The Chernobyl New Safe Confinement

History and Outlook

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The thirtieth anniversary of the Chernobyl accident on 26 April 1986 is an opportune moment to take stock of the measures planned and implemented to make the site of the world's worst nuclear accident environmentally safe.

The extent of the damage unleashed by the accident at Unit 4 is well documented. Large areas of Ukraine, Belarus and Russia were contaminated and radioactive plumes spread across Europe.

At least 30 people died at the Chernobyl site as an immediate result of the accident and during the construction of a hastily-built shelter to cover the ruins of Unit 4.

The number of long-term casualties attributable to the radioactive fallout from the Chernobyl accident has been the topic of many studies and debates. The human suffering has been huge.

The first impression for a visitor approaching the Chernobyl site these days is of a skyline dominated by the huge arch-shaped structure of the New Safe Confinement (NSC) that will eventually house the shelter, which has always been intended to be a provisional structure. In 2014, the two halves of the arch were lifted to their full height of more than 100 metres and in 2015 were joined together at the assembly site some 300 metres away from the old shelter.

The NSC is the largest movable structure ever built on land and a one of a kind project. Never has such a large structure been constructed in the vicinity of the site of a serious nuclear accident. When all the equipment has been installed, and before sliding the arch into its final position (which is now scheduled for late 2016), the weight of the NSC will exceed 35,000 tonnes. It will provide a barrier against any radiological releases as well as the equipment to deconstruct the shelter and to manage its radioactive inventory.

Background

The Chernobyl accident has dramatically raised awareness of the risks associated with the operation of first-generation Soviet-designed reactors, and has had a defining impact worldwide on the public acceptance of nuclear power. The G7 Action Plan to improve nuclear safety in eastern Europe and the countries of the former Soviet Union was launched at the Munich G7 summit in 1992. The focus of the action plan was on short-term safety upgrades and, subsequently, early closures. A number of bilateral programmes – notably the European Commission's PHARE and TACIS programmes – as well as many actions by individual governments, were initiated to improve nuclear safety.

The G7 and the European Commission invited the European Bank for Reconstruction and Development (EBRD) to set up a Nuclear Safety Account (NSA) – the first multilateral nuclear safety grant funds managed by the EBRD – with a mission to finance short-term upgrades in Bulgaria, Lithuania and Russia. Ukraine was added to the NSA portfolio after the country signed a Memorandum of Understanding with the G7/EU on the closure of Chernobyl in 1995. The agreement also created the basis for the Chernobyl Shelter Fund (CSF) to finance the Shelter Implementation Plan (SIP), a programme of actions to guide the conversion of the shelter into an environmentally safe state.

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Technical Solution - Shelter Implementation Plan

Hundreds of proposals for a long-term solution for the shelter were made following the 1986 accident. The absence of firm data on the shelter, coupled with the physical impossibility of collecting data given the high levels of radiation, represented serious obstacles to the delivery of an optimal solution.

The SIP, developed by a team of Ukrainian and international experts in mid-1997, finally offered a way forward. It devised a technical strategy and the programme for the conversion of the shelter into an environmentally safe system. For this the SIP identified five principal technical goals:

1. Reduce collapse probability – structural stabilisation
2. Reduce collapse accident consequences
3. Improve nuclear safety
4. Improve worker and environmental safety
5. Long-term strategy for conversion to an environmentally safe site.

The SIP also identified ten milestones, the three most important of which were the decisions on:

1. Strategies for stabilisation and shielding
2. Confinement
3. Removal of fuel-containing masses (FCM).

These decisions defined the scope, schedule and cost of the SIP.

SIP Implementation

The implementation of the SIP began at the end of 1998. The threat of imminent collapse of the shelter made emergency repairs of the beams supporting the shelter roof and the stabilisation of the vent stack, whose collapse was threatening both the shelter and Unit 3 (still operating at that time), an obvious priority. The site infrastructure was inadequate to meet even the minimum safety standards. It took until 2004 to build the necessary facilities, provide equipment, establish health and safety and radiation protection procedures – including a state-of-the-art biomedical protection and screening programme – and create the nuclear safety culture required for major construction activities in a heavily contaminated area.

The other key risks perceived at the time – the possibility that radioactive water present in the shelter basement would leak into the water table of the Dnipro basin, or act as moderator to the FCM and lead to a criticality excursion – were addressed during early stages of the work. An integrated and automated monitoring system was commissioned in 2010. Once the NSC is in place, the remaining water will dry out.

The scope of the shelter stabilisation received regulatory approval in July 2001. The preliminary FCM strategy, which deferred removal for several decades, served as one of the main inputs for the decision on the NSC. The option of a lightweight arch was chosen as the result of a consensus view that it is structurally efficient and the most versatile option. The concept designs received formal approval from the government of Ukraine in July 2004.

Arch main structure

The height of the steel arch is 108 metres, the length is 162 metres and the arch span is 257 metres. The main load-bearing structure of the NSC consists of 16 steel arch trusses. Each arch truss consists of two chords and a triangular truss girder. The distance between arch truss chords is 12 metres. The arch trusses are gathered in one supporting area on foundations. The trusses are coupled with a system of beams and connections. Upper cladding purlins are supported by the upper chord of the arch, while internal cladding structures are fixed on the lower chord. The main steel structure weighs around 30,000 tonnes.

Cladding

The external cladding covers an area of 85,000 m^2. It is a multilayer system of physical barriers restraining the spread of moisture, air and heat. The external cladding provides for resistance against atmospheric effects (rain, snow, extreme temperatures) for the whole 100-year operational life of the NSC, and is designed to withstand a tornado of class 3. It supports tightness of the annular space with possible atmospheric leakages of 65 litres per m^2 per hour at the beginning of the NSC operation and 275 litres per m^2 per hour at the end of the NSC 100-year service life.

The internal cladding of the arch consists of a smooth surface on the internal side of the building to minimise the risk of dust deposition and accumulation. It is made of 300mm wide and 0.5mm deep flat panels of corrosion-resistant steel. It is fire resistant, non-magnetic and supports tightness of annular space leakages to the same specifications as the external layer.

The contract for the design and construction of the NSC was signed between the Chernobyl Nuclear Power Plant and NOVARKA (a consortium of Vinci and Bouygues) in September 2007 after a complex procurement procedure which included independent technical and legal assessments and a thorough pre-contract analysis of the design basis for the concept design. The functional specification, the design safety criteria and the contractor's proposed concept design were combined into a concept design safety document by mid-2009. Requirements included the NSC's resistance to the impact of seismic events of a magnitude of level 6, to tornado class 3 and to heavy wind and snow loads, which represented a particular design challenge for the main arch structure (see left box below) and the cladding.

The design was divided into steps to allow for an early start of the works on the ground in stages. The NSC design had two licensing steps. The first one, including structural design of the arch and the foundations (see boxes), the cladding (see box), the main crane system and the preliminary safety analysis, was to allow for the start of manufacturing and erection of the arch steel structures. The second step was defined as the integrated NSC design including the auxiliary buildings and systems and the environmental impact assessment.

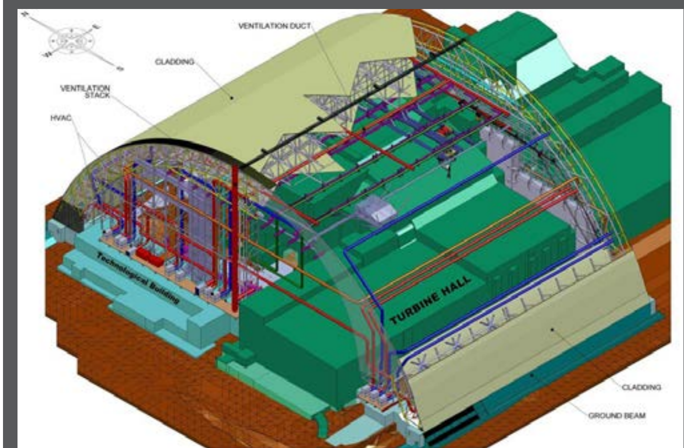
Corrosion control (see box below) for the 100-year design life had a defining impact on decisions such as the steel grade, coatings and ventilation and humidity control systems. The humidity-controlled over-pressurisation of the arch annulus with less than 40 per cent relative humidity serves to prevent corrosion.

Site preparatory works were largely completed in 2011. After the removal of contaminated soil, the concrete NSC assembly platform was built in the erection zone as a barrier against surface contamination. The "clean area" allowed simplified access, significantly reduced the need for radiation protection measures for workers and was a prerequisite for the arch assembly work which commenced in April 2012.

Work on permanent arch foundations (see box) required considerable redesign of piling and, occasionally, spectacular radioactive-waste management operations as both high-level waste and a wide array of contaminated objects buried after the 1986 accident were discovered.

Annular space corrosion control

The New Safe Confinement has an annular space of 12 metres between the inner and outer layers of the structure across the whole arch span of 257 metres. As a consequence of the radiation conditions around and above the Object Shelter, this vast annular space has to have an active corrosion-control system. The ventilation system being installed has to maintain low relative humidity of less than 40 per cent, and around 50 pascals overpressure with regard to the pressure in the main volume and outside the structure to avoid water ingress from outside and dust from inside the main volume. This system will recirculate around 45,000 m^3 of air per hour. The temperature and moisture regime in the annular space of the Arch is supported by the operation of the inlet drying system and nine recirculation systems with over 100 air-handling units.



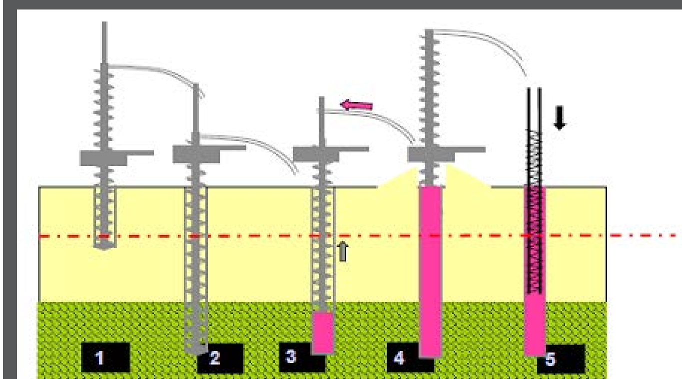
New Safe Confinement and SIP projects today

All of the SIP tasks, except those directly supporting the NSC construction, commissioning and early deconstruction, have been completed. Stabilisation of the shelter, which began in 2004, was completed in 2008 when 80 per cent of the roof load on the western wall of the shelter was transferred to the new supporting structure. Stabilisation has significantly reduced the probability of collapse and has allowed the work on the NSC to proceed. The shelter's lifespan has been extended by 15 years to 2023.

The NSC construction work has made outstanding progress since the assembly of the arch structure began in April 2012. A particular achievement is the excellent health and safety record. There has not been a single incident of a worker on the New Safe Confinement project exceeding international radiation dose control limits.

Arch permanent foundations

Foundations for the arch are designed as two concrete ground beams around 175 metres long (northern and southern parts) symmetrically located in relation to the arch. Each concrete ground beam consists of a monolithic reinforced concrete structure and reinforced concrete continuous flight auger piles of round section. 396 continuous flight auger piles, each of 25 metres length, have been drilled along the north and south trenches.



The construction of the New Safe Confinement is in its final stage. The primary structural work on the arch is complete and almost 90 per cent of cladding has been installed. The ongoing installation of the main crane system is scheduled for completion in June 2016. Pre-commissioning testing will start at the end of May and all the systems in the arch will be installed by October. Finalising as many of the testing activities as possible, while the arch is in the "clean area", is of crucial importance for keeping the collective radiation dose as low as possible.

Work on the Technological Building containing electrical and control systems for the NSC is being carried out in the vicinity of the shelter behind a temporary shielding wall which is 90 metres long and 35 metres high.

The most demanding remaining activity in terms of radiation protection and health and safety is the construction of the NSC-enclosing perimeter walls inside the turbine hall of Units 3 and 4, which are necessary to ensure the confinement function of the NSC. The sealing surfaces, where an elastic membrane interfaces with the existing structures of Unit 3, must be ready before the NSC is slid into its final position over the shelter. The work on the perimeter walls is making good progress and is on track.

The sliding of the arch into its final position is now targeted for November 2016, more than six months earlier than was planned less than a year ago. This is a unique task in which a total weight of more than 35,000 tonnes will be pushed over 300 metres on a rail system by 116 remote-controlled synchronised jacks. The sliding operation at a speed of 10 mph is expected to take two days.

The sealing operations, interconnections between the NSC and the shelter and the commissioning testing are scheduled for completion by November 2017. At that juncture the safety objectives of the SIP will be met. The overall cost of the NSC is projected to be in the region of €1.5 billion and of the entire SIP approximately €2.1 billion. More than 40 governments and the EBRD have provided the finances to convert the Chernobyl site into an environmentally safe state.

Chernobyl Nuclear Power Plant staff will play a major role in the testing and commissioning of the NSC and its ensuing long-term operation. Their first major task will be to deconstruct the most unstable elements of the old shelter before its licence expires in 2023. Over the 100-year lifetime of the NSC, the operators, scientists and authorities of Ukraine will have to find a solution for the FCM.

The SIP has provided the principal tools for long-term deconstruction and waste management to commence once conditions permit. The challenges of future tasks should not be underestimated but thanks to the SIP and for the first time since the 1986 Chernobyl accident, a clear path for the long-term future at Chernobyl has been established.

Main crane system

The main crane system is the central piece of equipment inside the arch to support long-term deconstruction of the shelter. It is installed inside the NSC just below the ceiling at 80 metres above ground level and will be controlled by a remotely controlled system and a video surveillance system that allow the operators to remain outside the NSC. It has been specifically designed for dismantling the main structures of the destroyed reactor and original sarcophagus and for handling heavily shielded waste disposal. It is composed of two bridges that are designed to carry three interchangeable carriages. The bridges are 96 metres in length and travel on six runway rails. There are two carriages for lifting, the secure and classic carriage with 50-tonne capacity, and one carriage that is a tool-delivery platform. It was designed and manufactured by PaR Systems Inc.

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