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Development, Construction, and Insurance of new Nuclear Power Plant Projects

Flamanville EPR Construction site (source: Atominfomedia July 2011)

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1. INTRODUCTION

For a number of countries nuclear power has become a serious option in order to secure a national energy supply. Once it has commissioned a nuclear power plant, or even a series of plants, a country commits itself to a life time of power generation. Therefore the entire nuclear industry is challenged to consider innovations, developments and the latest state-of-the-art technology when planning, designing, developing and constructing a plant.

The insurance sector caters to this demand and, in the continuous pursuit of excellence, tailors insurance concepts to be the, “best possible fit” for its customers.

Open sharing of experience, knowledge, fruitful discussions between participants of this working group along with their contributions enabled the group to ”compile” this paper looking into the complex areas and continuous challenges of Construction of New Nuclear Power Plants.

Goal and Scope of Paper

The goal of this paper is:

- Firstly, to raise the underwriters’ and readers’ awareness of critical issues that may occur during the long erection, construction and testing phases of commissioning a nuclear power plant.
- Secondly, to point out special areas requiring attention, and emphasise some possible consequences of underwriters’ oversights and failures that might occur if underwriting and risk assessment topics have not been addressed accurately when providing capacity for nuclear risks during construction (i.e. “just” accepting a follow share).

This paper attempts to give meaningful insights into the various underwriting, safety and loss prevention aspects which should lead to a better understanding of underwriting discipline and behaviour. Some topics reoccur in different chapters. This is a function of most chapters being written on a stand-alone basis and whilst chapters are complementary there is inevitably overlap.

It should be remembered that there is also a human responsibility aspect and that accidents do not only result in material and environmental damage but could lead to severe bodily injury with irreparable consequences.

Finally, it is worth remembering that human factors still remain, which influence the underwriting process and which will drive the exposure on-site.

Out of Scope

This paper does not look into any areas of refurbishments and / or dismantling of existing Nuclear Power Plants.

2. DESCRIPTION OF BASIC TECHNOLOGIES / REACTORS

Introduction

Nuclear energy is a way of creating heat through the fission process of atoms. The creation of heat to commercially generate electricity through the fusion process is also being pursued but is not under consideration in this paper beyond a brief reference to ITER under 'New Technologies'. All power plants convert heat into electricity using steam. At nuclear power plants, the heat to make the steam is created when atoms split apart; this is known as fission. Since the 1950s, when attention turned to the peaceful uses of nuclear fission, there have been a variety of types of nuclear power plant, developed. Initially, a number of experimental reactors were built using different types of fuel, moderator and coolant. Gas-cooled graphite-moderated reactors were popular but very soon lost ground to designs with light water moderators using enriched uranium. All reactors were designed and operated to achieve a self-sustained neutron chain reaction in their cores. There are now more than 440 nuclear units operating around the world. Over 100 new nuclear plant projects are in the licensing and advanced planning stages, with some 65 plants currently under construction (see Annexe for further details).

Generation 1, 2, 3, 3+

Early commercial reactors are normally referred to as **Generation I** reactors. These are commercial reactors developed in the 1950s and 1960s, and would include facilities such as the Dresden and Shipping port units in the US, and the Magnox reactors in the UK. Most **Generation I** systems were retired some time ago.

Generation II reactors are those reactors built up to the end of the 1990s. These would consist of the PWR/BWR/CANDU/VVER/RBMK and LWRs, i.e. the majority of plants currently in operation.

Generation III reactors are a development of many of the Generation II reactors, incorporating evolutionary improvements, which can include such features as improved fuel technology or superior passive safety systems. Examples include the ABWR, AP600, EPR and system 80+. More than a dozen advanced reactor designs are now in various stages of development. Some are evolved from those referenced above, referenced as **Generation III+,** and some are more radical departures.

As of the beginning of 2012, the number of new units being proposed, planned or under consideration remains an uncertain variable. With a number of replacement units planned and 65 units under construction, the range of potential new nuclear units varies from 100 to 400+ depending on the source of information. At the World Nuclear Symposium in 2011 one estimate based on nuclear fuel demand assessed that by 2030 there would be an increase of 142 units on the existing global fleet. This figure assumes a net reduction of 42 units in Europe and a net reduction of 2 units in the USA with a total of 298 units being commissioned and 156 units being decommissioned (298-156=142). Projections for the future of nuclear power in Europe compared to the US vary widely depending on a range of underlying assumptions. Even the diversity of views among European countries in this respect remains significant.

New Technologies (Generation IV)

According an OECD/NEA/IAEA report, at the turn of the century there were at least thirty-four new innovative nuclear designs being circulated for consideration. These ranged from liquid-metal fast reactors to very high temperature reactors, and from helium cooled gas reactors to molten salt reactors. However, the economics of building nuclear reactors, the general desire to move toward 'standardisation' and the requirements of the Generation IV International Forum, led to a reduction in the number of viable options based on eight technology goals, including safety, proliferation resistance and minimising of waste.

Current **Generation IV** technologies are a set of theoretical nuclear reactor designs currently being researched. Most of these designs are generally not expected to be available for commercial construction before 2030. There are six systems being researched: three systems are nominally thermal reactors and three are fast reactors.

ITER (originally an acronym of **I**nternational **T**hermonuclear **E**xperimental **R**eactor) is an international nuclear fusion research and engineering project, which is currently building the world's largest and most advanced experimental Tokamak nuclear fusion reactor at Cadarache in the south of France (see Annexe for more details).

3. DEVELOPMENT OF NUCLEAR SECTOR

Market Drivers

The desirability for energy security and the growing emphasis on reducing greenhouse gas emissions has been driving nuclear power development globally. However, concerns relating to high capital costs and nuclear safeguards may hinder the development of nuclear power. The World Energy Outlook has confirmed the increasing importance of nuclear power in meeting energy needs while achieving security of supply and minimising carbon dioxide emissions. Without a change to present policies, the world energy demand to 2035 is forecast to increase by some 2.2% per year accompanied by supply crises, creating a, "dirty, insecure and expensive" energy future which would be unsustainable. With the United Nations predicting world population growth from 6.6 billion in 2007 to 8.2 billion by 2030, demand for energy must increase substantially over this period. The report also declared that nuclear power could make a major contribution to reducing dependence on imported gas and curbing CO_2 emissions in a cost-effective way, since uranium fuel is abundant. However, it also concluded that governments need to play a stronger role in facilitating private investment, especially in liberalised electricity markets where the trade-off between security and low-price had been a disincentive to invest in new plant and grid infrastructure. Political opposition to nuclear remains an issue, with some countries, like Germany, choosing to abandon the technology completely.

In the U.S., the Energy Policy Act of 2005 was a driver to prompt utilities to expedite their efforts for new nuclear. Benefits included things such as risk insurance to owners of the first six plants, payment of 100% of costs for governmental and litigation delays for the first two plants--up to $500m per plant--and 50% for the next four plants. A production tax credit of $18 per megawatt-hour (MW) for the first 6000 MW of new nuclear power for up to 8 years--max $125m per plant--and a streamlined NRC licensing process were also allowed. In addition to government support and incentives in the U.S., the competitive cost of nuclear generation is another key market driver.

Economic & Political Aspects

The nuclear energy institute asserts that nuclear power is the lowest-cost producer of base-load electricity. It goes on to assert that nuclear production costs have remained steady in the US for more than 10 years averaging 2.14 cents per kilowatt-hour (kWh) in 2010. This includes the costs of operating and maintaining the plant, purchasing fuel, and paying for the management of used fuel. It is expected that the price of nuclear-generated electricity will remain stable because uranium fuel accounts for only a small part of production costs. If valid, this makes nuclear generation less susceptible to swings in fuel costs, which account for 80% of production costs in other forms of electricity generation. In 2010, the cost of electricity production in the US was as follows:

Nuclear: 2.14 cents per kWh

Coal: 3.06 cents per kWh

Natural gas: 4.86 cents per kWh

Oil: 15.18 cents per kWh.

These figures translate to other geographic areas showing that nuclear power is able to effectively compete with its two main counterparts in the base-load generation sector: coal and natural gas based power generation. The remaining emission-free technologies, such as solar, wind, geothermal and hydro, are a vital part of the energy mix but are not considered here as base-load.

In Europe, more than 150 GWe installed capacity comes from nuclear power. Maintaining or expanding nuclear power capacity would reduce its dependence on the import of fossil fuels, including natural gas from the Middle East and Russia. As with the US, nuclear power is not significantly affected by fluctuations or even significant increases in the price of uranium. Consequently, the price shocks and market volatilities evidenced in the oil and natural gas sector remain absent. Most countries, with a few notable exceptions, have not changed their stance on building new nuclear plants since the events in Japan in March 2011. Economics appear to be a key driver in the decision process. Western Europe is much like the US in regards to economics at this time. Some countries are in more financial trouble than others, but stagnant economic growth and low interest rates dominate global economics. However, there are key differences that are driving behaviours in different countries. For example, the UK economy closely resembles that of the U.S., but maintains significant differences in the electricity and energy demand market. Decommissioning its aging nuclear fleet has been an issue in UK energy demand. The technology used in many of the reactors did not grab the global market share enjoyed by PWRs and BWRs. The need to develop significant suitable replacement power became much more obvious to the UK government, and thus made nuclear a more acceptable option. The French have maintained a nuclear programme and have not indicated any rejection of nuclear. Germany has been divided about nuclear power, with the industrialised south generally more supportive of nuclear due to its low cost and high reliability. However, politics seem to have driven the country to drop the nuclear option. There is also an economic factor: Germany has considerable coal deposits, as well as significant economic interests in Russian natural gas. Together with low growth rates and moves to make wind and solar more sustainable, these unlikely interests have come together to eliminate nuclear from their current energy strategy. The Swiss had an initial reaction to follow the German lead, but at a measured pace. The Swiss have few external resources beyond the hydro-electric system. They have a mature economy with limited growth and so have time to make decisions. Other European countries, such as Italy, Spain and Belgium, are reassessing their current approach to nuclear power. Several eastern European nations have looked at Germany’s announced exit from nuclear power as a potential opportunity to provide energy in the shortfall. Poland and the Czech Republic both continue to be strongly supportive of nuclear programmes. In the emerging markets of China, India and the Middle East, economic growth is enormous and in many there is significant shortage of energy. There are few choices that provide large amounts of reliable power while still holding emissions and cost within some reasonable limit. It would appear that most of these countries have analysed what happened in Japan, concluded that modern designs are less prone to similar failures and are proceeding with new nuclear as quickly as they can safely do so. Alternative energy technologies are also being pursued aggressively.

4 (i) DESCRIPTION OF WORKS TO BE CARRIED OUT

Nuclear power plant project - General

During the construction of a nuclear power plant, risks are similar to any other large power generation plant. It is only at the point that nuclear fuel is introduced to the site that the risk profile changes significantly. Under a basic construction timeline, the nuclear fuel is not normally brought on site until the reactor and other hot zone/nuclear island equipment have completed cold testing and are ready for hot testing and commissioning. Typically this is considered to be 48 to 60 months into the construction project. However, history has shown that considerable delays may occur, adding up to 4 years to the project timeline.

NPP - Main areas

A Nuclear power plant comprises three main areas: the Nuclear Island, the Conventional/Turbine Island and the Balance of Plant.

Nuclear Island

The Nuclear Steam Supply System (NSSS) consists of a nuclear reactor and all of the components necessary to produce high pressure steam, which will be used to turn the turbine for the electrical generator.

A nuclear island of a pressurised water reactor plant holds the containment building, which houses the reactor and its high pressure steam generating equipment.

A boiling water reactor plant consists of the primary containment (which includes the suppression chamber, the reactor and recirculation pumps) and the reactor building (secondary containment), which surrounds the primary containment and serves many of the same functions as a pressurised water reactor's auxiliary building.

The main parts of a nuclear island are:

- Primary circuit
- Primary-side auxiliaries
- Nuclear island electrical supplies and Instrumentation and Control Systems (I&C)
- Heating, Ventilation and Air Conditioning (HVAC)
- Fuel storage

Turbine Island

The Turbine Island consists of the turbine building, which houses the steam turbines, condensers, and the electrical generator.

The main parts of a conventional island are:

- Steam turbine generator, including auxiliary systems and I&C
- Main and auxiliary transformers
- Diesel generators
- Water-steam cycle
- Electrical supply
- Heating, ventilation and air conditioning (HVAC)

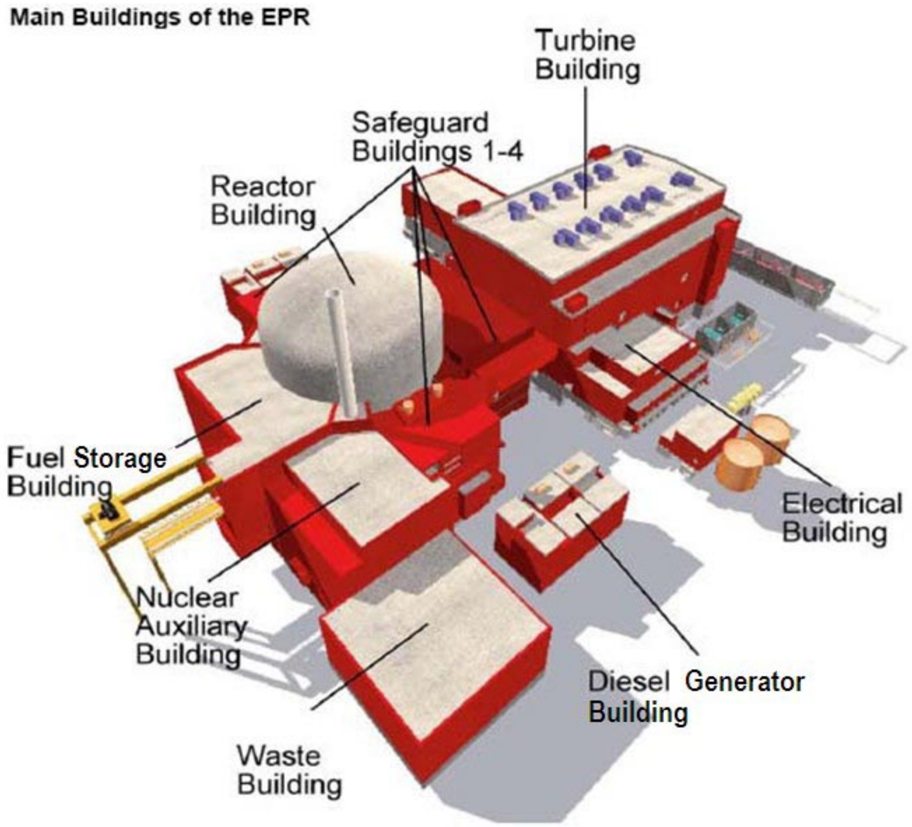
Balance of Plant (BOP)

BOP systems include such items as cooling water systems, cooling towers, administration buildings, warehouses, water treatment systems, waste treatment and storage, roads and switchyards. Unlike the nuclear island equipment and structures, BOP systems and structures are not normally critical path items. Infrastructure is normally available to build BOP systems and structures. Similar BOP systems and structures are required when building fossil power plants, process plants and commercial buildings.

Cooling water systems: Either intake/outlet tunnels from/to a large body of water, like a river, lake or ocean/sea, or a cooling tower system.

The auxiliary building, houses normal and emergency support systems, such as the residual heat removal (RHR) system, fuel handling and storage equipment, laboratories, maintenance areas, and the control room.

A layout example is shown in this graph:



A typical EPR plant layout (source: AREVA)

Nuclear power plant planning and implementation stages

A NPP Project consists of a range of stages/phases - illustrated in the figure below - which involve: planning, construction, erection/installation, testing and commissioning and finally, operation. The latter stages have historically been covered by the national pool or mutual insurers. An approximation of these stages/phases is as follows:

Stage 1: **Pre-Project:** Conceptual and preparatory activities that embrace all investigations on technical, economic, safety and regulatory aspects needed for the validation of a NPP project.

Stage 2: **Project Decision-Making:** Preparatory activities to create the national infra-structure necessary to support the launching of an NPP project, and the decision to go forward with the project.

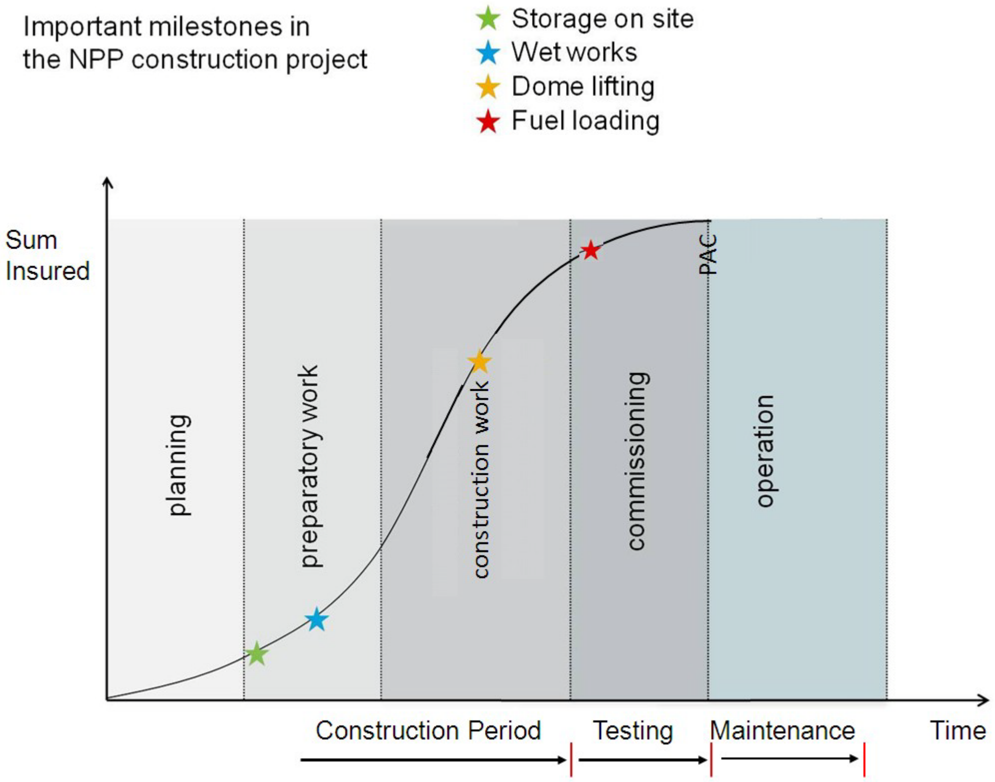
Stage 3: **Plant Construction:** Preparatory work is important. Typical examples include storage on site, access road infrastructure and construction in water areas. Work associated with cooling-water structures; a potential dock and shipping lanes often require dredging of the seabed, reclaiming sea area and construction on the shore.

In the nuclear power industry, the requirements for skilled labour are very high. At its peak about 6000 people are involved in the construction**.** There is a recognition that proper project management is crucial to meet construction deadlines.

Lifting of heavy equipment, e.g. dome or steam generator lifting, is a major risks during the construction phase.

Stage 4: **Plant Commissioning:** Cold and hot commissioning of the NPP are considered as separate stages. One of the most important milestones during the construction period remains the fuel loading of the reactor.

Stage 5: **Plant Operation:** This stage can be described as performance-oriented activities leading to the safe and reliable operation and life management of the plant. The primary concern of any NPP operator resides in the safe and reliable operation of its unit.



Manufacturing of equipment and components

Based on the specifications produced by project engineering, equipment will be manufactured and delivered to the site finished, approved and ready for installation. This activity requires mainly technicians and craftsmen of a variety of skills and qualification levels. It also requires adequate industrial infrastructure and technology.

Equipment and components represent the largest direct cost item for a NPP project. The construction of a 1000 MW(e) plant involves the casting of approximately 300,000 m^3 of concrete and the manufacturing of thousands of tonnes of steel, some of it of special grade. The site will consist of about 30,000 separate items, consisting of millions of parts requiring different levels of skills and quality for their production and installation. Some equipment manufacturing has to be started at least two to three years before the first structural concrete is cast.

Equipment manufacturing generates the largest block of man-hours in a nuclear project, approximately 20 million man-hours for a 1000 MW(e) plant. Labour required for the manufacture of things like ingots, sheets, forgings, or the mining labour for raw materials is usually considered part of the material costs. An underestimation of the manpower involved in the equipment manufacturing is not unusual. From an accounting perspective, the typical cost breakdown for mechanical and electrical equipment would be: 50% for direct and indirect man-hours for foremen, craftsmen, labour and administration; 10 to 15% for equipment engineering and production engineering; 20 to 25% for materials; and 10 to 20% for financing, plant amortisation, and general overheads. Equipment and components are divided into several safety classes according to the impact their failure could have on the safety of the plant.

In terms of safety, Nuclear Steam Supply System (NSSS) equipment and components and a large portion of the rest are included in Class 1, or the highest requirements. The quality requirement for such equipment is very high and a strict QA programme has to be applied. Conventional equipment not related to the safety of the plant is not subject to the same strict quality requirements, although higher standards than those normally applied in conventional fabrication are needed to ensure a high reliability and availability of the NPP. In countries with limited resources of highly skilled manpower, national participation would logically start with equipment of the lower degrees of nuclear specialisation, or of a lower safety class. Utilising developed manpower with experience in existing conventional industries depends on the industrial infrastructure, and is most easily done for equipment in the lower safety classes.

4 (ii) RISK EXPOSURES: The Parties Involved

Contractors and nuclear reactor vendors

The financial contribution of both the contractor and future operator or owner can be greatly impacted with any delay of construction and/or unforeseen security and safety demands.

A NPP construction project is characterised by long a construction period before any revenue is returned. Previously, construction periods were typically around 10 years. However, modern plants may be built within 4 years only, when the technology is well understood and the design and layout is streamlined.

For a variety of reasons original estimates of investment costs may be underestimated. In some cases it has been observed that subcontracted work is further subcontracted on multiple levels, which creates additional safety and quality of work issues for the construction project.

Accurate project management is of utmost importance in the construction of an NPP.

Public authority, regulators and licensors

At the initiation of a nuclear power programme or nuclear power project a public authority may play an important role in implementing or handing down the government's decision, setting up required infrastructure and contributing to regulatory and promotional activities.

An independent nuclear regulatory body has to ensure that not only are all safety and security requirements being met, but that proper supervision has been instituted.

Government licensing and certification procedures can also influence construction delays and costs.

Principal / future owner

The principal represents the future owner organisation of the plant who will be responsible for meeting power needs and for ensuring timely, economic and safe supply. Furthermore, they must ensure that the project meets the guidelines laid down by the public authority and the regulatory body. The principal may have large engineering and construction departments, and they may take on certain portions of the nuclear project. These may include infrastructure and site preparation activities, the inlet and outlet for the cooling water supply and other civil works. Depending on the utility's capabilities and previous experience, such project tasks may be performed by its departments or via direct subcontractors.

Project Management Team

Project management activities start with the decision to go ahead with a nuclear project following planning, feasibility and siting studies, and end with handing over the operating plant to another body which will be responsible for its operation and maintenance. The function of project management can be defined as the overall direction and co-ordination of project implementation tasks.

This is a very complex responsibility involving large risks, and that is why for a nuclear power project, it is advisable for an inexperienced owner to delegate the function to an experienced main contractor under a turnkey approach, or to an experienced architect-engineer under a split package approach. That said, the owner cannot delegate direct responsibility for control and supervision of the project, and should therefore be prepared to fulfil this commitment in the most efficient way.

Errors in project management have, in practice, been partly responsible for significant schedule and cost overruns in nuclear power projects. Although general management, engineering management or production management could equally be blamed, project management is the one area which is entirely devoted to, and specific to, a particular project and should have clearly defined schedule and budget targets from the early planning stage right through to the functioning product. The careful choice of the right lead personnel in project management, proper planning, the establishment of correct project organisation and its support are important steps towards successful project implementation.

Although additional licensing requirements, public intervention and funding problems have been blamed for most of the delays and cost increases, there is growing recognition that lack of proper project management has been a major factor. Project management is a management specialty primarily concerned with the definition, co-ordination and control of large undertakings, from the points of view of technical quality, schedule and costs. Improved steering, control and expediting of nuclear power plant projects by competent project management would reduce costs, not only through more efficient work sequences and higher productivity, but also through the reduction of accumulating interest during construction.

Main contractor / EPC contractor & sub-contractors

The manufacturers of key items are usually also main contractors for their portion of the contract. The main contractors are responsible for performing their contracted works. They also select and manage their respective subcontractors.

It is also a challenge for manufacturers, contractors and the principal whenever any changes materialise during the execution of works and their individual performances do not meet the necessary expectations.

Investors / lenders

The availability of adequate and secure financial resources is one of the most crucial constraints affecting the realisation of a NPP project. Lender / Banks and governments provide funds, and in return seek or require a great number of guarantees including the widest tailor-made insurance coverage. In most cases insurance needs to deal with special Lenders Clauses (see also Chapter 6).

4 (iii) RISK EXPOSURES: The Location Factors

With their high requirements for cooling, nuclear power plant sites are often located close to the sea or rivers, and thus are specifically exposed to natural hazards typical for these areas. But other perils also need to be considered:

Natural Perils

Earthquake/Tsunami

It is estimated that, worldwide, approximately 20% of nuclear reactors are operating in areas of significant seismic activity. However the seismic design of such plants is based on criteria far more stringent than those applying to non-nuclear facilities. Requirements for seismic design are, in fact, prescribed by national and international seismic design standards. Those seismic design criteria have received increased attention following the earthquake and tsunami that devastated Japan's Fukushima Daiichi plants on 11th March 2011.

The design criteria requires that structures, systems and components of a nuclear power plant withstand the effects of earthquakes and/or tsunami without losing the capability to perform their safety functions of:

- Maintaining the reactor coolant pressure;
- Shutting down the reactor and maintaining it in a safe condition; or
- Preventing or mitigating the consequences of accidents which could result in potential offsite radiation exposures.

Aside from an appropriate seismic design, integrated risk management[1] of a nuclear power plant plays a key role to ensure that safety functions are not lost in the event of earthquake and/or tsunami. Risks should be carefully evaluated and preventative measures should be considered to minimise losses due to those natural events. Such measures include and take into account:

- All various potential sources of tsunami that could generate an inundation/flood risk at the nuclear site.
- Nuclear site-specific risks, e.g. study of the regional topographic data, wave propagation and its impact, geological and hydro geological conditions, any coastal protection structure as breakwater, seawalls, reefs, etc.
- Mechanical strength and flood protection measures of all critical infrastructures for control, communication, monitoring, power including emergency power supplies, cooling, ventilation, drainage, transportation, etc. This should also include temporary facilities and structures needed for the construction of the plant.
- Implementation of a tsunami-monitoring system and/or seismic system able to issue early warnings at the nuclear construction site in combination with a proper preparedness/ evacuation plan where personnel have been properly trained to minimise any loss.

Storm

The meteorological and climatologically characteristics of a region around a nuclear site can highly impact the potential for losses. Phenomena such as tropical and extra tropical storms, tornadoes and lightning are among the most hazardous during the construction of a nuclear power plant, which can cause:

[1] IAEA-TECDOC-1209 "Risk management: A tool for improving nuclear power plant performance"

- Collapse or destruction of temporary and permanent structures;
- Impact of storm generated missiles on equipment and structures.

The determination of the exposure must be based on historical meteorological data and should include dates from recording stations in the entire region around the site. Particular attention should be given to seasonal effects, which will highly affect the scheduling of specific construction and erection activities that cannot be performed during periods of high winds. These are:

- Heavy lifts
- Marine/wet works necessary for the construction of cooling water intake/outfall structures.

Structures under construction often have incomplete or temporarily supported weakened structural systems, unsecured buildings' envelopes, loose materials and debris on the site.
High winds have been known to cause the collapse of cooling towers during the construction phase, although the design for the final structure had been based on much higher wind speeds. Heavy and tall cranes typically located near the reactor building can topple over and fall onto the costly buildings, such as the reactor containment. Even moderate wind gusts during lifting operations can destabilise cranes and can cause severe damage. Proper lifting protocols need to be established for all lifting operations.

Heavy Crane

Prior to imminent storm events, preparations to protect people and equipment must be initiated. All project works that can potentially be vulnerable to damage by the storm must be suspended. Materials and equipment that cannot be moved must be protected. If completion of structures is not possible or new construction is not fully strengthened, the installation of temporary bracing may be the only option for protection.

Flood

Construction of Cooling Water Pump Basin, slightly flooded

Depending on the site selection, there are a variety of flood hazards that need to be taken into account when determining the flood design basis for a nuclear plant. For coastal sites, the flood exposure is likely to be rated as the most severe hazard, and can be related to:

- Flood arising from storm surge

- Flood arising from tidal action
- Flood arising from seismically induced floods and water waves (tsunami)
- Flood arising from non-seismically induced water waves such as undersea landslides and volcanic eruptions/explosions
- Flood arising from wind, precipitation, tides and wave effects (in various combination).

For sites near rivers or lakes, the flood exposure might be less impacted by storm or seismic events, but highly influenced by high level of precipitation. The higher water volumes are to be removed by natural run off and artificial drain system of an area and lead to significant water level rises in rivers or lakes.

Seismically/non-seismically caused water waves, or the failure of artificial structures such as dams, may cause floods far more severe than floods caused by natural meteorological phenomena.

Site Location – Ground Conditions

Depending on the prevailing ground condition at a particular site an appropriate choice of the foundation has to be made, which takes the following surface and subsurface geological hazards into account:

- Surface faulting
- Volcanic activity
- Landslides
- Permafrost
- Soil erosion
- Subsidence and collapse due to underground cavities or caves
- Soil liquefaction
- Permeability
- Historical subsidence
- Ground water tables, streams or springs.

Geological hazards must be identified during the project development phase and require extensive geotechnical investigations and tests.

Aside from the geological hazards influencing the design of the foundations, other hazards in terms of potential ground destabilisation at or around the site must be considered so that appropriate countermeasures can be included in the design. A good plant implementation approach will also include the monitoring of soil settlement and lateral displacement during the construction.

Hazards to be taken into consideration are:

- Natural and artificial slope stability must be evaluated to reduce the risk of landslides affecting the side as a result of normal and, heavy rainfalls/flood that can affect the site.

Mudslide due to heavy rainfall

- Proper erection and stabilisation of temporary and permanent dykes and dams for the cooling water system or protection of the site.

Failure of protection dam

- Soil stabilisation to prevent erosion due to water, wind, wave action, etc.

Soil erosion due the wind and wave action

Local Workforce

The suppliers of nuclear power plants not only have to ensure that the site work is carried out within the schedule and budget constraints, but also that site work is being carried out to the codes and quality standards specified by the supply contract and the local laws.

In general, key positions in the project organisation such as engineering, site management, subcontract management, quality management, schedule and cost control, procurement, etc., are typically held by highly experienced individuals from the supplier. However, as the construction of a nuclear power plant may require several thousand workers during the peak phase, the suppliers have to enlist the services of local and/or external work forces.

The availability of qualified labour to support a specific project is viewed as one of the critical aspects of a successful and incident-free project implementation. With the increasing number of new projects, the risk of loss or damage due to insufficient skilled labour is likely to significantly increase in the future. A number of factors can complicate the recruitment of local skilled labour:

- General local labour is limited or non-existent due to construction taking place in underdeveloped area with little or no economic growth. Work force has to be brought in from outside.
- Local labour, possibly possessing only limited qualifications, may be employed in areas where none or very few high tech projects have been implemented in the past. Work force has to be developed and trained.

- Local labour is qualified but has been absorbed by other projects in the area.

In some instances, off-site prefabrication is chosen where qualified local labour is not available. While prefabrication may reduce the quantity of local qualified labour, it is likely to increase the construction cost.

Transit

During the construction phase of a new nuclear power plant, the transit risk is not that much different from any other large power generation plant. It should be noted however, that the standard inland transit policy extensions for erection all risk insurance policies pertains to locally procured items (unless heavy and critical components are locally supplied) and is typically limited to land conveyance only. All other transit risks are generally insured by means of separate marine cargo insurance.

The increase in recent years of modular design has also added new transit challenges. Larger and heavier loads are being transferred between manufacturers, storage and/or assembly places and the construction site. Hence a thorough transportation feasibility study is crucial to ensure a safe transfer of goods to the site. Specific exposures relevant to insurers include, but are not limited to, the analysis of the various following points:

- Identification of all critical cargo to be insured, e.g. type of item, value dimensions and weight.
- Review of transportation routes, means of transportation and special requirements for loading and unloading- in other words: distance; adequacy of roads and bridges to be used etc.; adequacy of transportation vehicle(s); availability of suitable cranes and rigs for on/off loading.
- Intermediate transits, e.g. between storage locations, pre-assembly yards and the construction site.
- Accumulation of critical cargo in intermediate storage or in same shipment.
- Potential liability risk, e.g. dust, noise, vibration, collision.
- Evaluation of transit control and supervision process.

Derailment of railroad wagon

General References:

IAEA Safety standard Series; External Events Excluding Earthquakes in the Design of Nuclear Power Plants
IAEA Safety standard Series; Flood Hazards for Nuclear Power Plants on Coastal and River Sites
IAEA Safety standard Series; Meteorological Events in Site Evaluation for Nuclear Power Plants

Political Considerations

The implementation of a new nuclear power plant project requires public acceptance, political commitment and liabilities of long duration. Before even considering a project site, aspects related to the ownership of the plant, the open access to the fuel market, waste management and funding, the presence or absence of a local nuclear regulatory institution, socioeconomic consequences to a region or country as well as the financial and environmental risks all have to be evaluated and determined within a political process. In general, a stable political system is viewed as a prerequisite to developing a sound nuclear project.

From an insurance perspective, the local presence of an established and strong nuclear body is clearly desirable. There may be configurations where the regulatory framework of a foreign experienced body is adopted as a solution for the short and medium-term time frame. Such a solution may not be ideal.

4 (iv) RISK EXPOSURES: Nuclear Specific Considerations

Erection works and handling

One of the key exposures during erection works is the heavy lifting and handling of many large and heavy pieces. The steel dome is especially important as the largest hung piece, using cranes specially designed and modified to hoist heavy objects safely and accurately without any misalignment. Some of the management qualities being adopted for this include: quality assurance, monitoring and detailed working procedures considering pre-inspection, site team for hoisting operations, empty hook tests, maintaining safety distances heavy lifts and wind impacts.

Critical construction operation: Lifting of large diameter dome onto reactor containment

Commissioning of a Nuclear Power Plant

Prior to the start of commercial operations of a nuclear power plant, the installation and functioning of structures, systems and components must be verified in order to ensure safe and reliable plant operation. During the plant commissioning it must be demonstrated that the individual components and the plant as a whole have been constructed, and are functioning in accordance with the design specifications. During this phase, the operating personnel will also become familiar with the operating characteristics, safety systems and maintenance procedures. Typically, a close liaison is maintained between the local regulatory body and the plant to obtain regulatory clearance upon reaching predefined hold points throughout the commissioning and start-up of the plant.

There is a clear distinction between cold and hot testing/commissioning, as it not only pertains to the condition of the plant at a particular stage during construction, but also to the assignment of responsibilities within the project organisation.

The objective of the cold testing phase is to verify completeness of the installation and readiness for the commissioning. This may include activities such as cleaning and flushing of components and systems, pressure testing, valve tests, motor and pump tests, instrumentation checks etc. Upon the completion of the cold testing phase, the installed systems are transferred to the commissioning group.

The objective of the hot testing and commissioning phase is to verify the proper functioning of components and systems under real plant operating conditions. During this phase, the interactions between the various systems are tested, adjusted and optimised to ensure that the plant as a whole is ready to be operated on a commercial basis. Upon completion of the hot testing and commissioning phase, the plant is transferred to the operations team.

For insurers of nuclear power plant construction projects, it is important to understand the commissioning sequence for the purpose of exposure assessing and definition of the insurance cover. A thorough analysis of the commissioning schedule is a prerequisite. This means that for individual systems, clearly defined transition points between hot and cold testing/commissioning need to be defined. For the main plant systems such as the Nuclear Steam Supply System, the steam turbine generator assembly, the non-nuclear water steam cycle etc., this transition needs to be defined in the insurance policy.

Typically, the highest exposure throughout the entire period of insurance is assigned to the hot testing and commissioning phase as the potential for possible loss or damage originating from machinery breakdown and/or fires and explosions increases significantly in this period. In addition, during this phase it can be assumed that practically all insured assets are on site.

The fire load in a nuclear power plant during the commissioning period is considerable. Large oil volumes are stored in the plant for the lubrication of the various rotating equipment alone. Any oil leakage onto hot surfaces can lead to fires. In addition, sealing failures of generator cooling systems or improper purging of the generator with inert gas, can lead to destructive explosions as in most electrical generators hydrogen is used as the coolant medium due to its favourable thermal properties. It is imperative that the fire protection and detection equipment is tested and put into operation prior to the start of the commissioning.

A critical phase during the hot commissioning of the plant is the start-up of the steam turbine, as it bears the potential for very large losses. There are an infinite number of causes that can lead to steam turbine losses. The causes with most destructive consequence may include:

- Turbine over speed
- Lubrication system failures
- Blade liberations events
- Improper balancing of turbine shaft, like high vibrations and turbine rubs.

The introduction of fuel into the reactor, or in some cases the achievement of first criticality, represents a pivotal point during the period of insurance as a portion of the risk is transferred from the conventional risk carriers to the pool or mutual insurers (for reference please see Chapter 6: Insurance Considerations). However, it must be noted that the above milestone is not synonymous for the start of the hot testing / commissioning phase of a nuclear power plant. The hot testing / commissioning phase of the Nuclear Steam Supply System and auxiliaries commences a considerable time prior to fuel loading. There is a distinction between hot testing / commissioning before and after the fuel load.

During the pre-fuel-load hot testing phase, the reactor coolant pumps are circulating water through the entire Nuclear Steam Supply System to the point where actual operating temperatures and pressures are achieved. For some plant configurations, sufficient steam can be generated for first admission of steam to the steam turbine and subsequent first synchronisation of the steam turbine generator with the electrical grid.

During the post-fuel-load hot testing phase, the reactor moderator is added and pre criticality tests are carried out to demonstrate the functioning of the reactor instrumentation and control system until first criticality of the reactor can be achieved. First criticality is reached at very low power levels and represents a reactor condition where a self-sustaining reaction can take place, i.e. idle condition of reactor.

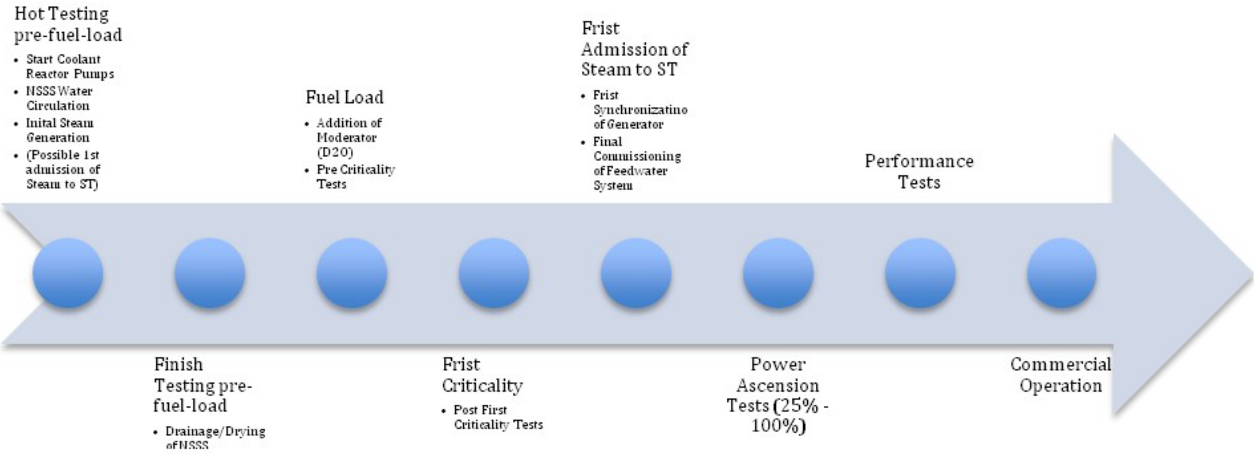
As indicated above, the introduction of nuclear fuel, or first criticality, is a crucial milestone during the construction of a power plant as a part of the risk is transferred to nuclear pool or mutual insurers. Special insurance clauses and definitions, as more specifically addressed in Chapter 6, must be implemented to precisely state at which point cover for certain plant equipment is transferred. It should be noted that the definitions with respect to the transferred equipment can vary depending on the type of reactor system to be implemented, e.g. PWR vs. BWR. Improper definition can significantly increase the exposure to insurers.

Upon successful achievement of first criticality and associated tests, power ascension tests can follow where the reactor power is raised in steps beyond the 5% power level, e.g. to 10%, 25%, 50%, 75% and 100% power levels.

The diagram below depicts a typical hot testing and commissioning sequence for a nuclear power plant. The absolute time periods between the various milestones have to be extracted from the project schedule. Typical time scales between the milestones for a 1000MWe nuclear power plant are:

- Hot Testing (pre-fuel-load): 1 – 2 months
- Fuel Load: 2 – 4 weeks
- Pre/Post first Criticality Testing: 2 – 3 months
- Power Ascension/Performance Testing: 3 - 4 months.

In comparison with a conventional thermal power plant, the overall hot testing and commissioning period of a nuclear power plant is significantly longer. However, there might be extensive shut down periods after achieving the various milestones to allow for the evaluation and submission of the collected data to the nuclear authority for approval.



Stages of construction works

Consequences of repairs during the commissioning

It should be noted that any repair in a nuclear power plant, whether caused by an insurable event or not, is inevitably much more complicated, time consuming and costly as the involvement of the nuclear authority is required in almost all cases. Repairs, especially on the primary side of the plant, require a stringent protocol which must be approved by the nuclear regulatory body. Access to the damaged equipment may only be possible after a significant waiting*/delay* period (up to 90 days) until radiation levels are below levels that allow access to the equipment. In addition, possible decontamination costs, if insurance cover is extended to cover accidental decontamination costs (see Chapter 6: Insurance Considerations), may have to be dealt with. In most cases, repairs on the primary side, carried out during the commission phase, result in considerable delays to the project.

New Technologies

The constant strive for safer and more economical reactor systems, inevitably leads to higher degrees of innovation in the design of nuclear power plants. Consequently, insurers are faced with increasingly challenging risk assessments arising from new technologies being implemented in new nuclear power plant projects.

While the available technology for deployment today has followed an evolutionary path, which is characterised by a strong emphasis on maintaining proven design features (up to Generation III+ reactors), future generation reactor systems will likely be of innovative design utilising fundamentally different technologies and concepts. The development of these systems still requires substantial R&D efforts. These new systems will not be commercially available for the next 15 to 20 years.

Technology exposures must be carefully assessed by insurers to evaluate the definition of specific deductible structures, sub-limitation of indemnity, degree of design cover provided and/or the definition of specific exclusions as indicated in Chapter 6.

Nuclear Steam Supply System (NSSS)

In the short and mid-term, the nuclear technology is likely to remain on an evolving design path, implementing moderate design changes to increase thermal efficiency and safety. Furthermore there is a clear migration toward standardised designs in order to improve the overall economics in terms of capital costs and maintenance. The most significant design features of the Generation III/III+ reactors currently introduced in the market may include four safety trains, double containments, Digital I&C systems and passive safety features. Many new designs also include severe accident mitigation features such as “core catchers,” a device designed to catch a molten reactor core in the event of a nuclear meltdown to keep it in the containment building.

Overall, construction of new plants has become easier where modularisation and standardisation have advanced. However, for the technology exposure assessment from an insurers’ point of view, it is crucial not only to understand new features that are implemented, but also the evolutionary path of a new reactor system in addition to the number of units in operation and associated operating history. Many of the projects involving the installation of the latest reactor systems available today have not yet been completed. Some of the projects have suffered substantial delays and budget overruns.

There is also a push towards harmonised requirements for licensing using the European Utilities requirements (EUR) as the basis. It is believed that this would not only accelerate the licensing process but also ensure the same level of safety across all new projects. For example, plants certified as complying with EUR include the AP1000, AES-92 (VVER-1000), EPR, and ABWR.

The following tables show the design evolution of the larger PWR and BWR reactors available today:

	Heavy Water Reactors		Light Water Reactors								
	General Electric / AECL		Westinghouse	Combustion Engineering							
1950	Candu Prototypes		Naval Reactors S W2	Naval Reactors							
			Naval Reactors A 2W		Rosatom / Atom Stroy Export (ASE)	Mitsubishi	Siemens				
1960	AECL	INDIA	Development of commercial PWR design		VVER 210	License from Westinghouse	License from Westinghouse				
		CANDU technology transfer to India			VVER-440	Installation of first PWR in Asia	Installation of first PWR in Europe	AEG			
		RAPP-1 (200MWe)					KWU (Siemens/AEG)		Framatome	KHNP (Korean Hydro & Nuclear Power Co.)	
1970	CANDU-500				VVER-440				License from Westinghouse Installation of PWR in France		CGNPG (China Guangdong Nuclear Power Group)
1980	CANDU-6 CANDU-750 CANDU-850	RAPP-2			VVER-1000 (V187)		Convoy design 1300 Mwe		CP0/1/2 (900 Mwe)		
1990			AP 600	System-800 (1300 MWe) C-E sold to ABB	VVER-640 VVER-1000 (AES 91/ V 392)				P4 (1300Mwe) N4 design 1400 MWe	Technology transfer from E-C (Sytem-80 design)	Technology transfer from Framatome 900 Mwe CP design
2000			former C-E part of ABB sold to Westinghouse		VVER-1000 (AES 92/ AV 466)		AREVA (Framatome/KWU)			(KSNP / KSNP+) OPR 1000	
	EC-6		Westinghouse (Toshiba / Shaw Group)					EPR			
2010	ACR-1000	AHWR 300 Mwe	AP 1000		VVER-1200 (V-392M/V 491) implemented in AES-2006 plant EUR version MIR-1200	APWR 1700 EU-APWR US-APWR	US-EPR			APR 1400 / EU-APR 1400	CPR 1000 ACPR-1000

It is noted that none of the reactors of the advanced design are in operation yet. The lead EPR, AP1000, APR1400, APWR1700 and VVER-1200 plants are currently under construction.

	General Electric						
1950							
		Hitachi	Toshiba		AEG		
1960	BWR 1 BWR 2	BWR license from GE	BWR license from GE		BWR license from GE Installation of BWR in Europe	Siemens	
	BWR 3	Installation of BWRs in Japan	Installation of BWRs in Japan	ASEA	KWU (Siemens/AEG)		Framatome
1970	BWR 4 ABWR technology transfer from license ASEA	ABWR technology transfer from license ASEA	ABWR technology transfer from license ASEA	BWR 69 BWR 75 ABWR	advanced BWR		
1980	BWR 5 BWR 6		further development BWR				
1990	SBWR (600 Mwe)			BWR 90+ ABB			
2000	GE /H/T				AREVA (Framatome/KWU)		
	GE / H		Toshiba				
2010	ABWR (1650 Mwe) ESBWR (1300 Mwe)		ESBWR (1650 Mwe)		KERENA		

There are a few additional reactor designs currently under development by a number of consortiums.

	Atmea (Areva / Mitsubishi)	Areva / EdF -CGNPC	Areva / EON	Consortium lead by Westinghouse
2010	Atmea 1 (1150MWe)	Further development of CGNPC's CPR1000	Further development of SWR1000 Kerena (1290 Mwe)	IRIS (335MWe) modular PWR

Aside from the introduction of the above design changes, most suppliers of nuclear reactors have increased their commercial offerings by introducing systems with higher output utilising scale-up methods. Scale-ups are applied to the entire Nuclear Steam Supply System (NSSS), including the reactor, reactor coolant pumps, steam generators and various circulation systems. However, there are inherent risks in applying scaling methods, especially in situations where a full-scale design validation is not feasible due to the large dimensions and associated cost to build full-scale testing facilities. For the validation of large-scale commercial nuclear reactor systems, suppliers resort to utilising small-scale test rigs in order to validate their design. Computer models are then calibrated to the test results so that they can predict the operating conditions at full scale. Although this approach has been successfully applied in the past, and the modelling capabilities to predict the behaviour at design dimensions have steadily improved, there is still a remaining uncertainty pertaining to the expected functioning at full scale. Aspects such as the introduction of a first series of a scaled up reactor systems, the combination of proven components/subsystem into a new overall system and/or the alteration of physical operation parameters, must be included in the insurers risk assessment.

In some cases the construction may have commenced already but the design of specific components has not been fully tested and validated, as the corresponding tests are still on-going.

Turbine Island

The main difference between steam turbines in nuclear power plants and their counterparts in fossil-fired power plants is related to the steam quality and associated energy extraction to generate power. Based on the relatively low temperature levels prevailing in water-cooled reactors, the live steam admitted to the steam turbine is saturated (steam that contains high moisture content on a mass percentage basis). Consequently, predominantly “wet-steam” turbines are employed in nuclear power plants, which differ substantially from conventional fossil-fuel turbines. Hence the flow path of these turbines must be designed to resist erosion from droplet impingement. This may be relevant, to a lesser degree, for gas-cooled reactors as a result of the higher temperature levels. Due to the low steam quality, very high steam flows are required in order to generate high outputs, necessitating large low-pressure turbine sections. In comparison with fossil fired steam power plants, the extraction of energy from the steam mainly occurs in the low-pressure turbine. Due to the large steam volumes, these LP sections are typically of the double flow tandem arrangement, resulting in long common turbine shafts. To keep flow velocities and associated exit losses at a minimum, large flow cross sections are required. As a consequence, long last stage blades must be utilised.

Much effort has been invested in recent years in the development of longer blades for the last stages of the LP sections. It must be distinguished here between full speed and half speed machines (3000 vs. 1500rpm or 3600 vs. 1800rpm in the 50Hz and 60Hz markets respectively). The development in this area has been boosted by the introduction of advanced 3D analysis tools such as Computational Fluid Dynamics and Structural Finite Element analyses. In addition, suppliers have invested in test facilities to validate new designs.

Currently, commercially available lengths of last stage buckets for half speed machines and full speed machines are around the 52” and 48” mark respectively. It should be noted that due to the higher moisture content at the LP exit, the overall loads imposed on last stage blades of nuclear steam turbines cannot be directly compared with their fossil fuel based counterparts.

While the technology for large electrical generators can be considered well-established, design modifications are constantly implemented in order to improve efficiency and reliability. Items like insulation materials, hydrogen cooling systems, excitation systems, protection systems, etc., are steadily being improved.

The insurer's assessment which related to the evaluation of the maturity of the turbine island may include, but is not limited to, the blade design, shaft arrangement, bearing design, the turbine control system. Turbine blade design may also be part of the insurer's exposure assessment.

Water Steam Cycle:

With the increasing electrical output of new nuclear power plants, other main plant components such as step-up transformers, moisture separators re-heaters (MSR), condensate/feed-water pumps, feed-water heat exchangers, etc., are also subject to evolutionary, and in some cases, innovative design changes. However, as this equipment is also used in conventional power plants, there exists a large experience base which drives the incorporation of new technological features. As there is less focus from the nuclear regulatory bodies on such equipment, it is particularly important to verify that the equipment is manufactured by renowned suppliers that apply "best in industry QA/QC standards".

Cooling water systems:

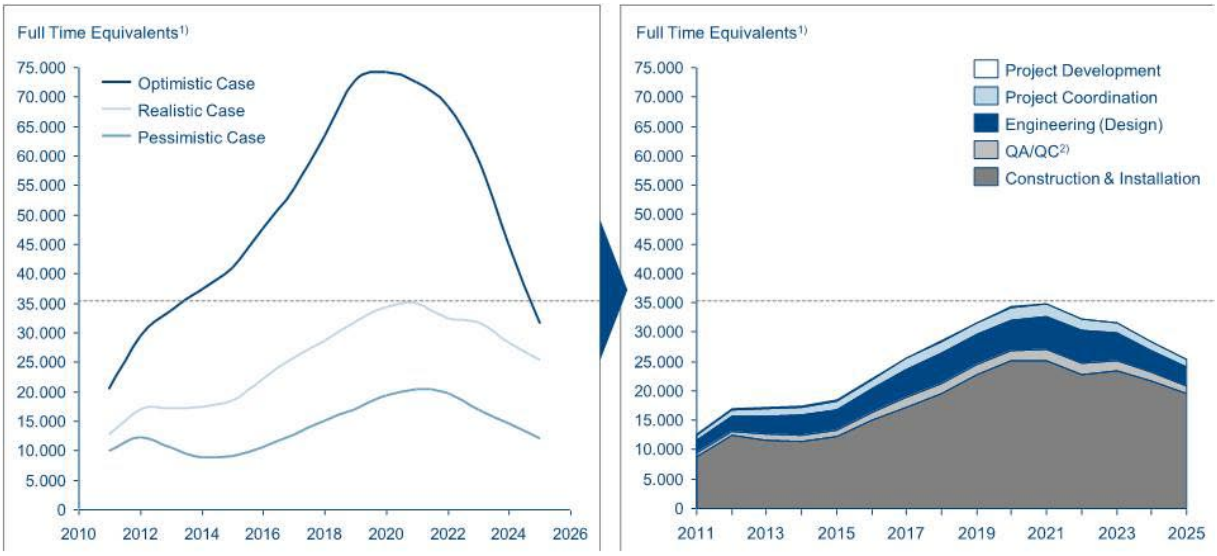
The plant cooling system of a nuclear power plant is one of the most vital systems because it is not only used to condense the steam in the main steam condenser, but also to remove the residual heat from the reactor in the event of a reactor shut down. While there are different cooling water system configurations, they all require the construction of large complex structures. Structures may include: cooling towers; water intake systems to extract water from rivers, lakes or the sea; large underground piping; tunnels; on-site ponds or canals; and water discharge structures. The erection of these structures is not necessarily unique to nuclear power plants. However, for the erection of structures such as tunnels, offshore piping or intake channels, highly specialised construction methods and equipment need to be applied which require experienced contractors. In addition, adverse weather conditions can further complicate these works. The installation of the cooling water supply and discharge system for a nuclear power plant can be a significant part of the contract price, and should be assessed very carefully as the loss potential due to collapse, and subsequent flooding, of insured property is considerable.

Technology Related Project Implementation Aspects:

The technical advances also translate into more complex project execution methods in order to avoid delays and cost overruns. New reactor technologies are subject to strong involvement of nuclear regulatory bodies, which may also increase the likelihood of project delays.

Unlike other industries, the nuclear industry has not had a steady growth over many decades and has only experienced some growth in recent years. During the downturn in building new nuclear power plants, a lot of experienced professionals left this field and the remaining work force has reached retirement age in recent years. This shortfall of experienced people has been compounded by the decreasing interest of young people enlisting in nuclear academic programmes due to the uncertain outlook in this sector. As a consequence, qualified and experienced personnel to construct and operate plants have become increasingly scarce.

While political commitments highly influence future labour demand in the nuclear industry, experts predict that the labour demand in Europe will reach a maximum towards 2020 for new nuclear power plants. Based on the labour availability today, this relates to an annual growth in labour demand of approximately 10% each year for the next 10 years. It should be noted that these predictions do not include supply chain labour for the manufacturing of equipment.



1) Europe without Russia
Source: Arthur D. Little

1) Europe without Russia
2) QA/QC = Quality Assurance/Quality Control
Source: Arthur D. Little

Demand of labour expected for new nuclear power plant projects during the next 25 years

For example, the availability of qualified welders to support new nuclear power construction is another element of great concern. It imposes a great burden on the main contractors to recruit and/or train professionals to be deployed to the construction sites.

The number of suppliers with nuclear quality credentials is increasing in order to meet future demand as may be required by regulatory bodies.

New engineering firms and manufacturers are emerging in the global power and utility sector. Many of these emerging firms are prepared to assume the risks of well-established manufacturers and suppliers at significantly lower margins and contingencies. While this approach may be attractive for owners and main contractors, it imposes an increased risk on insurers of nuclear power projects.

With the predicted number of new nuclear power plant projects worldwide, insurers' risks arising from non-availability of sufficient and qualified resources are likely to be exacerbated in the near future. Workforce development and retention are critical aspects to ensure the future health of the nuclear industry. New projects need to be developed.

Special Construction Plant and Equipment

Based on the scale of new nuclear power plants, highly specialised construction equipment is necessary to carry out heavy lifts during the construction phase (lifts up to 1500tonnes). In many cases these lifting cranes and rigs are one-of-a-kind and specifically designed and manufactured for a particular new project. They belong to the group of the world's largest cranes from both a dimensional and lifting capacity point-of-view. Aside from sophisticated boom structures to carry the high loads, these cranes also contain elaborate balancing and stabilisation features in addition to advanced drive trains and control systems. Some of these cranes include prototypical features and can present an added exposure if this equipment is covered as well.

5. CONSTRUCTION CONTRACTS & RISK ALLOCATION

Type of contract and Insurance Specification

Usually, the delivery contract between the owner and the contractor stipulates, firstly who will be responsible for the placement of the insurance, and secondly what kind of insurance cover such as EAR (Erection All Risks) / CAR (Contractors All Risks), ALoP (Advance Loss of Profits), TPL (Third Party Liability) etc., will be required. In addition it also may define some terms and conditions such as cover limits and retentions.

It is recommended that both parties have a clear common understanding of a seamless cover, also taking into consideration the changes that occur when – at commissioning stage - the liability switches to the owner and the risk to the pool or mutual insurers.

In particular in countries where the first nuclear plant is being / will be built and at present no national nuclear pool exists, insurers and reinsurers should be very well aware of how far the policy cover may have to extend, and anticipate “worst case scenario/awareness” for the future at date of fuel loading.

Furthermore it is necessary to fully understand the detailed contract structure along with all parties involved, their ownerships and responsibilities.

During the construction period transparency of the most critical open issues and a two-way communication helps to resolve matters in good time and meet each other’s expectations, respecting each other’s rights and obligations. Delays may lead to disagreements and change in behaviour on site.

Insurance - Critical Contractual Provisions

In order to meet the project schedule and avoid delays, most delivery contracts agree to “additional incentive payments”. These incentives should also be known to the insurers and what impact they may have to finish works under considerable time pressure, which would create an increase in risk, in particular in such cases where extensions have already been granted and issues still are pending.

Warranties

insurers should be aware and fully understand the provisions of warranties, how warranty triggers operate, especially which date they come into effect (e.g. Provisional Acceptance Certificate or during Hot Testing? etc.). If the warranty commences with hot testing, the liability of the insurer is greatly affected as the liability of the manufacturer / contractor prevails.

6. INSURANCE CONSIDERATIONS

Information Requirements

It is important that even the experienced underwriter has a sound knowledge of technical understanding of the functioning and design of nuclear power plants.

For evaluation purposes adequate and comprehensive underwriting information is mandatory to understand the different areas of exposure, especially when up-rated / upgraded technology or even new technology is used. However, specific consideration should be given to obtaining information in respect of the following areas:

The impact of incomplete information cannot be understated and adequate supply of adequate information should be seen as an absolute underwriting precondition.

i) Information regarding Participants

Principal / Contractors, including their references/experience in respect of NPP construction. Experience and qualifications of Licensors as well as EPC contract details.

ii) Natural Hazards/Site Location

Natural Peril information including rain precipitation, storm records, flooding, earthquake--in particular seismology--and tsunami information, geotechnical report / soil condition survey, flight zone and site layout with accessibility by air, rail, road, harbour / description of storage areas and safety arrangements.

iii) Project Details / Scope of Work

- Key features of the NPP and related process details. An up-to-date list of the latest modifications along with a specific description of any enhancements and, if possible, references. If this is not applicable, a confirmation that no equipment is prototypical or contains new unproven features.
- Major components, processing systems and processing equipment.
- Technical specification of key components and items along with their design parameters, for example: primary and secondary cooling system, reactor core, reactor pressure vessel (RPV), main pump, pressuriser, steam generator, containment, steam turbine, generator, including horizontal and vertical cross sections of the Conventional and the Nuclear Islands.
- Major Buildings and structures such as nuclear island buildings, conventional island buildings, balance of plant (including circulating water system, circulating cooling water treatment system, storage and service water system)
- Main Wet Works, including: water intakes, water outfalls, conveyance water tunnels, pump room, drainage systems and breakwaters.
- Shared facilities.
- Detailed bar charts (up to level 4) / work schedules and flow diagrams.
- Erection / and especially detailed hot testing duration / schedules, etc.
- Inventory of spare parts.
- Fire protections / designs and standards applied.
- Heavy lifts / special cranes.

iv) Detailed Time Schedule of Construction Works and Testing / Commissioning

v) Quality Assurance / Control Aspects

QA/QC procedures and methodology for implementation on site and allocation of responsibilities, Positive Material Identification (PMI), Non-Destructive Testing (NDT), etc.

vi) Correlation charts of various parties involved, critical paths, risk register and risk management measures.

vii) Transit / Storage
Value of goods. Type and method of stowage, origin of goods, value per vessel, place of disembarkation facilities, etc.
Location, manner of storage, goods stored, fire protection, security, maximum value in any one fire zone and environmental conditions.

viii) Value Breakdown
Breakdown of the estimated contract values of key items / units such as Nuclear Island (NI), Conventional Island (CI), Digital Control System (DCS), Balance of Plant (BOP) and others.

ix) Advance Loss of Profit Information
List of critical equipment, alternative method of work, financial information, critical paths , lead times for critical equipment (time to re-order, reship, reinstall and commission), list of spare parts for critical machines etc.

x) Third Party Liability
Determining third party exposures around the project.

EAR Wording & Endorsements and coverage specialities

General

The idea here is to highlight some of the essential coverage issues, related clauses whilst maintaining an overall picture. Some other clauses, e.g. Conditions for Fire Fighting Facilities, belong to the basic repertoire of a policy and need not be mentioned.

Understanding of the wording of the coverage and it's full extent is crucial.

During initial construction there is no significant difference between a conventional power risk and a nuclear risk.

However, care must be taken when, as is frequent with NPP projects, Lenders require special Lenders' Clauses included in the Insurance policy, in which the extent of cover may differ and widen the original cover defined in the underlying policy.

A major change in the Insurance provisions becomes relevant with the arrival and storage of nuclear fuel on site, and the risk increases further with the advent of fuel loading up to First Criticality[2]. From this phase the nuclear risk exclusion clauses apply for the conventional market and the national nuclear insurance pool and/or mutuals take over all nuclear and fire perils.

From first criticality the entire HRZ or Areas of any Nuclear Installation are excluded from the construction policy:

- Highly Radioactive Zone (HRZ) = a reactor vessel and its contents, fuel elements, control rods and spent fuel pool of irradiated fuel store.

[2] First Criticality is defined as the moment when, initiated by a neutron source, the reactor achieves a self-sustaining nuclear reaction chain first time.

- Areas = any area where the level of radioactivity requires the provision of a biological shield.

Cover of the nuclear insurance pool or the mutual usually attaches for named perils such as FLEXA, EQ**,** *Irradiation and Contamination*, and any other perils granted by a pool or mutual insurers normally apply to the entire construction site. Property fully excluded under a construction policy as per nuclear risk exclusions clauses (see below) may perhaps be reinsured facultatively on first loss basis.

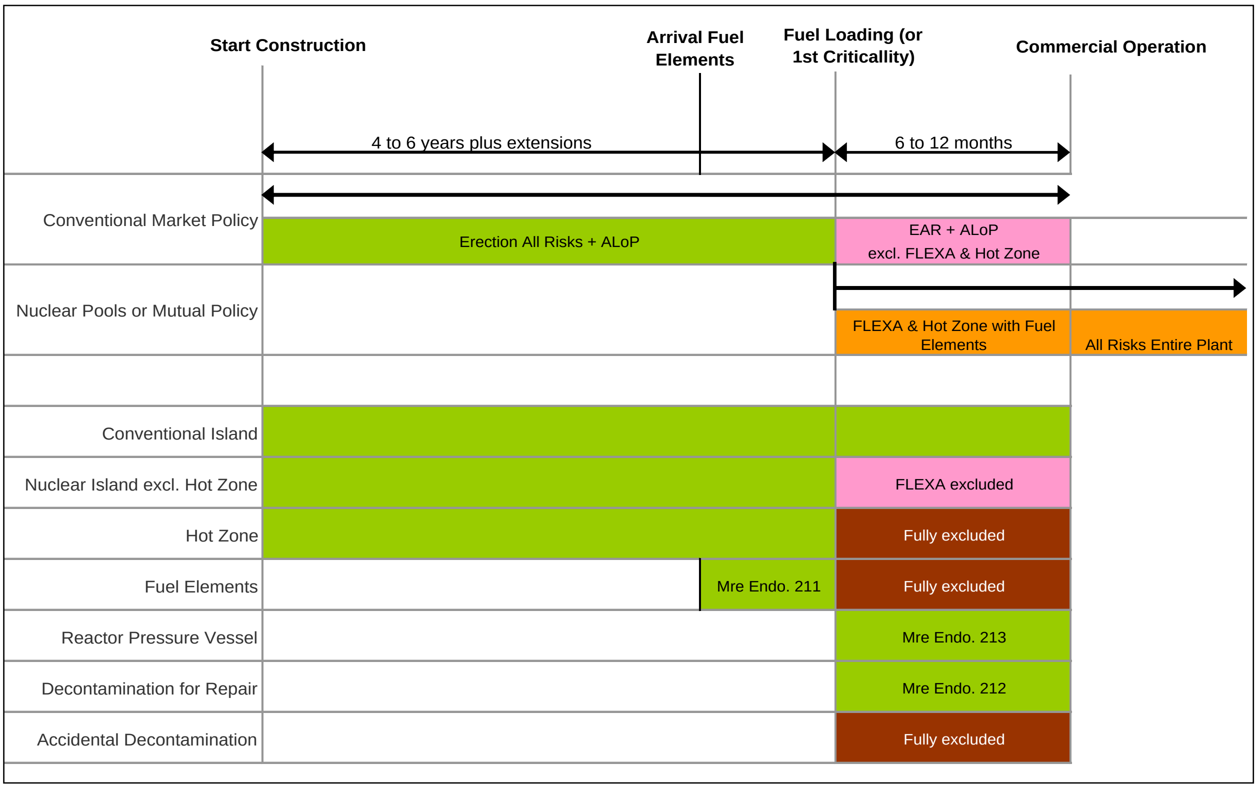
However the construction insurer still covers full machinery breakdown within the containment building from first criticality until handover to the principal, but does not cover the property within the HRZ.

The point of risk transfer from the construction insurer to the pool or mutual insurer can vary by pool / country and must be mutually defined and stated in the policy contract. It is usually the loading of nuclear fuel into the reactor, but may also be as early as arrival on site, but the latest would be the date of first criticality.

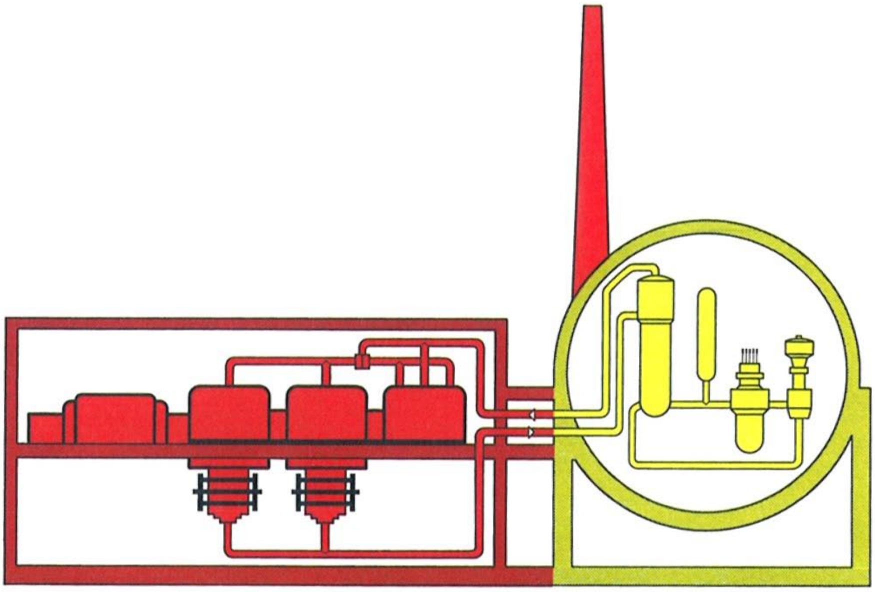
Therefore:

1) It is highly recommended to clearly discuss this date with the principal and the national nuclear insurer and define the estimated date of risk transfer within the construction policy.

2) Ensure that the construction policy leaves no coverage gaps with the attaching nuclear pool or mutual insurer cover. This should also be considered when tailoring a new construction policy for a country that is building its first nuclear power plant and where a pool does not yet exist.



Areas and perils insured by the Nuclear Pool policy during Phase 2 of the project:



The scope of cover provided by Nuclear Energy and Fire insurance.

Source: Munich Re

Further special issues

Nuclear Fuel Elements are generally excluded as they are part of the NMA exclusions, but can be added to the contract works' insurance, if insurers provide a special acceptance based on MRe Endorsements 211.

Cover for this inclusion is to be retained, net, or reinsured only facultatively.

Cover for fuel elements starts with unloading at the site and ends with insertion into the reactor. Nuclear Pool perils remain excluded.

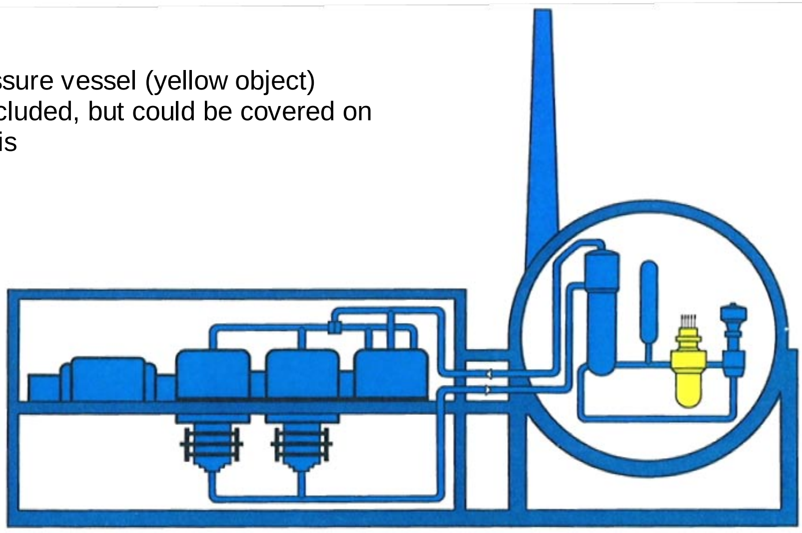
Indemnifiable costs are as follows:

- Extracting fuel, inspection and storage
- Reprocessing, repair, replacement
- Assembly to fuel elements
- Transportation.

The RPV is fully excluded after loading of fuel into the reactor, because it forms part of the NMA exclusions due to its radioactive content and nuclear contamination. A first loss limit cover may be provided as special acceptance, as in the case of MRe Endorsement 213. Due to the NMA exclusions, this first loss cover must be retained within the net retention or reinsured on facultative basis.

The cover would include the RPV and its internals, except fuel and absorber elements, during Phase 2 (hot testing) but excluding perils covered by the nuclear pool or mutual insurer.

Reactor pressure vessel (yellow object) generally excluded, but could be covered on first loss basis



Scope of cover of an EAR policy during the nuclear trial operation phase. (During the conventional construction phase the objects insured here on a first-loss basis also form part of the cover.)

Objects covered by EAR insurance.

Objects covered on a first-loss basis.

Source: Munich Re

Decontamination costs involved in repairing a conventional EAR loss would be excluded by the NMA exclusion clauses. However, they could be covered under first loss basis as a special acceptance for net retention facultative reinsurance, like for MRe clause 212.

Policy and Treaty Nuclear Energy Exclusion Clauses

There are three reinsurance treaty exclusion clauses which need careful attention, having been based on their own historical backgrounds, and each having led to standard nuclear exclusion within all conventional insurance policies:

- Nuclear Energy Risks Exclusion Clause (REINSURANCE) (1994) Worldwide excluding U.S.A. and Canada - NMA 1975a (10/3/94)
- Nuclear INCIDENT Exclusion Clause – Physical Damage -REINSURANCE – U.S.A. – 12/12/57- N.M.A. 1119
- Nuclear INCIDENT Exclusion Clause – Physical Damage - REINSURANCE – Canada – NMA 1980a (01.04.96)

Design Clauses and Prototypical Features

It is highly recommended to carefully consider to what extent design cover, e.g. a LEG Design Cover, can be granted in respect of upgraded designs, new designs and prototypical features. This applies especially when considering ALOP (Delay in Star-Up) cover in view of the delays most difficult to evaluate and separate into their insured and non-insured components of technical implications - redesigning, repair/replacement - and other factors involving public authorities in investigations and re-licensing, etc.

Insurers may consider restricting the cover or even excluding prototypes, prototypical features and processes on the basis of detailed technical analysis.

Definition of Testing Stages and Responsibilities

Milestones usually refer to different testing stages, from initial cold testing of various items, like components and parts, up to hot testing and completion of commissioning. From an underwriting / policy point of view testing stages should be clearly defined, in particular for key items, like steam turbine, the first admission of live steam and other essential steps until PAC.

The duration of the various phases has a strong impact on pricing of the testing period and may lead to quotations that are not comparable if they do not evaluate the same elements. Whilst pricing, of course, remains a concern of the individual insurers, parameters on which pricing is based should be clear and transparent to all.

Partial Handover

Partial handover may be considered when more than one unit is constructed. When two units are to be constructed then clearly, certain facilities are likely to be commonly shared.

In such a case it would be necessary to endorse the policy and agree upon which of the shared facilities would be taken over by the nuclear pool, and which would still remain under the construction policy valued sum insured with its allocated sum insured.

Maintenance Covers for Nuclear Power Stations

Irrespective of the date of attaching nuclear pool or mutual cover, maintenance cover will only apply as from provisional acceptance certificate (PAC) for the power plant. Nuclear pool perils remain equally excluded.

Costs Involved

The total contract value to be insured compares to any other power plant project. However nuclear fuel value – if it is to be included – must be declared and rated separately.

Special attention needs to be given when evaluating and accepting the originally provided estimated sum insured. It has often been experienced that during a long and additionally extended construction period, the total contract value increases to a substantially higher amount.

There is a correlation between contract value and megawatt output per plant / unit. If this is not properly assessed then, in the case of a claim, underinsurance may apply and/or insufficient premium results.

Increases in the total contract value are likely to occur and cost drivers lead to substantial adjustments of the total sum insured. PML calculations and respective shares accepted by insurers / reinsurers may be affected.

Advanced Loss of Profits and Third Party Liability Covers

Evaluating Loss of Profits Risk

Before considering granting ALoP cover, every insurer / underwriter should be aware of the implications of a long-term commitment of insurer / coinsurers and reinsurers.

An accurate estimation of the ALoP sum insured based on detailed data is required in combination with a sufficient indemnity period. To be factored into this consideration is that the nuclear industry is new to some countries, or new plants have not been built in the last 20-30 years. In other words, there will be an important learning process in many areas, such as shortage of skilled labour, costs increases, design change impacts, implementation of lessons learned during the construction process that will lead to far longer construction periods.

As mentioned earlier, substantial adjustments of the ALoP sum insured may be required, affecting the combined PML amount at risk and impacting the share of risk that can be accepted.

Handling of ALoP losses at the end of a long and delayed contract period is quite challenging and demands continuity of insurance companies, their underwriters and their reinsurers as well as of loss adjusters.

Evaluating TPL Risk

The above general nuclear exclusions do equally apply to TPL cover i.e. Section II of standard EAR policies. The special extensions mentioned under “EAR Wording & Endorsements and coverage specialities” above do not change this fact.

If TPL cover - Section II of the policy - is granted, then cover should always end with PAC, otherwise the policy may pick up claims during the attaching maintenance period when General Liability and Nuclear Poll policies already apply.

Place of Jurisdiction and Applicable Law

In order avoid to any ground for disputes, the place of jurisdiction should also apply to the TPL section of the policy, it should be clear which law is applicable, as well as being stated in the local policy and Reinsurance agreement (see also IMIA WGP 71(11)).

Underwriters require extensive local legal knowledge if they need to assess in depth, *inter alia* law in Arabic countries, or in the USA where law can be different within the various states (TPL cover under an EAR / CAR policy is usually not granted in the US).

Delays

The types and causes of delays are crucial from a financial and an underwriting point of view. Underwriters have to be aware of their reasons and possible impact prior to a claim and, of course, in particular in case of an indemnifiable claim. Information on critical paths is indispensable to get a realistic picture of the project status and outlook.

Some challenges may occur in case of loss when delays are substantially impacted by governmental and political influences, and requirements as well as matters of change in design. This is of special relevance for any nuclear project being under scrutiny of the public and government. The challenge is to separate the technical insured delay for carrying out repairs from the delays described above.

Possible Maximum Loss versus Probable Maximum Loss Considerations

It is the intention of this paper to raise awareness when establishing the maximum loss which lies within the responsibility of the individual insurer. According to the maximum loss definition applied--Possible Maximum Loss, Probable Maximum Loss, or Estimated Maximum Loss--either a more conservative approach or perhaps aggressive underwriting approach may be taken which, in the end, decides what kind of capacity the insurer can provide.

The chosen PML scenario drives the PML amount. insurers should all have the same common understanding of the technical PML rationale.
The most typical scenario is fire within the containment building prior to fuel loading when last contract works including cold testing are carried out and fire prevention measures, such a sealing of cable ducts and doors are not complete. Fire and smoke may spread within the building and its full value is at risk.

Further policy “add-on inner limits” are to be added to the technical PML amount, plus TPL and the ALoP sum insured. When applying waiting periods instead of time access, no monetary deductions are to be made.

Project length and deductible considerations

Recent projects have shown that considerable extensions (at least 3-4 years) need to be endorsed to the original policy period. Long-lasting projects therefore need to be extended which require insurance capabilities with professional consistency. In other words, underwriters should preferably have a meaningful track record with their Insured and be fully familiar with historical developments and the spirit/intent of the contract.

In this respect, adequate contract values, as described earlier, and proper deductible levels should be considered and factored into consideration. This is true for both for MD and ALoP which reflect 6 to 8 year construction periods, plus additional a 2 year maintenance and further expected extensions of the contract period. Inflation / devaluation and/or currency fluctuations have a strong impact and should be anticipated from policy inception.

Risk Management, Risk Registers, Progress and Loss Monitoring

Insurers / reinsurers usually apply their own format of Risk Management Activities, including site surveys and related follow-ups, which possibly address a list of recommendations to which must be adhered. Underwriters feel more comfortable if they gain knowledge of the projects' own Risk Management processes which should cover:

- Identifying and quantifying risks, (including those to third parties);
- Identifying pro-active measures to eliminate or mitigate the risks;
- Identifying methods to control risks;
- Allocating risks and their ownerships to the various parties involved.

Needless to say that it is important to observe the same positive quality level, or better, of Risk and Project Management during the entire project.

The risk managements Risk Registers are mandatory in order to have identified individual risk areas and exposures, to define the ownerships between the parties involved and to clarify how risks need to be controlled among various directly and indirectly connected parties. Full insight into the Risk Registers allow insurers / reinsurers to grade how the projects' risk management recognises the constant changes of risk elements during the different phases of a long project. Insurers - in comparison to the projects' risk management teams, key contractors, manufacturers and the principal - may have a different perception of existing exposures, their probable and possible maximum loss scenarios, their consequences and time frame to react.

Regular and accurate updates are crucial for the timely and effective functioning of, "live and active" Risk Registers, which in case of an incident, set the immediate and appropriate measures to be taken.

Progress and Loss Monitoring Reports on monthly / quarterly basis present good opportunities to learn about the developments and challenges on site, provided that these reports also openly discuss critical issues. Furthermore, site surveys – minimally carried out at key stages and milestones of the project – will allow insurers to get a clearer picture of critical issues and allow them to respond adequately. Analyses of critical path matters and the reasoning behind extensive delays (being either technically driven, claims driven or just due to external influences), will give insurers the opportunity to evaluate the risks correctly. This is especially true when ALoP cover has been purchased by the Principal. Delays which require further policy extensions need very careful consideration.

Other Lines

Machinery Breakdown insurance is not being discussed in this paper. Please refer to IMIA Paper – WGP24 (02).

7. Essential Safety and Loss Prevention Aspects

Nuclear power plant projects deal with highly critical technology, very high concentration of values and are subject to intense political and public awareness. They require adequate, and an "above-normal" level of safety, quality assurance and loss prevention measures, not only during operation but already during planning and construction of such plants.

Quality Assurance is one of the most vital issues to minimise loss or damage due to deficiencies in design, manufacturing, workmanship and construction. From an insurance point of view the quality issues apply throughout each phase of a project. The quality requirements must be specified between owner, contractor and regulatory authorities for each element of supplies and workmanship and qualification of staff, engineers and workmen employed. The project organisation must be in place to ensure that quality management system is ensured between all parties throughout the project period by a transparent and efficient communication.
The underwriter must enquire and understand at the time of underwriting, what project management organisation will be set up to control quality performance. Adequate measures should be taken to remedy any discrepancy in the manufacture, supply and construction phase, including the testing phase.

A great number of standards have been developed for nuclear power plants. However, while most of the protection and safety measures have been developed for plants actually completed and ready to function for the operational phase, there is often a lack of adequate measures during the construction phase, when essential parts of the works, very high property and business operation values and specific public concerns in safe proceedings of nuclear projects are at risk. This is where principals, contractors and insurers have to pay specific attention to.

The IAEA standards

The International Atomic Energy Organisation IAEA, the world's centre of cooperation in the nuclear field, has set up a number of safety requirements, standards and guides applicable right from the planning stage. The Agency works with its Member States and multiple partners worldwide to promote safe, secure and peaceful nuclear technologies. It runs and supports research centres and scientific laboratories. The IAEA Statute is based on three main pillars - or areas of work - underpinning the IAEA's mission:

- Safety and Security
- Science and Technology and
- Safeguards and Verification.

Their publications are of high relevance for designing such plants and should be the basis for consideration in the construction of NPPs. The recognition and consideration of the IAEA Standards / Guides by public organisations, principals, manufacturers and contractors in the planning, design, construction and during operation of nuclear power plants, should be understood as a basic requirement for insurance.

The IAEA standards provide a system of fundamental safety principles. As the primary publication in the IAEA Safety Standards Series, **The Fundamental Safety Principles** establish the objective and principles of protection and safety. They convey the basis and rationale for the safety standards for persons responsible at senior levels in government and regulatory bodies. (See, *inter alia*, the **International Basic Safety Standards for Protection Against Ionising Radiation and for the Safety of Radiation Sources,** Series No. 115, published March 21, 1996 especially pages 13 to 44 http://www-pub.iaea.org/MTCD/publications/PDF/Pub996_EN.pdf).

The **Safety Requirements** publications establish what must be met to ensure the protection of people and the environment.

The **Safety Guides** provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus on the measures recommended. The Safety Guides present international good practices, and they increasingly reflect best practices, in order to aid users who are striving to achieve the highest standards of safety.

The IAEA safety standards require that a safety management system is in place. This can be done in line with the IAEA Publication, **Application of the Management System for Facilities and Activities** Series No. GS-G-3.1, published July 28, 2006. This Safety Requirements publication defines the details for establishing, implementing, assessing and continually improving a management system.
(http://www-pub.iaea.org/MTCD/publications/PDF/Pub1252_web.pdf).

In the ANNEXE to this IMIA paper there is a selection of IAEA Safety Guides which are specifically of interest already at the planning, designing and construction phases of a nuclear power plant.

These regulations and guides may not be easy to read and may also be subject to revision in line with experience gained. Many of the safety principles, requirements and guides are kept more general and in certain respects are not specific to the application, layout and arrangements of individual plants and their local conditions. Therefore great attention must be given to the level of experience and expertise of the principal, the designers, manufacturers and contractors involved and responsible for the safety of the works, the quality assurance, loss prevention and emergency planning.

Specific aspects and measures

For achieving adequate safety and loss prevention, insurers are for the period of construction specifically interested in the following items:

- Site conditions, geotechnical situation, natural hazards, e.g. earthquake exposures, tsunami risks, storm and flood exposures, and the measures taken to adequately prevent loss or damage during the individual phases of construction. The present publications available do not yet adequately consider experience gained from the latest earthquake and tsunami in Fukushima, Japan in March 2011. This paper refers to some considerations made in respect of understanding tsunami characteristics and ideas how to modify design and layout of plants at coastal regions exposed to possible tsunami hazards.
- Principal's and contractors' safety and quality assurance organisations, their consideration of IAEA safety standards requirements and guides and any emergency planning during construction and testing phases.
- List of main suppliers, main contractors and their records of experience.
- Spacing of plant sections, storage conditions and protections, plant maintenance and hot work areas.
- Site security measures.
- Fire protection measures.
- Site transportation conditions.
- Handling procedures for mobile plant and cranes.
- Handling of heavy plant items like the reactor vessel, steam generators, cooling pumps, transformers, emergency generator sets, turbine and generator components.
- Location and protection of critical areas, such as the control rooms, transformers, emergency power generation, fire brigade etc.
- Training of site personnel, staff and workers.
- Construction and testing procedures / time schedule.

Many of these are not much different from what is essential also for conventional plants, but here special consideration should be given to the major perils listed below:

Fire protection

To get a detailed idea of what is recommended for fire protection of nuclear power plants it may be suitable to study the International Fire Protection Guidelines recommended by the Nuclear Pools.
http://www.amnucins.com/library/Int%20Fire%20Protection%20Guidelines,%20Edition%204%20Febr%2019%202006.pdf

Additionally the National Fire Protection Association (Massachusetts, USA) issued various Standards for fire protection in nuclear power plants. These are:

NFPA 804	Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants
NFPA 805	Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants
NFPA 806	Performance-Based Standard for Fire Protection for Advanced Nuclear Reactor Electric Generating Plants Change Process.

All these recommendations apply to operating plants and are often not enforced during construction; during hot testing (at the latest), they should definitely be enforced.
The project insurance underwriter's main interest in fire safety / protection during construction should, in any circumstances, include the following questions:

- Has a fire brigade been setup or does one exist nearby? If not, from when during the construction phase will one exist?
- Is satisfactory spacing and accessibility warranted in all relevant areas of the site, separating, *inter alia*, storage areas, workshops / welding areas and contractors plant service areas?
- Have temporary or fixed fire water supply and extinguishing systems been provided? If not, where and at what point in time during the construction works will they be?
- Is training and awareness of fire risks and their handling procedures assured for staff and workers during the construction phases?
- Have the site cleanliness, safe storage of waste material and non-smoking rules been organised and followed up strictly?

Regular site reviews are needed to ensure that these measures are reasonably developed and complied with. Employing experts in risk management for risk surveys is highly recommended.

General flood / inundation protection

Due to the importance of ensuring cooling of nuclear power plants under any circumstances, proximity to bodies of water such as rivers, lakes or the sea, is always required even if cooling is normally done by use of cooling towers. This involves, by nature, a high risk of flooding. During the Construction phase work is specifically exposed to rain storms, flood and inundation.

Typically, dewatering systems and protection walls / dams usually are under construction and in the early stages are not able to fulfil their intended tasks. There are large excavations, open trenches and other areas specifically exposed. Therefore, the project insurer should be interested specially in the following questions:

- What specific exposures exist for the location of the site?

- o Is the maximum rain precipitation adequately known and considered in the construction planning? Locations exposed to rain storms, cyclones and hurricanes require special consideration.
- o Will contractors establish a suitable flood monitoring/forecasting system? For storm and potential flood forecasting, the implementation of appropriate risk monitoring measures during the project implementation phase is paramount and can considerably reduce insurers' exposures in terms of actions taken to prepare for imminent events. In general, sites should have a monitoring system for the basic atmosphere parameters, or online access to a close meteorological station. In addition, coastal sites should have a tsunami monitoring or notification system.
- o Are adequate dewatering systems provided at an early stage and redundant pumping systems available for open excavations?
- o Are essential plant areas and storage facilities located on reasonably elevated ground and / or protected by dams? If not, from what point in time will they be?
- o Are shore protections at coastal locations provided from the outset? Do they adequately consider potential storm and flood hazards during seasonal periods?

  In principal, a site may be protected against external flood hazards by two main methods:

  - Elevation of the site level: this typically requires substantial backfilling at the site and may create other challenges pertaining to the selection of suitable structural fill material to minimisation soil settlement and potential future soil erosion.
  - Permanent site protection structures: these structures include shore walls, levees, dams and external barriers. The implementation and completion of these structures may not be possible during the initial stage of the projects, as the construction of sea/lake/river side cooling water structures, or open site access to bring in large pieces of equipment by means of vessels or barges, may prevent the full closure of such structures.

For both methods, all flood hazards individually or in combination should be taken into account to arrive at a sufficiently conservative design basis. Design water levels are generally established by using deterministic and probabilistic methods. Optimistic design approaches may be driven by cost reduction measures, or reliance on historical data only. insurers should request full details and rational behind the calculation of design flood levels and decisions taken in terms of the flood protection measures described above.

Equally important is the proper design of the plant drainage system to ensure sufficient drainage during intense precipitation, including side hill drainage or temporary overtopping of the permanent site protection structures during an extreme event. A comprehensive design for protecting the integrity of a nuclear plant also includes the identification of strategic locations for key plant equipment required for ensuring plant safety, e.g. placement of emergency diesel generators and switchyard. In addition, waterproofing should be applied to the plant structures essential for the safety of the plant such that in the event of a flood impacting the project, the safe shut-down of the reactor is ensured. Poor sealing of the structural joints, cable conduits or inspection openings can lead to leakage into the plant structures and components compromising the proper functioning of any equipment whether safety related or not, e.g. contamination of equipment with water, sand and debris. In-leakage can occur from flood events and/or the presence of ground water.

During the construction phase, temporary structures are particularly vulnerable as the design basis for these structures typically relates to lower return periods for flood events than the permanent structures. Such temporary structures may include cofferdams, sheet pile walls and other types of retaining walls, which are generally used for the construction of the cooling water intake and outfall structures. During a flood event, overtopping or even breach of these temporary structures can cause severe damage to the project.

- o Consideration of tsunamis

  Following the Fukushima disaster in March 2011 it may be questioned whether a nuclear site is suitable in such an exposed area at all. Experience has shown that even dams deemed of suitable height to match a tsunami can prove insufficient to protect a plant in the event of a tsunami. Unlike “normal sea waves” due to heavy weather and tide accumulation, tsunamis have a much more hazardous character in that the wave comes with an incredible depth of water and at high speed. This can cause a substantial build-up of the water height whilst still far out at sea, long before it approaches the coast and dams where the flow is hindered. Straight barriers or dams lying parallel to the wave are easily overtopped by such an accumulated water mass with tremendous force.

  In areas potentially exposed to tsunamis, it is vital to analyse:

  - The safety and protection measures being taken in respect of shoring off of essential parts of the plant, i.e. reactor and turbine buildings, transformers, switch yards, power lines, control rooms, fuel storage building, diesel generator sets, control rooms, cooling pump station and cooling water circuit.
  - The point in time that shoring-off measures become effective during construction - does this also include storage areas?
  - Is essential plant construction and equipment located at adequately elevated levels or with suitably high foundations?
  - How do these measures compare with others?
  - Can water flow around or underneath preventative measures?
  - Are building and plant structures designed at strength to withstand the impact of tsunami waves?
  - Are pump houses, power supply, switch stations, transformer stations and control rooms built to withstand such occurrence, providing insulation from seawater entrance and what redundancies exists?
  - Could critical plant elements like storage facilities, control rooms and diesel generator sets, etc., be placed at more secure locations?
  - Could power line masts be built high enough and protected by high concrete cylinders?
  - Could power lines nearer the plant be replaced by underground cables?

  There may be, of course, other aspects to be considered in each individual case.

- o On and Off-Site Storage

  Throughout the project implementation phase, various large on and/or off-site storage locations are utilised for temporary storage, laydown and possible pre-assembly of large structures. Aside from other exposures such as fire or theft, often the main exposure to storage locations is flood. The most ideal location from a flood protection point-of-view may not always be found due to logistical or topographical reasons. Consequently storage locations need to undergo a thorough evaluation in terms of flood protection design described above. Temporary measures such as drain systems, rising of storage elevation, etc., may need to be considered by contractors. The insurers’ exposure to loss or damage due to flood can be significant during temporary laydown of heavy components and equipment. The declaration of all storage locations, whether off or on site, is essential for insurers’ risk assessment.

Temporary open storage of equipment at an elevated place on site: Equipment covered by tarpaulins. The area is clean, not endangered by dry grass and shrubs and is placed on a slight incline to the left for easy run off of water

Storage of materials and equipment supplied early and the accumulation of equipment due to delays in works will affect the exposure. This requires special storage management and facilities. In some cases delays may last years, and proper storage and conservation considerations are needed. Corrosion protection, theft protection and physical conservation measures may apply, and insurers need to ensure that professional action is taken. Among these, protection against damage due to mice, vermin and insect attack may be relevant as well.

"Mite / Insect attack"

8. TYPICAL LOSS EXAMPLES

Much effort was spent in collecting non-nuclear and nuclear related claims examples from nuclear power plant projects, in order to illustrate what can happen and lessons that were learned. It proved to be very difficult to provide significant claims information which was either not available in detail, or subject to not being granted permission for publishing. However, some typical examples are listed below which speak for themselves. Some of the losses occurred after PAC during the operational period, but could have occurred during the extensive testing period.

Occurrence	Damaged Object(s)	Cause of loss	Comments
Large fire in warehouse	Warehouse and contents.	Due to delays, not unusual for nuclear power projects, excessive amounts of material supplied to the site accumulated in warehouses. The shortcut of a cable ignited plastic wrapping of goods setting the whole warehouse on fire which was most difficult to fight due to the congestion in the warehouse	Major loss amount and further substantial delays resulted. Only material damage was covered
Cable fire in containment building	Damage to cables and some other equipment and severe soot and smoke contamination in most areas of the containment building.	An overheated cable caught fire during testing operations in the containment building. Soot and smoke could penetrate into many areas of the building, due to the fact that during these testing works provisional / temporarily needed cables were laying through gangways, doors and cable ducts which were not then closed or sealed off	The largest part of the claims amount was involved in the decontamination works
Crane fell over building when lifting the dome cover over the reactor contain-ment	Damage to heavy load crane, prefabricated dome and building.	Insufficient foundation / support of crane	Substantial material damage claim resulted
Damage to steam generator vessel during lowering of the vessel into the reactor building	A nozzle of the vessel suffered deformation.	The nozzle of the vessel impacted an obstructing building structure during the lowering of the vessel.	Repair was quite expensive. The investigation into the seriousness of the deformation, stress analyses and working out a suitable method of repair resulted in the majority of the expenses involved
Damage to break water during construction	Major damage to breakwater works	Due to heavy storm and huge waves the incomplete works of the break water construction were damaged	The break water construction was part of the NPP project for protection of the site of the power plant

Occurrence	Damaged Object(s)	Cause of loss	Comments
A unit at a PWR plant operated at only 39% load following a refuelling outage. Fire in circuit breaker cabinet	The generator of the turbo set ran down without lubrication	A fire in the 4160 V circuit breaker combined with a failure of DC emergency power breaker caused unavailability of the turbine's emergency lube oil system	Loss amount around 60 Million USD
A unit at a BWR plant operating at 93% Power Fire and lube oil leaks	Significant damage to turbine, generator and exciter.	A breakage of low pressure turbine blades caused excessive vibration and subsequent oil leaks and fire. Turbine blades also penetrated condenser tubes causing flooding in the turbine and radioactive contamination in buildings	Loss amount around 200 Million USD.
Category 4 Hurricane passed directly over two units of a PWR plant. (also two fossil fired units on site)	Main plant areas of the nuclear plant sustained relatively little damage. Significant damage to ancillary buildings and fossil units	Category 4 Hurricane / Cat Nat.	Loss amount around 144 Million USD. (80 Million associated with nuclear warehouse)
Fire at NPP erection site		Careless handling during heating of concrete structure before continuing pouring of new concrete. Wooden supports and insulation materials ignited a fire which continued for four hours	Bad risk management. Could have been avoided with proper surveillance during the hot works. Considerable post-testing for checking possible damage to concrete Amount of loss 1.5 M US$
Damage to critical concrete elements	Major delay of the erection project	Faulty construction. Missing expansion seams between concrete elements. Inferior concrete quality	Proper scrutiny of drawings had not been performed. More stringent quality control recommended
Defective welding of reinforcement steel bars		Unsatisfactory specification of welding procedure and welders' qualification	Re-evaluation of soundness of reinforced structures significantly delayed the construction project. Amount of loss unknown
Tools left in the generator after revision		Careless quality assurance by assembly	Delay of start up
Generator rotor broken in BWR plant.	Major damages also to the steam turbine and to the machine hall.	Faulty manufacture: A corner radius at a diameter change of the rotor had been machined leaving too small a radius causing fast fatigue cracking	Remedy: Amended design. Event occurred during warranty period

Occurrence	Damaged Object(s)	Cause of loss	Comments
Generator trip activated by the on-line vibration monitoring system	Generator rotor almost broken.	Fatigue crack in generator shaft caused excessive vibration.	Faulty design in radius of shaft transition to larger diameter. Loss occurred during warranty period
Worker was hit by a falling reinforcement steel bar during a lifting operation	Bodily injury and damage to steel bars and impacted items.	The lifting operation was performed in a way violating the instructions	The event could have been avoided by applying proper instructions and supervision
Fire	Transformer.	No details given	Delay of several months of the construction project
Typhoon	Various civil works	No details given	

9. SUGGESTIONS

It may be recommendable to establish a code of practice for the nuclear industry similar to the Tunnelling Code of Practice which may help principals, contractors, risk managers and insurers to better achieve good quality control, safety and planning of loss prevention measures.

The objective of this Code would be to promote and secure best practice for the recognition and management of risks associated with the design, construction, refurbishment, testing and commissioning of a nuclear facility. It sets out practice for the identification of risks, their allocation between the parties to a contract and contract insurers, and the management and control of risks through the use of Risk Assessments and Risk Registers. Guidelines should also deal with Management of Change.

It is suggested that this Code applies to the Contractors / Erection works and for the testing and commissioning phase of a Nuclear Project. The adoption or recognition of this Code would be beneficial for all parties involved.

The Code would be intended to operate in conjunction with, and not derogating:

- Statutory duties, responsibilities and requirements of Local National Legislation relating to health and safety, or the design and subsequent implementation of construction activities in respect of a nuclear project.
- Local National Standards and/or Codes of Practice appropriate and applicable to design and construction of a nuclear project, including those relating to workmanship and materials.

10. CONCLUSIONS

Underwriters should be well aware of the increasing technical developments and improvements within the next years, which are being introduced in conventional and non-conventional areas of a nuclear power plants.
It is hoped that this paper has addressed the major topics of concern to be identified and assessed by insurers in order to professionally deal with the clients' needs and demands.

SOME SPECIFIC LINKS AND ABREVIATIONS

WNA World Nuclear Organisation (http://www.world-nuclear.org)

WANO World Association of Nuclear Operators (http://www.wano.info)

NEI (http://www.nei.org)

IAEA (http://www.iaea.org)

AMEC (http://www.amec.com)

Electrabel (http://www.gdfsuez.com)

Exelon (http://www.exeloncorp.com)

Nuclear Engineering – Theory and Technology of Commercial Nuclear Power by R A Knief

World Nuclear Industry Handbook 2011 – Nuclear Engineering International

World Nuclear University Primer: Nuclear Energy in the 21st Century – Ian Hore-Lacy

NPP	Nuclear Power Project
NI	Nuclear Island
CI	Conventional Island
DCS	Digital Control System
HRZ	Highly Radioactive Zone
EPC	Erection, Construction, Procurement
LP	Low Pressure
BOP	Balance of Plant
QA/QC	Quality Assurance/Quality Control
PMI	Positive Material Identification
NDT	Non- Destructive Testing
PML	Possible/Probable Maximum Loss
PAC	Provisional Acceptance Certificate
RHR	Residual Heat Removal
RPV	Reactor Pressure Vessel

NSSS	Nuclear Steam Supply System
PWR	Pressurised Water Reactor
EPR	Advanced evolutionary reactor of the PWR
BWR	Boiling Water Reactor
FBR	Fast Neutron Reactor
ITER	International Thermonuclear Experimental Reactor

APPENDIX 1 - IAEA Safety Guides

Loss Prevention in NPPs

Selection of IAEA Safety Guides, specifically of interest for the planning, designing and construction phases of a nuclear power plants:

The Management System for the Processing, Handling and Storage of Radioactive Waste Safety Guide

Series No. GS-G-3.3, published July 02, 2008 Series No. RS-G-1.4, published Tuesday, May 08, 2001. This Safety Guide supports the Safety Requirements publication on the Management System for Facilities and Activities. It provides generic guidance to aid in establishing, implementing, assessing and continually improving a management system that complies with the requirements.
(http://www-pub.iaea.org/MTCD/publications/PDF/Pub1253_web.pdf).

Design of Reactor Containment Systems for Nuclear Power Plants
Series No. NS-G-1.10, published September 22, 2004.
For use by organisations responsible for designing, manufacturing, constructing and operating nuclear power plants. In accordance with the concept of defence in-depth, fundamental safety function is achieved by means of several barriers and levels of defence. In most designs, the third and fourth levels of defence are achieved mainly by means of a strong structure enveloping the nuclear reactor. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1189_web.pdf).

Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants - Series No. NS-G-1.11, published October 04, 2004.
The paper helps to assess the possible consequences of internal hazards in nuclear power plants and provides interpretation of the possible Safety Requirements on Design and recommendations on how to fulfil them. It reviews such internal hazards as missiles, collapsing and falling objects, pipe failures and all of the above's consequences. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1191_web.pdf).

Design of the Reactor Core for Nuclear Power Plants - Series No. NS-G-1.12, published May 26, 2005. This paper makes recommendations concerning the safety features for incorporation into the design of the reactor core for a nuclear power plant.
(http://www-pub.iaea.org/MTCD/publications/PDF/Pub1221_web.pdf).

Instrumentation and Control Systems Important to Safety in Nuclear Power Plants – Series No. NS-G-1.3, published March 29, 2002. This Safety Guide provides guidance on the design of I&C systems important to safety in nuclear power plants, including all I&C components, from the sensors allocated to the mechanical systems to the actuated equipment, operator interfaces and auxiliary equipment. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1116_scr.pdf)

Design of Fuel Handling and Storage Systems in Nuclear Power Plants - Series No. NS-G-1.4, published August 08, 2003. The paper provides recommendations on the design of handling and storage systems for fuel assemblies associated with thermal nuclear reactors that are land based. It addresses all stages of fuel handling and storage, which include:
— the safe receipt of fuel at the nuclear power plant;
— the storage and inspection of fuel before use;
— the transfer of fresh fuel into the reactor;
— the removal of irradiated fuel from the reactor;
— the reinsertion of irradiated fuel when required;

— the storage, inspection and repair of the irradiated fuel and its preparation for removal from the reactor pool.
(http://www-pub.iaea.org/MTCD/publications/PDF/Pub1156_web.pdf).

External Events Excluding Earthquakes in the Design of Nuclear Power Plants - Series No. NS-G-1.5, published December 17, 2003. The first step in the design of a nuclear power plant against external events (such as aircraft crash, external fire, explosions, floods, wind storm, biological phenomena and volcanism) is to identify those events that are considered credible for a particular site.
(http://www-pub.iaea.org/MTCD/publications/PDF/Pub1159_web.pdf).

Seismic Design and Qualification for Nuclear Power Plants - Series No. NS-G-1.6, published October 20, 2003. This paper makes recommendations on categorising the structures, systems and components (SSCs) of a nuclear power plant in terms of their importance to safety in the event of a design basis earthquake. All procedures for seismic design should be firmly based on a clear appreciation of the consequences of past destructive earthquakes, and this knowledge should be adopted and realistically applied. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1158_web.pdf).

Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants Series No. NS-G-1.7, published Thursday, September 02, 2004. The paper provides recommendations and guidance to regulatory bodies, nuclear power plant designers and licensees on design concepts for protection against internal fires and explosions (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1186_web.pdf).

Design of Emergency Power Systems for Nuclear Power Plants –
Series No. NS-G-1.8, published September 01, 2004. This Safety Guide describes how the requirements should be met in the design of emergency power systems (EPSs) for nuclear power plants. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1188_web.pdf).

Design of the Reactor Coolant System (RCS) and Associated Systems in Nuclear Power Plants – Series No. NS-G-1.9, published September 23, 2004. The RCS forms a pressure retaining boundary for the reactor coolant and is therefore a barrier to radioactive releases in all modes of plant operation. In the design of the RCS, consideration should be given to ensuring the integrity of its pressure boundary and to providing a high level of operational reliability. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1187_web.pdf).

Flood Hazard for Nuclear Power Plants on Coastal and River Sites - Series No. NS-G-3.5, published February 26, 2004. The design basis flood has to be derived from the flood hazard for the site, which is a probabilistic result derived from the analysis of all the possible flooding scenarios at the site (storm surges, rain storm, waves, tsunami, combined events) (http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1170_web.pdf).

Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants - Series No. NS-G-3.6, published March 11, 2005. This Safety Guide discusses the geotechnical engineering aspects of the subsurface conditions and not the geological aspects, except where these directly affect the foundation system. It discusses the programme of investigations that should be carried out to obtain an appropriate understanding of the subsurface conditions, which is necessary for determining whether the conditions are suitable for the construction of a nuclear power plant. It also provides a description of the geotechnical profiles and the parameters that are suitable for use in performing the geotechnical analyses that are required for the design of a nuclear power plant. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1195_web.pdf).

Safety of Nuclear Power Plants: Design - Series No. NS-R-1, published October 31, 2000. This Safety Requirements publication takes account of the developments in safety requirements by, for example, including the consideration of severe accidents in the design process. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1099_scr.pdf).

Site Evaluation for Nuclear Installations Safety Requirements - Series No. NS-R-3, published December 18, 2003. This paper establishes the requirements for the elements of a site evaluation for a nuclear installation so as to characterise fully the site specific conditions pertinent to the safety of a nuclear installation. The purpose is to establish requirements for criteria, to be applied as appropriate to site and site–installation interaction in operational states and accident conditions, including those that could lead to emergency measures for:

(a) Defining the extent of information on a proposed site to be presented by the applicant;
(b) Evaluating a proposed site to ensure that the site related phenomena and characteristics are adequately taken into account;
(c) Analysing the characteristics of the population of the region and the capability of implementing emergency plans over the projected lifetime of the plant;
(d) Defining site related hazards.

(http://www-pub.iaea.org/MTCD/publications/PDF/Pub1177_web.pdf).

Seismic Hazards in Site Evaluation for Nuclear Installations Specific Safety Guide – Series No. SSG-9, published September 15, 2010. This paper provide recommendations and guidance on evaluating seismic hazards at a nuclear installation site and, in particular, on how to determine: (a) the vibratory ground motion hazards, in order to establish the design basis ground motions and other relevant parameters for both new and existing nuclear installations; and (b) the potential for fault displacement and the rate of fault displacement that could affect the feasibility of the site or the safe operation of the installation at that site. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1448_web.pdf).

Commissioning for Nuclear Power Plants - Series No. NS-G-2.9, published June 16, 2003. This Safety Guide makes recommendations based on international good practices in commissioning for nuclear power plants, as currently followed in Member States, which will enable commissioning to proceed safely and to a high quality. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1152_web.pdf).

Recruitment, Qualification and Training of Personnel for Nuclear Power Plants - Series No. NS-G-2.8, published November 19, 2002. In order to achieve and maintain high levels of safety, nuclear power plants are required to be staffed with an adequate number of highly qualified and experienced personnel who are duly aware of the technical and administrative requirements for safety and are motivated to adopt a positive attitude to safety. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1140_scr.pdf).

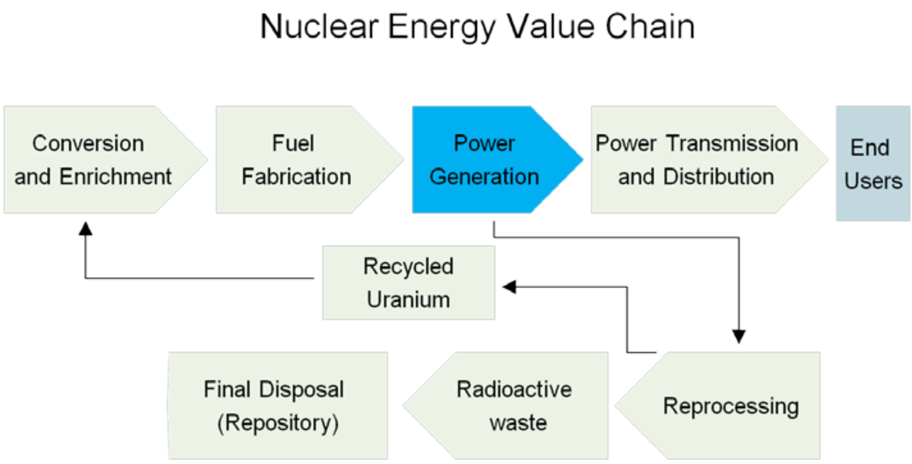
A System for the Feedback of Experience from Events in Nuclear Installations - Series No. NS-G-2.11, published Wednesday, June 14, 2006. (http://www-pub.iaea.org/MTCD/publications/PDF/Pub1243_web.pdf).

Safety of Nuclear Power Plants: Commissioning and Operation Specific Safety Requirements - Series No. SSR-2/2, published July 14, 2011. Protection must be optimised to provide the highest level of safety that can reasonably be achieved. (http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1513_web.pdf)

APPENDIX 2 - Technical Information on Nuclear Power Plants

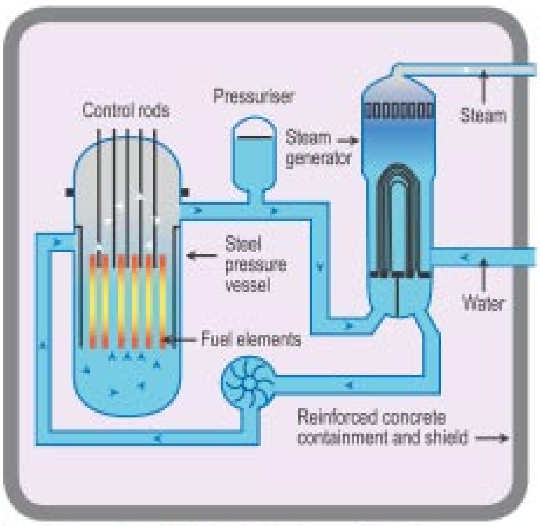
An operational NPP is a part of the nuclear energy value chain, which begins with the uranium supply--exploration, mining and milling--and ends with the creation of energy, or end use, and nuclear fuel waste handling. Up to 95% of spent fuel produced after nuclear fission can be reused in power generation facilities after reprocessing. Reprocessing separates components of spent nuclear fuel such as reprocessed uranium, plutonium, minor actinides, fission products, etc. The by-products of reprocessing, mainly radioactive liquids, can be stored in borosilicate glass and put into interim storage before final disposal.

Illustrative figure:



The common existing operating technologies can be described as one of the following:

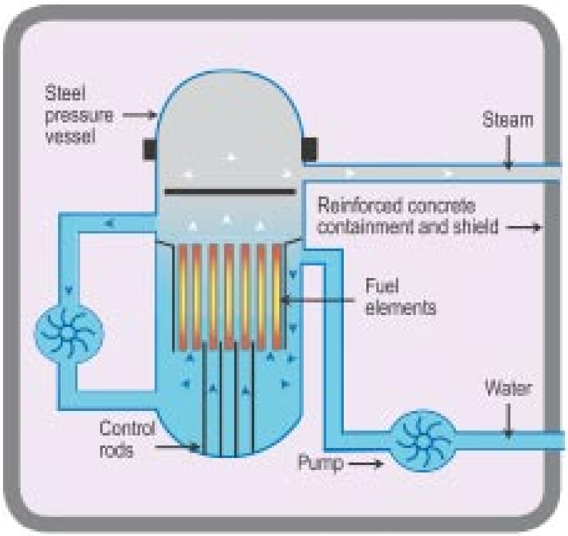
<u>Pressurised Water Reactors (PWRs)</u>



A Pressurised Water Reactor (PWR)

Pressurised Water Reactors are known as "PWRs". Pressurised water reactors heat the water surrounding the nuclear fuel, but keep the water under pressure to prevent it from boiling. The hot water is pumped from the reactor vessel to a steam generator. There, the heat from the water is transferred to a second, separate supply of water. This water supply boils to make steam. The steam spins the turbine, which drives the electric generator to produce electricity. In PWRs the water from the reactor and the water that is turned into steam are in separate pipes and never mix. PWRs can be found mainly in France, Japan, Russia and the USA. As of December 2010 there are some 220 PWRs in operation globally.

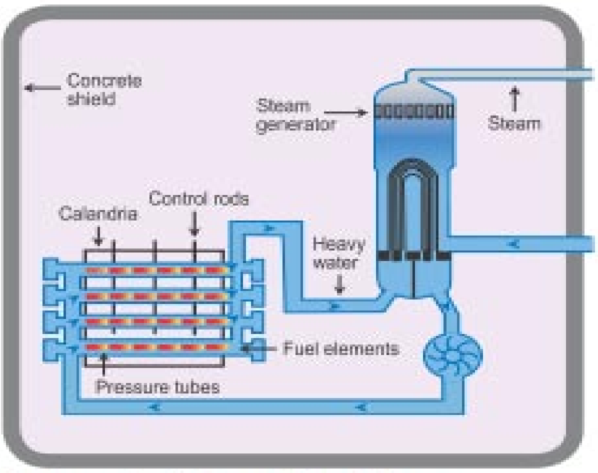
Boiling Water Reactors (BWRs).



A Boiling Water Reactor (BWR)

Boiling Water Reactors are known as "BWRs". In BWRs, the water heated by fission actually boils and turns into steam to turn the generator. Boiling water reactors heat the water surrounding the nuclear fuel directly into steam in the reactor vessel. Pipes carry steam directly to the turbine, which drives the electric generator to produce electricity. BWRs can be found mainly in Japan, Sweden and the USA. Globally, there are over 90 units in operation.

Pressurised Heavy Water Reactors (“CANDU” short for CANada Deuterium-Uranium or PHWRs).



A Pressurised Heavy Water Reactor (PHWR/Candu)

These reactors use heavy water as the moderator. The advantage of using heavy water as a moderator is that it absorbs fewer neutrons than light water and so allows for the use of natural uranium instead of enriched uranium for fuel. Natural uranium fuel is less expensive than enriched fuel, although somewhat more fuel must be fed through the reactor to produce the same amount of energy. The reactor functions in a manner similar to a PWR. Pressurised coolant is passed through the fuel bundles to cool them. This hot, pressurised cooling water is carried to a steam generator where the heat energy is transferred to light water and converts it into steam. This steam is then used to turn the steam turbines which turn the generator, creating electricity. CANDU reactors are to be found mainly in Canada, with another version to be found in India. Globally, there are almost 50 units in operation.

Gas Cooled Reactors (Magnox or AGRs). These are technologies that did not gain popular commercial favour in spite of some very unique safety features. They are in the process of being phased out, and 18 are located in the UK.

Light Water Graphite Reactors (RBMK/VVER). The Soviet designed RBMK (*reactor bolshoy moshchnosty kanalny*) is a PWR with individual fuel channels that uses ordinary water as its coolant and graphite as its moderator. It is very different from most other types of reactor as it derived from a design principally intended for plutonium production and power production. VVERs are a Russian-designed reactor found mostly in Russia, but also operating in Armenia, Bulgaria, the Czech Republic, Finland, Hungary and the Slovak Republic. The name is an acronym for a water-cooled, water-moderated energy reactor. In essence, VVERs (veda-vodyanoi energetichesky reactor) are also Russian-designed PWRs. Globally there are more than 50 units in operation, some 13 of which are RBMKs.

Fast Neutron Reactor (FBR). A fast neutron reactor is a category of nuclear reactor in which the fission chain reaction is sustained by fast neutrons. Such a reactor needs no neutron moderator, but must use fuel that is relatively rich in fissile material when compared to that required for a thermal reactor. These can be found in France Japan and Russia. Globally, there are less than 10 in operation and are currently uneconomic to operate.

The International Thermonuclear Experimental Reactor (ITER) project aims to make the long-awaited transition from experimental studies of plasma physics to full-scale electricity-producing fusion power plants. The project is funded and run by seven member entities - the European Union (EU), India, Japan, the People's Republic of China, Russia, South Korea and the United States. The EU, as host party for the ITER complex, is contributing 45% of the cost, with the other six parties contributing 9% each. The ITER fusion reactor itself has been designed to produce 500 megawatts of output power for 50 megawatts of input power, or ten times the amount of energy put in. The machine is expected to demonstrate the principle of getting more energy out of the fusion process than is used to initiate it, something that has not been achieved with previous fusion reactors. Construction of the facility began in 2007, and the first plasma is expected in 2019. When ITER becomes operational, it will become the largest magnetic confinement plasma physics experiment in use, surpassing the Joint European Torus. The first commercial demonstration fusion power plant, named DEMO, is proposed to follow on from the ITER project to bring fusion energy to the commercial market. Technical and estimated final costs continue to challenge this venture which is currently predicted to be at least three times higher than the original estimate of €5 billion.
