCE IN DEPTH IN NUCLEAR SAFETY

The concept of defence in depth in the early stage constituted an increasingly effective approach, combining both prevention of a wide range of postulated incidents and accidents and mitigation of their consequences. The early stage defence in depth concept generally includes three levels:

- conservative design, providing margins between the operating conditions foreseen (covering normal operation as well as postulated incidents and accidents) and the failure conditions of equipment;
- control of operation, including response to abnormal operation or to any indication of system failure, by the use of control, limiting and protection systems to prevent the evolution of such occurrences into postulated incidents and accidents;
- engineered safety features, to control postulated incidents or accidents in order to prevent them from progressing to severe accidents or to mitigate their consequences, as appropriate.

Lately, the concept of defence in depth has been refined to include consideration of external hazards, quality assurance, automation, monitoring and diagnostic tools. Furthermore, additional severe accidents have been considered in studies and probabilistic safety analyses. Feedback of experience and investigation of severe accidents has led to these new extensions of the concept of defence in depth:

- additional measures have been introduced to cope with significant multiple failures such as a complete loss of redundant systems (such as the scram system, the electrical power supply, the steam generator feedwater systems, or the ultimate heat sink);
- implementation of accident management system to prevent accidents or, in the event of non-postulated accidents, to mitigate their consequences;
- symptom oriented emergency procedures developed;
- provision made for on-site and off-site emergency response to mitigate the effects on the public and the environment of the release of radioactive materials.

APPROACH TO DEFENCE IN DEPTH

Defence in depth is a hierarchical deployment of different levels of equipment and procedures in order to maintain the effectiveness of physical barriers placed between radioactive material and workers, the public or the environment, in normal operation, anticipated operational occurrences and, for some barriers, in accident at the plant. The objectives of defence in depth are:

- to compensate for potential human and component failures;
- to maintain the effectiveness of the barriers by averting damage to the plant and to the barriers themselves; and
- to protect the public and the environment from harm in the event that these barriers are not fully effective.

The strategy for defence in depth is twofold: first, to prevent accidents and, second, if prevention fails, to limit their potential consequences and prevent any evolution to more serious conditions. Defence in depth is generally structured in five levels. Should one level fail, the subsequent level comes into play.

The objective of the first level of protection is the prevention of abnormal operation and system failures. If the first level fails, abnormal operation is controlled by the second level of protection. Should the second level fail, the third level ensures that safety functions are further performed by activating specific safety systems and other safety features. Should the third level fail, the fourth level limits accident progression through accident management, so as to prevent or mitigate severe accident conditions with external releases of radioactive materials. The last objective (fifth level of protection) is the mitigation of the radiological consequences of significant external releases through the off-site emergency response.

Irrespective of these efforts, there can be no guarantee that conditions that exceed design basis accident conditions will not occur. Such conditions are anticipated by both preventive measures and mitigatory measures (for accident management). Should engineered safety features fail to protect the integrity of barriers, and should accident conditions arise with consequences exceeding those anticipated in the design, the next line of defence would be to manage an accident so as to prevent progression of the accident, to limit radioactive releases from the plant or to mitigate the consequences of such releases. Thus the importance of emergency preparedness and response cannot be underestimated.