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CHERNOBYL: BRIEF HISTORY OF THE WORST NUCLEAR DISASTER

Andre Salloum[1], Orhan Gurbuz[2], Sergey Deriuga[3]
Mathieu Scherer[4], James T. Cameron[5] and Farhang Ostadan[6]

[1] EX-IN Senior Civil Engineer, Program management Unit, Slavutich, 07100 Ukraine
[2] Gurbuz Consulting, 16162 Tortola Circle, Huntington Beach, CA 92649 (ogurbuz@aol.com)
[3] Technical Manager, Program management Unit, Slavutich, 07100 Ukraine
[4] Bechtel Senior Structural Engineer, Project management Unit, Slavutich, 07100 Ukraine
[5] Engineering Supervisor, Bechtel National, San Francisco, CA 94105
[6] Bechtel Fellow, Chief Engineer, Bechtel Corporation, San Francisco, CA

ABSTRACT

On April 26, 1986, at 1:24 am Moscow time, the worst nuclear accident in history occurred at Chernobyl Nuclear Power Plant (ChNPP), Unit 4. The beyond design basis accident completely destroyed the reactor core and, extensively damaged the reactor and the nuclear steam supply system (NSSS), and the biological shield building. Steam explosion destroyed walls and ceiling of the Central Reactor Hall, premises of the drum-type steam separators, main circulation pumps, emergency core cooling system, 2 upper floors of the Deaerator Stack, and Turbine Hall roof. The columns of the Deaerator Stack framework were displaced by the explosion shock wave in the direction of the Turbine Hall; the rooms were piled with the structures' debris. A fierce fire followed the explosion and caused additional damage. High levels of radioactivity were released to the environment which spread around the world.

The citizens of the neighboring cities of Chernobyl and Pripyat and many villages in 30 km zone around ChNPP were evacuated. People had to find shelters for temporary accommodations or had to ask for help from relatives living in other republics of the former Soviet Union. Due to the heroic efforts of the accident liquidators, the burning reactor was soon brought under control by dumping thousands of tons of different neutron-absorbing and localizing materials on the wreckage of the Central Hall and surrounding premises left without roof, at the cost of many helicopter pilots' lives. In 1986 "Object Shelter (OS)" was built and commissioned within the next 6 months after accident's active phase ended. It covered the damaged 4th reactor building with a roof and walls to limit further release of radioactivity.

A new town was built nearby at Slavutich to accommodate some of the victims and operational personnel. This city still stands today and serves the engineering and construction professionals involved in the projects implemented at ChNPP site to remedy the devastating effects of the accident and perform decommissioning of ChNPP Power Units.

Over 25 years since the accident, additional measures were implemented to further reduce the potential health hazards for the personnel, population and environment from the impact of radioactive materials contained in the OS. In late 1990s a program was initiated to design and construct a new safe protective structure that would forever eliminate any additional danger to the environment and human beings.

This paper will summarize the accident, activities immediately after the accident, longer range projects for remediation and the current status of the four nuclear power units that made up the ChNPP.

CHRONOLOGY

On 29 September1966 the USSR Council of Ministers issued a Decree approving the planned power capacities for the USSR Power industry for the period of 1966-1977. Pursuant to the Plan, it was decided to construct a new NPP in the region of Chernobyl (see Figures 1 and 2) with the following schedule:

ChNPP 1st Power Unit commissioning was completed on 26 September 1977.
ChNPP 2nd Power Unit commissioning was completed on 17 November 1978.
ChNPP 3rd Power Unit commissioning was completed on 3 December 1981.
ChNPP 4th Power Unit commissioning was completed on 21 December 1983.

Figure 1 – Location of Chernobyl NPP in Ukraine

Figure 2 – Aerial view of the 4 Chernobyl NPP power units in Ukraine

On 26 April 1986, at 1:23:49 am by Moscow time the Accident occurred at Chernobyl NPP Power Unit 4 (Figure 3). The consequences of the accident were the severest in the entire history of nuclear power industry. This Accident completely destroyed the reactor core and damaged the majority of the bearing structures of the power unit core. Chernobyl Unit 4 stopped existing as a power unit. The accident generated 190 tons of radioactive dust in 10 days, with radiation levels 90 times higher than Hiroshima (20 Sv/h at proximity of the Unit 4).

The citizens of Pripyat city (51,000 inhabitants) were evacuated on 27 April 1986 from 2pm to 5pm, using 1,390 buses. The neighboring city of Chernobyl and the other villages in 30 km zone (116,000 inhabitants) were evacuated on 2nd May 1986.

Figure 3 – ChNPP Unit 4 Accident on 26 April 1986

In October 1986, a decision was made on construction of a new satellite-town Slavutich about 50 km east of the plant for housing the Chernobyl NPP employees and their families as well as to use as centre of engineering activities.

Power Unit 2 operation was resumed in November 1986, and indefinitely stopped in 1991 after a fire declared.

Power Unit 1 operation was resumed in December 1986, and stopped in 1996.

On December 1987 Power Unit 3 operation was resumed, and had been running continuously till 2000. But on 15 December 2000, Ukraine, showing good will and pursuant to Memorandum of Understanding between the Ukrainian Government, G7 countries and the European Commission about Chernobyl NPP shutdown, stopped the last of the remaining three Power Units of the Chernobyl NPP.

Today about 3700 people are still currently working at ChNPP site, for the support of the two major tasks:

- Decommissioning and dismantling of Units 1, 2 and 3
- Shelter Implementation Plan (SIP – see further), to transform the former Unit 4 into an ecologically safe system

THE "OBJECT SHELTER" (OS)

The first priority task for emergency works at Unit 4 was to resume control of the situation, stop radioactive releases into the environment and reduce level of radiation at the ChNPP site.

In May 1986, a Governmental Commission made a decision on long-term preservation of the destroyed Unit 4 by construction of a "Shelter." This task was complicated by extremely high gamma-radiation fields, absence of reliable information about the degree of destruction of Unit 4, absence of international experience in the area of elimination of such accidents.

600,000 "liquidators" (laborers who worked on the emergency tasks) from all over the Soviet Union were involved, with a peak of 200,000 "liquidators, including 90,000 dedicated to build the "Shelter". The "Shelter" design started on May 1986. The "Shelter" was built and commissioned on November 1986, within only 6 months after the accident's active phase ended (Figure 4). Sequence of Work during construction of "Shelter" was the following:

- Cleaning and concreting the area around Unit 4.
- Construction of protective walls along the perimeter.
- Construction of separating walls between Units 3 and 4.
- Construction of Cascade wall[1]
- Roofing of the Turbine Hall.
- Construction of a high Buttress Wall.
- Installation of supports and covering over the reactor unit.

- Installation of ventilation systems and control and measurement communications and instruments.

[1] Stepped concrete wall intended to form enclosing protection from the release of radioactive substances from the north side of the Unit 4, which was destroyed as a result of the beyond-design accident 1986.

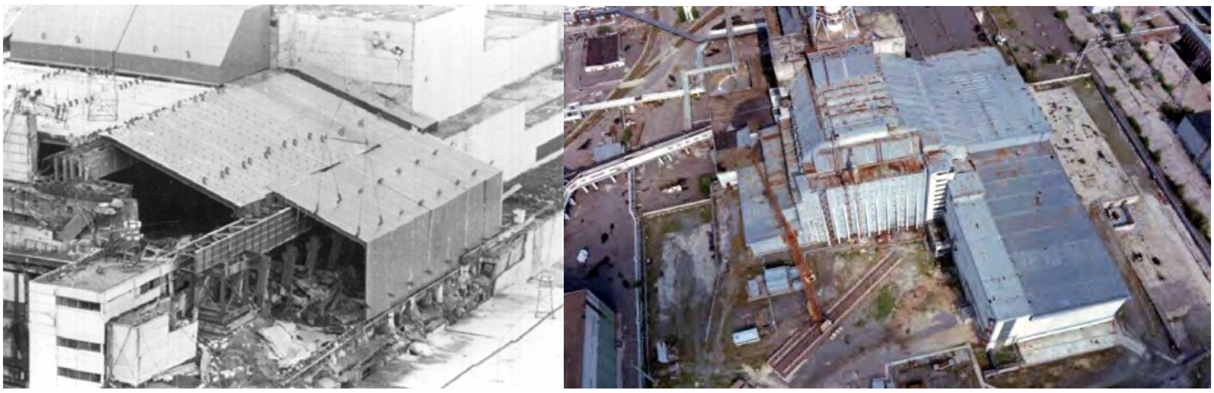

Figure 4 – Construction of the “Object” Shelter (April 1986 – November 1986)

After the accident the ChNPP Unit 4 became well-known all over the world as the “Object Shelter” (OS).

Since completion of construction, the state of the OS is characterized by a set of risks related to the fact that OS structures do not meet the safety requirements of normative criteria and technical documents applicable to mechanical durability, structural integrity, desired reliability, and their operation life is not defined

THE SHELTER IMPLEMENTATION PLAN (SIP)

A panel of Western and Ukrainian experts was formed to develop a “Shelter Implementation Plan (SIP)” which would define a road map for an acceptable, economical and ecological approach to resolve the problems of ChNPP Unit 4 “Object” Shelter. The SIP document was completed in May 1997 and has been in use since then.

1992: International competition of projects and technical solutions for Object Shelter transformation into ecologically safe system was announced, that became a first step to the international cooperation.

1994: European Community Commission announced the tender on Feasibility Study development for the 1st and 2nd stage of the Concept of Object Shelter transformation into an ecologically safe system and stabilization of existing Shelter condition and "Shelter - 2" construction.

1995: Feasibility Study development on Object Shelter transformation is completed

1997: Agreement between Ukraine and European Bank for Reconstruction and Development (EBRD) on Fund activity (“Framework Agreement”) was signed.

On April 20, 1998 the Contract with the tender winner on SIP - Project Management Unit (PMU) Consultant was signed. That Consortium included the following companies: Bechtel National Inc. (USA), Battelle Pacific Northwest National Laboratory PNNL (USA) and Electricite de France EDF (France). The Contract was signed with the purpose to regulate, coordinate and control the project compliance with the quality and safety standards.

Main SIP objective is **transformation of the Object Shelter into an ecologically safe system from the point of view of personnel protection, radiological safety and environment safety**. SIP identified 22 tasks, organized on the basis of five goals to achieve during its planned implementation. These five goals and the corresponding tasks were as follows:

Goal 1: Mitigate the risk of collapse – structural stabilization

Task 1: Integrated stabilization project
Task.2: OS western part stabilization
Task 3: Stabilization and shielding of the "Mammoth" beam and its southern part
Task 4: Stabilization and shielding of eastern and northern parts
Task 5: Stabilization of roofing and roofing supports
Task 6: Structural investigations and monitoring
Task 7: Geotechnical survey
Task 8: Seismic characteristics and monitoring

Goal 2: Mitigate the accident consequences (collapse)

Task 9: Emergency readiness
Task 10: Dust management
Task 11: Emergency dust-suppression system

Goal 3: Nuclear safety improvement

Task 12: Criticality and nuclear safety
Task 13: Water management
Task 14: FCM characterization

Goal 4: Personnel and environment safety improvement

Task 15: Radiological protection program
Task 16: Industrial safety, fire safety, and access control
Task 17: Integrated monitoring system
Task 18: Integrated database

Goal 5: Strategy and Feasibility Study (FS) for OS conversion in ecologically safe system

Task 19: FCM removal and RAW management strategy
Task 20: Development of FCM removal strategy
Task 21: New Safe Confinement strategy
Task 22: Design and Construction of New Safe Confinement (NSC)

The SIP tasks are funded by the Chernobyl "Shelter" Fund, for which the administrator is the European Bank for Reconstruction and Development (EBRD), and the <u>contributors</u> are Austria, Belgium, Great Britain, Greece, Denmark, the European Commission, Ireland, Spain, Italy, Canada, Kuwait, Luxemburg, The Netherlands, Germany, Norway, Poland, Russia, USA, Ukraine, Finland, France, Switzerland, Japan, Island, Israel, Korea, Portugal, Slovak Republic, and Slovenia.

SIP PROJECT IMPLEMENTATION PHASES

<u>Phase 1 (1998 – 2007)</u>:

This is a phase of the information collection, investigations, conceptual design development, and program decisions based on the data collected. Performance of these tasks was necessary for design and construction work deployment in Phase 2. In addition to the stabilization of existing "Object Shelter" structures, other measures were taken for increasing operational reliability and durability of constructed facilities and for improving OS safety monitoring systems.

During this phase, two urgent stabilization measures were completed:

1) ***Ventilation Stack of ChNPP Units 3 and 4 foundation strengthening and bracing repair – 1998.***

Project funding was provided out of the trilateral contribution proceeds which included the USA, Canada and Ukraine. The Construction Contractor was "Ukrenergostroy" and the Design Contractor was Ukrainian design institute NIISK.

2) Reinforcement of Beam B1 and B2 Supports – 1999.

Immediately after the accident a temporary roof was designed and constructed with great difficulty over the damaged reactor 4. The roof included beams B1 and B2 which supported pipes placed side by side, with a plate cover over the pipes. An earlier engineering evaluation of the entire Shelter found the B1/B2 beam supports to be the components most urgently in need of improvement, especially considering the potential consequences of roof collapse causing a new round of radioactivity release. The beams were heavily loaded and inadequately supported; in some cases, the supports were deformed due to overstress, the beam webs were locally buckled, and the beams had rotated from the vertical. The Construction Contractor was "Ukrenergostroy" and the Design Contractor was Ukrainian design institute NIISK.

All the operations on installation of shielding and protective equipment, fabrication of formwork for concrete placement and implementation of welding operations were first worked through at the specially created mockup facility in Chernobyl. The specific feature of this project was implementation of works inside Object shelter at the upper elevations under extreme conditions associated with significant temperature difference and high radiation fields.

With the successful completion of the B1/B2 Beams Stabilization Project the high probability of roof collapse was significantly reduced.

Stabilization Project (1998-2007). In addition to the urgent stabilization measures performed in 1998-1999, design and construction of 9 additional stabilization measures (9 measures) were implemented within the framework of the first phase, promoting OS safety by decreasing the probability of building collapse for the period up to 15 years.

Stabilization Project was realized in 4 stages:

Stage 1 –June 1998 - May 2001. Determination of stabilization measures lists

Stage 2 –June 2001 - February 2002. Stabilization conceptual design required for elaboration of Detailed Design.

For stage 1 and 2, the Contractor was the Consortium ICC(MK) JV, comprised of Morrison Knudsen (USA), NIISK, KIEP, ISTC (Ukraine).

Stage 3 – May 2002 - August 2003. Detailed design of stabilization measures.

To carry out the detail design of the stabilization measures in this stage, a consortium comprised of NIISK, KIEP, ISTC (Ukraine) was selected. The final list of urgent measures included in this stage is presented below in Table 1:

Table 1 Stage 3 Stabilization Measures

№	Stabilization measure description
2	Reinforcement of Western Fragment (Buttress Wall and fragment located along the axes 50)
3	Stabilization of Deaerator Stack frame (installation of additional frames)
3b	Stabilization of Deaerator Stack frame (installation of additional struts)
3c	Stabilization of Deaerator Stack floor slabs on elevation 38,60
5	Northern Buttress Wall along axes C and adjacency point with Northern "Hockey Sticks"
8	Joining of Southern "Hockey Sticks" with Southern panels.
11	Joining of Northern "Hockey Sticks" with northern part of Buttress Wall with a help of fixation anchors.
14	Reinforcement of western support of "Mammoth" beam
14a	Reinforcement of eastern support of "Mammoth" beam

Stage 4 – September 2003-December 2006: Construction and commissioning of stabilization measures:

The stabilization measures shown in Table 1 were implemented during Stage 4. The Contractor for this work was a Russian-Ukrainian Consortium "Stabilization", with Consortium Leader ”Atomstroyexport”, UTEM, AESP, and RAES (Ukraine).

The location of stabilization measures is shown in figure 5. The most significant stabilization measure was Stabilization Measure #2, consisting of stabilization of the Western Zone and partial unloading of supports of beams B1/B2 using jacks. (See Figure 6.)

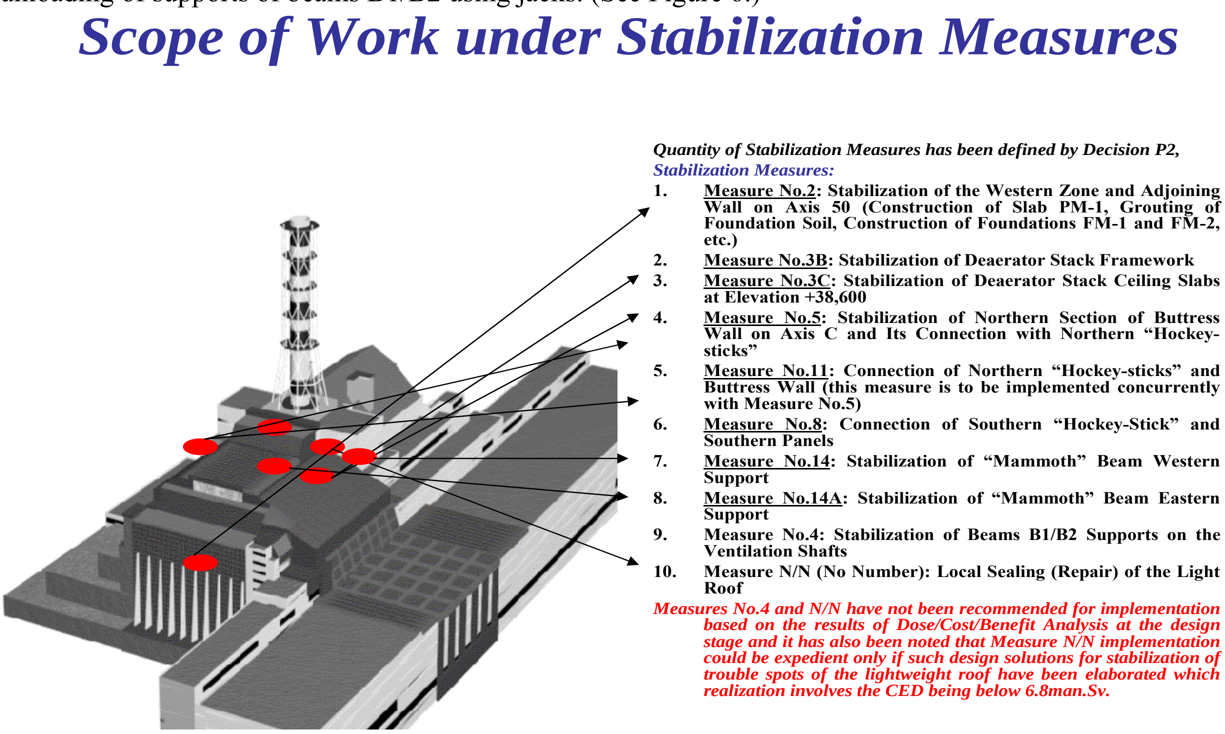

Figure 5– Location of Stabilization Measures

Figure 6 – Stabilization Measure #2 – stabilization of OS Western Wall (Before/After)

In parallel, during the period 2001-2007, prior to start of work on construction of New Safe Confinement, preparatory works were performed and required infrastructures were created to ensure a safe and efficient construction of the New Safe Confinement:

Preparatory Works:

- *area clearance and leveling*
- *excavation activities*
- *construction of a new ventilation stack (NVS)*

Other required infrastructures:

- *change facility,*
- *rehabilitation center,*
- *sanitary lock,*
- *non-heated storage facility, etc.*

Phase 2 – Commissioning Stage 1 - Design and Construction of a New Safe Confinement (2007-2015):

The most important phase is the creation of the additional protective barriers, specifically the New Safe Confinement (NSC), which will provide the following benefits during Phase 3:

- Provide necessary conditions for technical work and safety of the personnel inside the NSC,
- Protect the population and environment around the OS by preventing release of radioactivity,
- Permit the preparatory engineering work aimed at development of the technologies for Fuel-Containing Material removal from the OS, and,
- Allow creation of infrastructure for Radwaste Management removed from the OS.

A contract was signed on August 10, 2007 between the Employer (Chernobyl Nuclear Power Plant (ChNPP)) and the Contractor NOVARKA, France (**a** Joint venture comprised of VINCI Construction Grands Projets - 50% / Bouygues Travaux Publics - 50%) to Design, Build and Commission the New Safe Confinement. The Contract is managed by the Engineer, i.e the Shelter Implementation Plan Project Management Unit (SIP-PMU) (comprised of ChNPP employees and consultants from Bechtel National Inc. (USA) and Battelle Memorial Institute (USA)). The current Contract completion date is October 15, 2015.

Main NSC Functions: The main role of the NSC is summarized below

1. Limit the radiation impact on public, personnel and environment within the established boundaries, both during normal Shelter Object operation and in case of abnormal events, emergencies and accidents, including accidents occurring during dismantling of unstable structures and future management of fuel-containing materials (FCM) and radioactive waste (RAW).
2. Limit the spread of ionizing radiation and radioactive substances contained within the Shelter Object.
3. Technology process support – i.e. creating conditions for dismantling of unstable structures, future FCM and RAW removal, accumulated water removal, ensuring that measures on monitoring and maintenance of the Shelter Object and its Industrial Site are implemented.
4. Monitor all the Shelter parameters and manage technology processes.
5. Physical protection – i.e. prevent unauthorized access to FCM and RAW, and ensure functioning of the IAEA safeguards system.

Main Parameters of NSC:

The NSC consists of a 24860 ton Arch steel structure with external and internal cladding providing confinement of the "Object" Shelter below the internal cladding. Dimensions of the Arch structure are exceptional, with a span of 257 m, a length of 162 m and a height of 110 m (see figure 7) The steel structure is closed into an annular space formed by the External and Internal cladding, and the enclosed annular space is ventilated to maintain a low relative humidity < 40% to ensure durability of the Structure.

The NSC is considered a facility category I in terms of nuclear and radiation safety, and as such is designed to extreme climatic event such as extreme temperatures -43°C to +45°C, extreme wind pressures, extreme snow and ice load with a return period of 10,000 years.
In addition the NSC is designed to keep structural integrity, durability and work capacity under the impact of earthquakes intensity 6; with a zero period acceleration of 0.13g and peak spectral acceleration of 0.30g, and the impact of a Tornado Class 1.5.

Finally while the tornado Class 3.0 is considered a beyond design basis event, the Arch structure is designed so that under a Tornado Class 3 the stability of the Arch foundation and the Arch main structure is assured, the displacements would not result in a complete functional loss of the main lifting equipment and no significant radioactive releases to the Environment would occur.

In addition to the main Arch structure the NSC will be equipped with a Main Cranes system which will allow performing dismantling of the unstable "Object" Shelter structures, and is equipped with a set of auxiliary buildings and auxiliary systems to ensure operation of the New Safe Confinement.

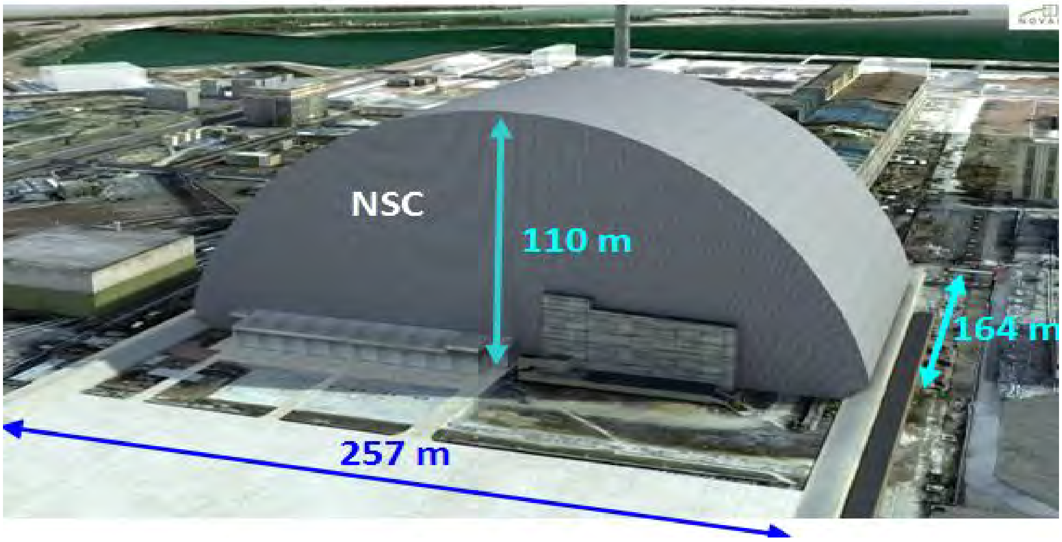

Figure 7 – NSC Structure and Dimensions.

Current status of the NSC Project (As of Early 2013**)**

Design:

- Design of the NSC Structures (Arch, Cladding Foundations) -approved by Regulatory Authorities
- Design of the NSC Auxiliary Structures and Auxiliary systems - complete, under Regulatory review.
- Working Documentation - in progress

Site Progress (NSC Structures):

- Erection zone foundations - 100% complete .
- Erection zone platform -100% complete.

- Assembly of arch steel -started on March 2012 - 1st lift of the Eastern half of the Arch structure completed in November 2012 (out of 6 lifts in total - 3 lifts for each half).
- Transport zone foundation - 83% complete
- Service Zone Foundations - Production piles (400 CFA piles) to be drilled in the North from March to August 2013, followed by the south trench from August 2013 to April 2014.
- Final sliding of the arch planned to be performed in September 2015

Phase 2 - Commissioning Stage 2 – infrastructure for dismantling activities

After the NSC is completed, there will be implemented construction of all infrastructures necessary to support dismantling of OS unstable structures and further deconstruction of the entire OS. Design is currently in progress.

Phase 3 – Early Dismantling

During the third stage, after commissioning of the CS-2 and Process Building as a part of the integrated RAW management system at the ChNPP site, the early dismantling of the unstable structures inside the Object Shelter can be started to the extent specified at a relevant detailed-design stage. Early dismantling activities and management of dismantled structures and associated RAW will be performed using process lines located within the Process Building.

CONCLUSIONS

The OS was somewhat effective in meeting the short-term goals of preventing water ingress and confining radioactive contamination releases. However, within a few years of its construction, it became evident that the OS had an unacceptable risk of collapse, was allowing considerable ingress of rain/snow water, and was allowing radioactive dust to escape. A long term strategy to provide adequate confinement of the OS was developed in 1997 by a team of Western and Ukrainian experts in order to reduce the risk to workers, the general population, and the environment, and to transform Chernobyl into an environmentally safe site for the next 100 years.

The NSC will cover and enclose the entire Unit 4 reactor and OS. It will prevent ingress of water, prevent release of radioactive dust (even if the OS were to collapse), and provides the means for deconstruction of the OS, the Unit 4 reactor, and for removal of remaining nuclear fuel containing materials.

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