One hundred years of safety

A gigantic airtight enclosure is under construction at Chernobyl. It is designed to survive temperature extremes, earthquakes and tornados and prevent corrosion in order to protect the environment from the encapsulated but still dangerous reactor. Clad in molybdenum-grade Type 316L stainless steel, the structure will safely contain radioactive dust and debris for more than a century.

The meltdown of the Chernobyl nuclear reactor Unit 4 in 1986 will long be remembered as one of the largest man-made disasters in history. It produced and broadly distributed severe radioactive contamination. The threat of additional dispersion was ameliorated soon after the disaster by constructing a large sarcophagus-like enclosure (the "Object Shelter," or OS) around the reactor to prevent further release of radioactive particles.

Unfortunately, weather and corrosion have degraded the steel and concrete OS since it was built nearly 30 years ago, and there is now danger that it might collapse. The international community has taken on the task of securing the site with a new permanent and much safer confinement structure, the New Safe Confinement (NSC). This project is being funded by the Chernobyl Shelter Fund at the European Bank for Reconstruction and Development, which raised €1.3 billion as of November 2015. When finished in 2017, it is expected that the project will have cost more than €2 billion and will have over 40 nations and organizations as contributors to the fund.

The challenges for this unusual project were clear: to safely confine radioactive dust and debris that might be released in the case of the OS' failure; to eliminate the need for human maintenance of the structure because of the dangers posed by radioactivity; and to ensure that the structure could withstand without damage, temperatures ranging from -45°C to 45°C, a Class 3 tornado (a once-in-a-million-year occurrence) and an earthquake with maximum intensity of class 6 on the MSK64 scale (a once-in-10,000-year occurrence). The NSC also had to provide the capability to safely dismantle unstable reactor parts and remove radioactive waste and corium (solidified magma made from melted fuel and internal components) from the enclosed reactor. Furthermore, it would have to last 100 years to allow time for development of as-yet untested technologies to remove the radioactive debris.

The new structure – a monumental challenge

The NSC looks amazingly like a pre-WWII Zeppelin hangar. The stunning arch-shaped frame alone weighs 25,000 metric tons, and when fully equipped the building will weigh 31,000 metric tons. It stands 108 meters high, 162 meters long and 257 meters wide. The immense structure encloses a volume of about 3 million cubic meters, equal to that of London's O2 arena. The mammoth structure is taller inside than the Statue of Liberty, and could contain Notre-Dame de Paris or London's St. Paul's Cathedral. The finished structure will weigh nearly as much as four Eiffel Towers! To further complicate matters, the entire building had to be constructed about 200 meters away from the reactor buildings to limit workers' exposure to radiation, and will need to be slid over the existing OS and associated structures when finished. While much of the component fabrication could be accomplished off site, site preparation, erection, outfitting and placement has to be done on site with all its related radiation hazards.

Primary goal – prevent release of radioactive particles

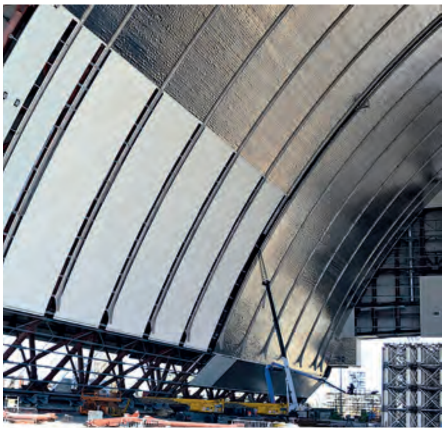
The innovative arch structure uses a 12 meter-thick, three-dimensional lattice frame made from structural steel tubes. The OS is strictly confined by the NSC thanks to stainless steel cladding that completely wraps the arch both inside and outside of the lattice. The frame creates a 12 meter-wide annular space between the inner and outer skin. To ensure that interior air will not leak to the atmosphere, the annular space will be maintained under slight overpressure, while the volume under the arch will be maintained under negative pressure. This way, the annular space provides additional protection against leakage of contaminants.

Clad metallic walls close off the arch on each end. On the east end, the 4 meter-thick wall is contoured to closely fit the outline of the existing reactor building. When the structure is in place, closure panels attached to the wall will be remotely positioned to seal the wall. On the west end, an 8 meter-thick wall closes the open space under the arch. Both end walls hang from the arch structure so as not to transfer any load to existing structures. A confinement and dismantling information and control center will be located outside the west wall and adjacent to it.

Preventing corrosion

Dehumidified air will be constantly blown into the annular space to maintain the relative humidity below 40%. The combination of controlled ventilation and pressurization will prevent corrosion of the structural steel lattice from initiating. Both walls will employ the same internal atmosphere-control measures used in the annular arch space.

The people installing the interior cladding are dwarfed by the immense arch structure. © ChNPP



Installation of the internal cladding. © ChNPP

The arch frames are made from four hundred 813 mm-diameter, 12–40 mm-thick S355 carbon-manganese round steel tubes of a quality used in offshore oil rigs. Tubes are welded to gusset plates to form nodes that are connected by approximately 560,000 tension-controlled bolts. The lattice components have both an initial anticorrosion coating and a supplemental epoxy coating for corrosion protection.

The stainless envelope

As spectacular as it is, the details of this impressive lattice construction will be completely hidden for more than a century because it is covered by the stainless steel cladding inside and out. Stainless steel was a natural choice given its durability, high corrosion resistance and mechanical strength.

The arch's interior skin is Type 304 stainless steel, a non-magnetic grade used to minimize radioactive dust accumulation that would impair accessibility to dismantle reactor components. The interior surface required 80,000 square meters of 0.5 mm thick stainless steel sheets. The panels are tightly fitted to a galvanized deck. No ribs are present in the panels in order to further reduce dust collection. Tape seals and fire- and radiation-resistant silicone mastic ensure that the interior wall is airtight. Interior panels have a highly reflective bright-annealed finish to enhance brightness inside the building. The interior cladding requires no insulation, but the exterior surface employs a complex four-layer insulation package to meet stringent specifications.

The design team chose molybdenum-grade stainless steel for the exterior skin. This surface is clad with 88,000 square meters of 489 mm wide 0.6 mm thick Type 316L stainless steel sheet profiles. Choosing Type 316L with 2% molybdenum for enhanced corrosion resistance ensured the required durability for a cladding with a 100-year life expectancy.

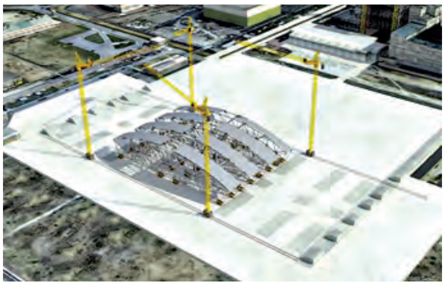
The stainless steel was annealed and pickled to create an evenly matte exterior finish in order to minimize reflections that might hamper the vision of pilots flying within view.

It was supplied by Aperam and delivered to the worksite by Kalzip in 1,000-meter coils. The Type 316L stainless steel was roll-formed on site into 100-meter long profiles for the roofing and 50–70 meter long profiles for the cladding of the eastern and western walls. The system allowed the forming of up to 200 square meters per day. After a profile had been positioned and clipped into previously installed Type 304 stainless steel fasteners called halters, the next profile was brought into position with the larger seam overlapping the smaller one. Fasteners were mounted through the water-proofing membrane by means of Type 316L self-tapping screws. Finally, a special seaming machine crimped all profiles to each other over their entire length.

Mountaineering skills were necessary to install the Type 316L stainless steel exterior cladding. © Novarka

Construction and assembly

Ongoing radioactive emissions made it necessary to build the new containment structure at a safe distance of about 200 meters from the damaged reactor ›



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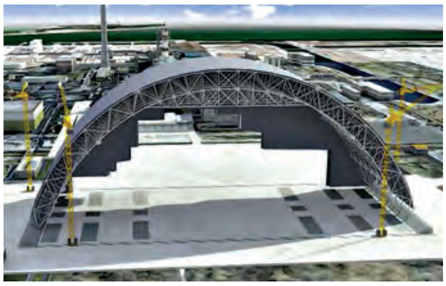

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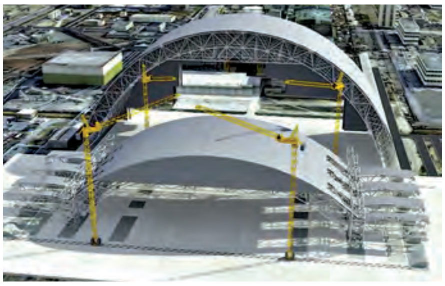

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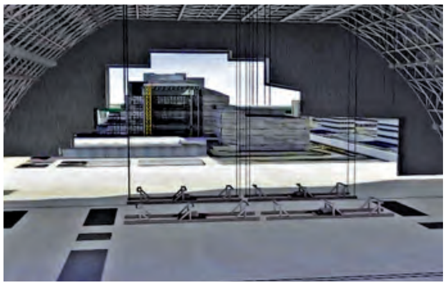

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1: Assembly of upper section of first half-arch. 2: Assembly of lower section and connection to upper one. 3: Lift first half to final height of 105 meters. Eastern wall is installed. Completed first half-arch is moved to waiting area to make room for assembly of second half-arch. 4: Assembly of second half-arch. 5: Connect two halves to form the complete arch. 6: Assembly of overhead bridge cranes and lifting in place 85 meters above. They are intended for dismantling the old sarcophagus and removing the debris of the damaged reactor. © Novarka

building. Half-arches were fabricated and preassembled on the ground in this area and outer insulating components as well as the cladding were installed at that time. Each half was then connected as the arch structure was completed. This process required a number of carefully planned steps as outlined in the graphics above.

While the accomplishments to date are truly impressive, important work remains to be done. Internal components must be fitted to the structure; the completed arch must be moved to its final position over the OS and its associated buildings; end panels must be completed and sealed; and the required ancillary buildings must be constructed to manage and control NSC systems. The project is not scheduled to be complete until late 2017, but all indications are that it will be an impressive success when finished. In this massive structure, Type 316L stainless steel will have helped to ensure a safe and contained environment for the next century. (Thierry Pierard)

How to move a monument

During site preparation, carefully aligned concrete beams were constructed to provide “rails” to move the structure on specifically designed and synchronized “skid shoes”. In March of 2014, the system was used when the newly completed east half-arch was successfully transferred 300 meters to allow space for the assembly of the west half-arch. In July of 2015, the west arch cladding was completed and in August the two halves were joined with nearly 1,000 bolts and sealed. Once it is completed, the new containment will be moved on these rails to its final position above the old sarcophagus and the Unit 4 building.

The two half-arches are joined to complete the building before it will be moved over the damaged reactor site. © ChNPP