# Technical modifications & management innovations in exporting nuclear reactor projects

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**Abstract**: As a main channel for the foreign economic cooperation of China nuclear industry, China Zhongyuan Engineering Corporation (CZEC) has been constantly engaged in technical modifications and management innovations in its exporting nuclear reactor projects. In the implementation of heavy water research reactor contract in Algeria, CZEC had established a complete and adequate design standards system in compliance with the international standards, and made significant modifications to the reference reactor in the aspects of reactor power and reactor safety, solved quite some technical issues which affected the reactor technical performance. The modifications and improvements enabled the technical parameters, safety features, reactor multipurpose application to attain to the advanced level in the world. In the 300 MWe PWR NPPs in Pakistan, safety features had been updated in line with upgrading regulatory requisites. The design philosophy and technology application demonstrated CZEC's creation and innovation on basis of constant safety enhancement of nuclear power projects. Efforts had also been made by CZEC in promoting China made equipment items and components exportation.

**Key words**: research reactor; technical modifications; management innovations; safety

## 1 Introduction

China Zhongyuan Engineering Corporation (CZEC) is a main channel for the foreign economic cooperation of China nuclear industry. On February 28, 1983, the Governments of China and Algeria signed "Agreement on Cooperation of Peaceful Utilization of Nuclear Energy", which specified that China would help Algeria in establishing a heavy water research reactor and relevant facilities, and the two countries would start cooperation in the field of peaceful utilization of nuclear energy, and that accounted for establishment of CZEC. After being approved by the State Council of the People's Republic of China on April 25, 1983, the Ministry of Nuclear Industry designated CZEC to undertake works defined in the Agreement.

From 1987 to 1995, CZEC completed Algeria Heavy Water Research Reactor and Its Auxiliary Facilities Project (871 Project) and Fuel Element Inspection Hot Cell and High /Low Pressure Test Loop Project (911 Project) in two phases.

On December 31, 1991, China and Pakistan inked the Contract for 300 MWe Chashma Nuclear Power Plant Phase-I Project (C-1 Project), and as a General Contractor, CZEC was responsible for implementation of the Contract in Pakistan. On May 4, 2005, the Contract for 300 MWe Chashma Nuclear Power Plant Phase-II Project (C-2 Project) was signed between the two countries and CZEC was designated as the General Contractor again for the Contract implementation. The successful cooperation between China and Pakistan in the field of nuclear power development attracted the eyesight of other countries, and quite some of them showed interests and intents of cooperation with China in developing their nuclear power capability.

As a company specially and exclusively conferred with the certificate of nuclear projects export right by the Government of China, development process of CZEC is closely linked with China's nuclear project export. Developing countries all think highly of the success of 871 Project, and regard it as epitome of south-south cooperation. The Pakistani Government highly praised the achievement of CZEC in construction of Chashma nuclear power plants complex as "Crystal of Sino-Pakistan Friendship".

CZEC constantly sticks to the principle of "Giving the first priority to safety and quality, initiating technical improvement and innovation and seeking for the perfect completion of each and every construction project to the satisfaction of the owners.

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## 2 Technical modifications adopted in Heavy Water Research Reactor and Its Auxiliary Facilities Project (871 Project) in Algeria

The project construction started in January 1987. The reactor realized its initial criticality on February 13, 1992 then operated in its rated power of 15 MW in July 1992. The project was qualified in its full power operation as per acceptance criteria after being operating continuously for 120 hours. On December 15, 1992, CZEC and the concerned authorities of Algeria signed 871 Project Provisional Acceptance documents. After one year of operation under the cover of the Project Warranty Period, the project Final Acceptance documents were signed on December 21, 1993 and the same month also witnessed the occasion when the project was crowed with "Epitome of South-to-South Cooperation" in the IAEC Annual Conference 1993.

In March 1995, a committee formed of 17 experts including academicians from Chinese Academy of Science and Chinese Academy of Engineering evaluated 871 Project and reached the conclusion that the 15 MW multipurpose heavy water research reactor provided to Algeria had made important scientific and technical innovations, "Compared with other heavy water research reactor in the world, the research reactor in Algeria ranked at the advanced level in the aspects of technical parameters achievement, safety and multipurpose features, operation and maintenance convenience, etc." In October 1995 and December 1996, the First Prize of Science & Technology Progress was conferred on 871 Project by China National Nuclear Corporation and the Chinese Government respectively.

The design of reactor and its facilities under the cover 871 Project had been done on the basis of the modified heavy water reactor (HWRR-II) design of China Institute of Atomic Energy (CIAE), which was established in the 1950s. Keeping in view of the low safety standard adopted at that time, significant innovations to the reactor was performed in the 1970s, with the change of core and the relevant systems, the reactor rated power had been escalated from 7 MW to 12 MW with the maximum allowable power of 15 MW, and its safety features had been improved as well. In February 1983, Algeria requested to build the similar type of heavy water reactor with steady thermal power of 15 MW for the multipurpose of scientific researches, education, fuel element tests, radioisotopes production, etc. Whether China is able to export such a research reactor up to the international standard? Certain people in the Ministry of Nuclear Industry had different views at that time, but in the end, the majority of people reached to the consensus that we had such capability as we had accumulated several decades of technical reserve and operation experience.

871 Project had a unique design mode. There was no overall design subcontractor and CZEC organized a joint design team with over 180 professional design engineers from the CIAE and Beijing Institute of Nuclear Engineering (BINE). The joint design team leader was designated by CZEC responsible for the team management, interface coordination and important design issues disposal. The CIAE was responsible for design of reactor main process and nuclear engineering safety, and the BINE was responsible for design of for the project general layout, buildings and structures, water/electric/air/heat supply systems and auxiliary facilities. With the effective coordination of CZEC, the joint design team had fully incorporated with operation experience and technical innovations of the reference reactor accumulated in the past 30-odd years, meticulously analyzed the deficiencies of the reference reactor and elaborately worked out the design modifications for the research reactor in Algeria by taking advantage of modern research reactor design conception and criteria of the USA, Canada and France. The design principle of 871 Project could be boiled down as "Advanced technology, safe operation, adequate applications and economic construction". Under the preconditions of adopting ripe and reliable technology, the designers were encouraged to adopt up-to-date techniques and innovations in the design modification for the research reactor in Algeria so as to let its performance be in line with the similar research reactors developed by the other countries.

The major technical modifications and innovations adopted in 871 Project are described as below.

### 2.1 Establishment of a complete and feasible design standard system

In the old days, most of research reactors in China adopted the Russian design codes and standards plus certain sections from the USA, the European countries as well as the Chinese GB. Keeping in view that adoption of different code and standard systems might cause confusion in design and construction, and the practice was not in compliance with the IAEA's requisites to nuclear safety and international open bidding competition, CZEC clearly mentioned the point in 1983 to all the technical staffing involved in 871 Project that the design must be extensively in line with the international practice. In October 1984, the implementation of 871 Project was stopped due to certain reasons, but CZEC made all the possible efforts and mobilized quite some reactor engineering experts to study codes and standards of research reactors published by the IAEA, Russia, the USA and China. As no systematic codes and standards could be found from the international and domestic standardization authorities, an organization with experts mainly from the CIAE plus some BINE's experts was established for preparation of a set of codes and standards of research reactors upon the request of CZEC in 1985. Based on design experience of research reactors in China, and taking reference of the relevant codes and standards of the IAEA, ASME, IEEE, ISO, ICE. etc., a complete set of standard system adequate to design of research reactor in Algeria was finally worked out in 1986. The standards filled up the notch of unavailable heavy water research reactor design standards in China, and served as technical safety requisites guidance in the design of research reactor exported to Algeria. The standards include the follows:

871 Project Research Reactor Safety Design Criteria Plus 22 Guides

105 China GB Standards in Basic Design

76 China GB Standards and Vender/Enterprise Standards in Detail Design

After obtaining Approval from the concerned authority of Algeria, the set of standards served as design and construction basis of 871 Project as well as reference basis of the Owner's safety review, design approval and project acceptance. The successful completion of 871 Project indicated that the design safety criteria prepared by China in 1986 were in compliance with the codes issued by the IAEA in 1992 and the relevant regulations of ICRP.

## 2.2 Escalation of reactor rated power to 15 MW

Upon request of Algeria, the research reactor designed should be able to be operated in rated power of 15 MW all the year round. This was a fundamental design requirement without compromising and the most difficult point for our designers.

As the reference reactor's rated power of 10 MW was the modified escalation by from the originally designed 7 MW, further power escalation by 50 % on the basis of reference reactor would be involved with unprecedented difficulties raised from the necessity of significant design modifications and verification tests in the area of nuclear physics and thermo-hydraulics, reactor core structure, fluid systems as well as shielding etc.

Operation feedback of the reference reactor indicated that leakage of coolant was the biggest obstacle standing in the way of power escalation; it meant that part of heavy water would directly enter into heavy water cavity in the vessel through flow distribution chamber by annular gaps between process plug and socket and could not be used for fuel element cooling. One of the direct reasons accounted for modification to the reference reactor was that leakage of coolant had increased by 40 % caused by socket fretting and reactor failed to operate normally at the rated power of 7 MW, however, the problem could not solved thoroughly, as years of continuous and big power operation after the modification had induced increment of coolant leakage from 7 % to 30 % and phenomenon of socket wear become even worse due to vibration, the reactor was forced to reduce its power to 8 MW in operation. The CIAE organized its experts and had topic discussion on the issue, and according to comments of experts, it was proposed to add anti-corrosive zircaloy bushing at flow distribution chamber process tube socket to solve the problem of abrasion. As hardness of zircaloy was similar to that of stainless steel, the zircaloy electrode potential was similar to aluminum one, and its thermal neutron absorption cross section is smaller, zircaloy was a suitable material for bushing. CZEC supported this proposal, requested the CIAE to quicken the pace of experimental verification, and agreed to pay all the expenses of researches and experiments of the consequence. After performing 300 hours of "The Overall Hydraulic Test to Process Tube of the MHWRR" in China, the pipe socket and plug was observed with extremely small wear, and the modification was proved out for implementation in 871 Project. The root cause of socket fretting was vibration, and key point of solution was to eliminate the activated vibration mechanism by modifying process tube structure and taking measures for improving water flow status. The design modification had solved the coolant leakage problem once for all, assured the long and stable operation of the reactor at rated power of 15 MW, and extended the service life of the reactor.

Reactor power distribution inclination remained as another important factor that restrained escalation of reactor power. Designers focused their eyes on the improvement of reactor power distribution induced the hot channel power reduce in the modification for assurance of steady operation at 15 MW and satisfaction of non-boiling criteria. In nuclear design, two more shim rods were added for the purpose of control rods even distribution, which had been proved as an ideal improvement.

In thermohydraulics design, the primary coolant overall flowrate of research reactor in Algeria was not permitted to exceed the value set for the reference reactor. The major modification was to change the diameter of process pipe throttling rod, and increase throttling element resistance at the fuel assembly outlet. The modification had induced pressure escalation of reactor core coolant, and in the mean time, realized the optimum distribution ratio in different flowrate zones.

In the steady state design, we had followed the international practice i. e. when the element cladding surface temperature on heat spot in each flowrate zone did not exceed wall temperature on the point of the first bubble generation, the coolant could be judged as a design in compliance with the nonboiling criteria. The design had kept optimum safety margin on basis of conservative consideration.

In the fluid system design, we replaced three reactor coolant pumps and two heat exchangers installed in primary loop of the reference reactor with three branches each with one coolant pump and one heat exchanger. The modification enabled the reactor to increase its total flowrate to 600 $m^3/h$ (with one branch standby). With respect to the secondary water system, we adopted high efficiency mechanical ventilation cooling tower and advanced circulating water treatment technology, and added special heat exchanger water scale removal system for better heat-transfer performance.

To tally with radiation protection requirements in the consequence of reactor power escalation, and meet with shielding requirement of 15 MW reactor, the following modifications had been made:

1) Lead blocks and steel plates in different thickness were paved from the center to the fringe of the reactor top water tank;

2) In reactor hall, brick walls were replaced by concrete wall of 0.5 m in thickness;

3) Horizontal channel cast iron protecting doors were replaced by multi-cylinder rotary protecting doors in cast steel and paraffin laminated structure;

4) Reactor coolant loop room concrete walls were thickened to 0.8 ~ 1.1 m.

The above mentioned modifications extensively enhanced the shielding capability, and dosage measurement on reactor top had been decreased by 10 to 20 times compared to the reference reactor.

The evaluation conclusion of experts committee to the research reactor in Algeria highlighted that "Significant modifications and improvements made in the design of physical, thermohydraulic and fluid systems as well as the important equipment items, especially technical innovation conducted to the inner vessel and important process tube components of the reactor in Algeria, which had solved the inherent deficiency of Beijing reference reactor in process pipe socket severe fretting caused by big coolant flowrate, enable the research reactor to escalate its rated power to 15 MW and neutron flux to $2.4 \times 10^{14}$ n/($cm^2$), both were 50 % higher than parameters of Beijing reference reactor. Compared with the other heavy water research reactor of low enrichment uranium (LEU) in the world, the research reactor in Algeria was advanced in reactor neutron flux availability. "

## 2.3 An advanced reactor safety design in the world

In the design of 871 Project, CZEC stuck to the principle of "Safety First and Quality First.", pursued the nuclear power plant design conception of "In-depth Defense, Expensive Protection and Multiple Barriers." and worked out a reliable and free-of-risks safety setup system. The in-depth defense setups were composited by the following three categories:

1) The First Level Defense  The First Level Defense had been designed to prevent deviations to normal operation condition, remove accident root cause as far as possible, establish strict and feasible quality standard, assure the reliability of important safety systems and components and reduce the accidents probability to its minimum.

2) The Second Level Defense  The Second Level Defense had been designed to inspect and rectify deviations from the normal operation condition, prevent the anticipated operational occurrences upgrading to accident condition. Design modification or improvement on of reactor protection systems, process monitoring system and electric system enabled the reactor to have more reliable safety auxiliary shutdown system, emergency power supply system, etc. as well as monitoring system (for detecting of process tube temperature difference, fuel element failure, main heat exchanger heavy water leakage and radioisotope sample capsule damage, etc.). Design of reactor building, systems and components had all incorporated earthquake defense and fire prevention requirements.

3) The Third Level Defense  The Third Level Defense had been designed to lessen consequence of accident, maintain the reactor in a stable and acceptable state in the wake of accident condition, and take measures against all postulated accident possibilities. Compared with the reference reactor, emergency core cooling system, reactor core residual heat removal system, the secondary water accident water supply system, accident air exhaust system, reactor building anti-flooding system, etc. had been added for the purpose minimizing the accident risks and consequences.

The following physical barriers had been designed against radioactive material release:

1) The First Barrier  Fuel element rod of Φ8 mm in diameter with $UO_2$ fuel pellet and Zr-2 cladding;

2) The Second Barrier  Reliability enhancement of reactor coolant system pressure boundary;

3) The Third Barrier  Confinement reactor building with accident air exhaust capability.

We had implemented extensively the ALARA (As Low As Reasonably Achievable) principle in the nuclear radiation protection design. Based on years of operation experience of the reference reactor, we worked out effective measures for operation and maintenance staff protection by establishing radiation zoning layout, installing adequate radiation monitoring facilities and taking preventative measures against cross contamination, and reducing the radwastes outcome. It had been proved that dosage uptake of both on-site staffing and off-site public were much lower than the limits defined by the IAEA.

## 2.4 Perplexed technical bottlenecks of the reference reactor removed

**2.4.1** Issues related to power oscillation of the reference reactor

After the modification of the reference reactor, issues related to power oscillation had not been resolved for years. The same problem with an amplitude of ±30 % occurred in the research reactor in Algeria while conducting low-power rate physics experiment, which went even worse than the case of reference reactor. CZEC mobilized experts and had an in-depth study and verification to this phenomenon. After conducting a series of tests and experiments, the experts reached the conclusion that power oscillation was induced by swing movement of control rod in its guide tube. The originally designed gap between control rod and guide tube for the reactor in Beijing was 2 mm, the modified reference reactor was 3 mm and research reactor in Algeria was 4 mm. big gap remained as the root course for reactor power oscillation. Based on the expert comments, we modified the design and reduced the gap to 1.5 mm, from then, the power oscillation phenomenon disappeared in general. The operation of research reactor in Algeria at different power rate stage including full power operation all witnessed power oscillation of less than ±10 %, and such a percentage of power oscillation occurred in a low frequency could be regarded normal and adjustable fluctuation.

**2.4.2** Issues related to cross radioactivity contamination

According the finalized design layout, the problem of cross radioactivity contamination remained as an outstanding issue of the reference reactor for years. In the design of the research reactor in Algeria, reasonable radiation zoning had been made as per requisites of safety codes and our years of operation feedback i. e. isolated pathway was added on the top of spent fuel transfer water channel in the reactor hall for isolating the hall from the water pool. Operations with radioactivity surroundings like targets access, refueling etc. will not be conducted in the reactor hall but through the way of reception room to water pool via isolated pathway. The modification solved radioactive contamination problem in the reactor hall, reactor cubicles, pathway on the third floor and other inspection and maintenance spots.

**2.4.3** Issues related to oil leakage of helium blower

The oil leakage of helium blower remained as a big problem due to helium gas escaping into the blower lubricant. When the helium containing oil circulating in reactor core helium gas layer, content of explosive gas would be increased in the wake of explosive decomposition. Moreover, the helium containing oil or decomposed solid materials would contaminate and deteriorate heavy water, even adhere to fuel element surface and impact heat transfer and operation safety. For solution of this problem, we developed new type of blower by adopting combined seal of rubber bellows moving seal mechanism and screw seal. The oil leakage was proved up to the specification after modification and operation safety was significantly improved then.

## 2.5 Multipurpose applications characteristics of research reactor in Algeria

In the design of 871 Project, we had taken full consideration of the Owner's requirements to this multipurpose research reactor. As the research center was scheduled to have stage-wised construction, we had worked out reasonable planning for expansion of its future applications. Optimum channel design and core array equipped with the advanced experimental facilities available in the world market enabled the research center to perform extensive fundamental and application researches as well as radioisotopes and radiopharmaceutical production, mono-crystalline silicon neutron transmutation doping, irradiation experiments of fuel elements and materials, neutron activation analysis, cold neutron researches, nuclear instrumentation graduation, etc. Neutron flux availability design for the research reactor in Algeria was proved sufficient for research works in the fields of physics, chemistry and biology. For those countries especially developing countries, who are not able to afford to build many monopurpose research reactors, the type of research reactor we provided to Algeria remains as an ideal selection.

In respect of application performance of research reactor in Algeria, expert evaluation committee had such conclusions that "Compared with other similar type of research reactors in the world, the research reactor in Algeria has characteristics in its multipurpose application design. Optimization and modification made to test loop and irradiation condition enable the research reactor in Algeria to raise radioisotopes production capacity, increase the yield of mono-crystalline silicon neutron transmutation doping and upgrade the capability and scope of neutron activation analysis. By adopting the advanced technology, automatic operation capability of the reactor has been significantly improved." Compared with other 12 running heavy water research reactors with LEU of 3 % in the world, the research reactor in Algeria was ranked in leading position in the aspects of performance and application show.

## 3 Technical modifications adopted in Chashma 300 MWe Nuclear Power Plant Projects (C-1 Project & C-2 Project) in Pakistan

Contract for Chashma 300 MWe Nuclear Power Plant Projects were signed between Pakistan Atomic Energy Commission (PAEC) and China National Nuclear Corporation (CNNC) on the basis of framework agreement on peaceful utilization of nuclear energy cooperation signed between the government of China and the government of Pakistan. Chashma 300 MWe Nuclear Power Plant Project Phase I (C-1 Project) was a 300 MWe PWR NPP exported to Pakistan by CNNC in turn key mode. C-1 Project contract was signed on Dec. 31, 1991, and came into force on Feb. 25, 1992 after being approved by the government of China and the government of Pakistan respectively. The provisional acceptance of C-1 Project was realized on Sept. 25, 2000, and with the ending of warranty period in March 2004, the final acceptance realized in March 2004.

Since its connection to the national power grid of Pakistan, C-1 plant has kept an excellent operation record by maintaining factor load of over 80 %, which attained 96.4 % in four fuel cycles. The Pakistani government and people all thought highly of the project, and the national leaders of Pakistan and China regarded the project as the crystal of Sino-Pakistan friendship and epitome of south-to-south cooperation.

On May 4, 2004, CNNC and PAEC signed Contract for Chashma 300 MWe Nuclear Power Plant Project Phase II (C-2 Project). The contract came into force on Dec. 1, 2004. C-2 Project construction is in progress at present stage.

C-1 Project was the biggest hi-tech cooperation project with exportation of labor power and complete set of equipment. The work scope of CZEC included: engineering design, equipment procurement and fabrication, civil and installation works, personnel training, plant commissioning and pre-operation, etc., that was to say, CZEC handed over an integrated plant to the Owner in Pakistan in turn key mode in the end. In respect to C-2 Project, the work scope was similar to that of C-1 Project, but the six BOP items had been undertaken by PAEC and personnel training activities had been removed from the C-2 Project contract.

As a backbone enterprise affiliated to CNNC for implementation of economic and technical cooperation contracts, CZEC had been authorized by CNNC as the general contractor with full responsibility for implementation and management of nuclear power projects in Pakistan.

### 3.1 Improvement on safety and technical performance of C-1 unit

The reference plant of C-1 unit is Qinshan Nuclear Power Plant, the first NPP developed by China with her own intellectual property right. The reference plant construction started in 1983, connected to the state grid of China in 1991 and has been operating for about 18 years with sound and safe operation record. Started from its $8^{th}$ fuel cycle, the continuous operation of the plant has been maintained over 400 days and 469 days the longest. Fuel reliability, chemical indexes and collective radiation dose uptake all better than the mean values of similar plants in the world.

The optimized and modified design of C-2 Project is based on feedback of C-1 plant construction and operation e.g. simplified flow process, reduced numbers of equipment items by comprehensive utilization of them, etc. The most important modification is embodied in the aspects of the plant safety enhancement and optimum nuclear island buildings layout, which are of vital significance to the improvement of safety features and technical performance of 300 MWe PWR nuclear power plant units.

#### 3.1.1 Safety enhancement measures

Qinshan NPP design based safety criteria are "Safety of Nuclear Power Plants Design Rev. No. NS-R-0, 1978" promulgated by IAEA in 1978 and the corresponding Nuclear Power Plants Safety Regulations HAF-102 promulgated by the National Nuclear Safety Administration (NNSA) of China. After nuclear accidents of Three Mile Island NPP of the USA and Chernobyl NPP of Soviet Union, IAEA promulgated "Safety of Nuclear Power Plants Design Rev. No. NS-R-0, 1988" in 1988 by incorporating new experience obtained in the development of nuclear power. The new revision of safety criteria gives more strict and concrete requisites to the design of nuclear power plant in consideration of the possible severe accident prevention and mitigation, and emphasizes the application of Probabilistic Safety Assessment (PSA) in the design of nuclear power plants.

As the corresponding new revision of NNSA's Nuclear Power Plants Safety Regulations was not available in the time of C-1 Project Contract signature, it was defined in the contract that safety criteria of "Safety of Nuclear Power Plants Design Rev. No. NS-R-0, 1988" promulgated by IAEA in 1988 should be followed. In C-1 Project design, we had worked 14 safety modification measures against severe accident according to the best we could do in meeting the requisites of IAEA's new revision of safety criteria.

1) Thickness of reactor containment building foundation slab was increased from 3.0 m to 5.4 m for retarding foundation slab meltdown time and taking emergency measures.

2) Two types of measuring ranges of barometers installed in the containment were designed i.e. broad range 0 ~ 1.0 MPa, narrow range -0.01 ~ 0.3 MPa.

3) Broad range radiation monitoring instruments ($10^{-2} \sim 10^{5}$ Gy/hγ) were added in the containment.

4) Reactor in-vessel water level monitoring system was added for inspection of reactor core exposure.

5) ATWS mitigation system actuation circuitry (AMSAC) was designed against the anticipated transients without scram (ATWS) accident.

6) Steam Generator Tube Rupture (SGTR) monitoring system was designed including N16 monitoring instrument, SG blowdown radioactivity monitoring instrument and condenser extraction radioactivity monitoring instrument.

7) Design of auxiliary feed water system had been modified for upgrading its operation reliability. The original design had two motorized auxiliary feed water pumps respectively installed on the each trains of auxiliary feed water system, and design modification had added two diesel auxiliary feed water pumps respectively to each train. Moreover, reactor start-up/shutdown feed water system was added as an Engineered Safety Feature (ESF) for reducing the probability of severe accident.

8) Two component cooling water pumps of 100 % capacity were designed and installed respectively on the each train of component cooling water system for upgrading reliability of the system and reducing the probability of severe accident caused by loss of the heat sink.

9) High temperature monitoring instruments were added in the reactor cavity for indication of high temperature changes against reactor pressure vessel meltdown.

10) Design modification had been made in the secondary main steam atmosphere discharge system by adding two standby release valves respectively on the each discharging line for better reliability of the secondary side reactor core residual heat removal and reduction of probability of severe accident.

11) The Main Control Room (MCR) design had incorporated requirements of Human Factor Engineering (HFE).

12) Technical supporting center was designed.

13) Emergency control center was designed.

14) The third set of emergency diesel generator was designed for emergency power supply in case of the plant blackout and reduction of probability of severe accident.

**3.1.2** Improvement on the nuclear island layout

Compared with the reference plant, optimum nuclear island layout of C-1 Project was a significant improvement. In C-1 Project new design, safety related systems and components of A and B trains were respectively installed in two centralized zones physically separated by concrete structure walls, and such a design raised safety and reliability significantly. The advanced basic diagram methodology application in the new design of fire prevention zoning, anti-flooding measures and radiation zoning was gradually perfecting the internal event prevention design. As safety related systems and components as well as pipelines and cables of different train were profiled in different centralized zone, no additional separation measures were required. Such a design had induced an economic construction result.

The geological features of Chashma NPPs site in Pakistan is sandy soil sedimentary formation of over 200 m, where requests safe shutdown earthquake (SSE) of 0.25 g in design. Structure design and general layout of nuclear island (NI) buildings on the sandy soil site with such a high SSE requirement was really very difficult, as it was the first time for the Chinese to design its NPP on sandy soil site with few reference plants of the similar geological information available in the world. The solution of uneven sediment was the key point in the design. The overall weight of NI buildings and structures was 200 000 t approximately, the uneven sediment (inclined sediment) caused by sandy soil would overturn the nuclear power plant. An entirely new structure design and general layout of nuclear island (NI) buildings in compliance with the site geological and earthquake conditions was a must. A structure group including reactor building (RX), nuclear auxiliary building (NX), electric building (EX) and fuel storage building (FX) was integrally designed on a concrete foundation raft of 84 m × 85 m with NX as its center. Adequate measures were taken for aseismic design of NI structures. The center of gravity of NI structures was designed to register with that of foundation raft as far as possible for even sediment of foundation raft. For assurance of safe operation of the plant, the reasonable layout of buildings and structures on NI should also include a comprehensive consideration of such factors like external NI pipeline connection, sediment impact of structures and buildings around the NI. In the course of C-1 Project construction, the periodic monitoring records indicated that up to April 1998, the $5^{th}$ year after starting the civil works, NI foundation raft trended towards stable sediment with actual measurement of 51 mm, which was quite close to the theoretical calculation value of 60 mm, and the uneven sediment was only 3 mm. Design and construction of C-1 Project was proved a success.

### 3.2 Improvement on safety and technical performance of C-2 unit

**3.2.1** Further improvement on safety requisites in line with new revision of IAEA's Safety Code

Before signing C-2 Project Contract, IAEA promulgated "Safety of Nuclear Power Plants Design Rev. No-NS-R-1" by in 2000. The corresponding Nuclear Power Plants Safety Regulations HAF-102, 2004 was promulgated by the National Nuclear Safety Administration (NNSA) of China in 2004 after Pakistan Nuclear Regulatory Authority (PNRA) formulated its safety code PK/911 according to IAEA's Safety Code Revision I of 2000. How to implement IAEA's Safety Code Rev. I of 2000? Different countries have their different interpretation. At that time, as all the nuclear power plant project under construction or scheduled to build in China had not incorporated IAEA's Safety Code Revision I of 2000, it was defined in C-2 Project Contract that "All activities including design, and design verification, manufacture, construction, verification, inspection, QA, commissioning, operation, maintenance and surveillance of the Contract Plant shall be conducted in accordance with the codes and standards (and guides) applicable on October 12, 2003 to the licensing of commercial nuclear power plants in China." That is to say, C-2 Project safety design criteria would be the Revision No-NS-R-0 promulgated by IAEA in 1988.

In the design of C-2 Project, we had fully incorporated operation feedback, and modification experience of Qinshan NPP, and moreover, under the guiding principle of "Reasonability, Reliability and Feasibility", we taken the following 11 measures to further enhance the safety of C-2 in preventing and mitigating severe accident according to requisites of PNRA's PK/911 (IAEA's Safety Code Revision No-NS-R-1 promulgated in 2000) as far as possible:

1) The first level PSA had conducted in the course of design i. e. making analysis to internal events occurrence in full power operation of the C-2 plant by evaluation program RISK SPECTUM, which had been adopted extensively in the world. The major event tree covered small loss of coolant accident (S-LOCA), large loss of coolant accident (L-LOCA), steam generator tube rupture (SGTR), loss of operating power (LOOP), TT/RT, loss of feed water (LFW), loss of flow accident (LOFA), loss of important instrumentation functions and power supply, etc. We had made calculations to 587 initial event sequences induced core damage, and reached the conclusion that the top 10 initial even sequences would contribute to 66.6 % of core damage frequency (CDF) of C-2 plant. Based on the above-mentioned PSA, we worked out the detailed operation requirements and improvement measures to charging pump of chemical and volume control system (CVCS) and stop valve of auxiliary feed water system (AFWS), added off-site power source, auxiliary core cooling (ACC) power source, the minimum flowrate cycling pipe route of residual heat removal pump, connection line between the two safety injection pipe lines, interlock of pumps and cooling fans in essential service water system (ESWS), etc.

2) In respect of the second level PSA, we had categorized all the event sequences with over 95 % of contribution to CDF as dominant severe accident sequences, and made analysis to five event sequences including anticipated transients without scram (ATWS) mitigation system, the whole plant blackout, mid-loop operation, various boron dilutions and LOCA. Based on calculation and analysis, the possible internal and external dose uptake of MCR personnel in severe accident was given and the corresponding measures against possible radioactivity release were worked out.

3) We had defined the environmental conditions of the reactor containment in severe accident, and made improvement on the reactor containment boundary and its internal equipment items.

4) The reactor cavity water injection system in severe accident was added for retarding the possible reactor containment meltdown time in the consequence of core melting.

5) Hydrogen concentration monitoring system was added in the reactor containment for assurance of normal operation of equipment and components under severe accident condition and provision of hydrogen and

oxygen concentration information in the reactor containment to the operation staff for reference of the post accident administration.

6) Improvement had been made on the reactor containment de-hydrogen system by adding passive hydrogen recombination device against explosion of concentrated hydrogen in severe accident.

7) The corresponding preventative measures had taken against supercriticality of reactor possibly induced by boron free water in the reactor core.

8) One motorized pressure relief valve was added in the pressurizer pressure relief system for reduction of probability of core melting in consequence of the high pressure.

9) Loose part monitoring system (LPMS) was added.

10) Safety system bypass and non-operative indication system were added. The hardware of the system was designed to share with the plant computer system (CPC). Protection system or systems driven or actuated by protection system and the relevant auxiliary system and supporting system for protection system were able to bypass certain safety functions to non-operative mode in the periodic tests or outage of the plant for reduction of probability of severe accident induced by operator's mistakes.

11) Quite some improvements had been made on the MCR design in the aspects of MCR layout, indication, monitoring, control, etc. so as to let C-1 plant MCR perfectly meet the safety and operation as well as human factor engineering requirements.

**3.2.2** Electricity generation escalation improved the economic performance

Compared with Qinshan NPP 300 MWe PWR unit, the rated power output of C-1 plant has been escalated to 325 MWe, and the rated power output of C-2 plant has been further escalated to 340 MWe under the circumstance of not changing the nuclear steam supply system. Such a rational conversion from nuclear energy to thermal energy to electric energy done by 300 MWe NPP, enables the plant to enjoy the designed economic performance improvement.

**3.2.3** Further escalation of reliability of the plant systems and equipment items

According to operation feedback and modification experience of Qinshan NPP plus operation feedback of C-1 plant, the following significant modifications have been made to the related systems and equipment items in C-2 Project design.

1) The ultimate heat sink design was modified, and the closed cycle ultimate heat sink was combined with the ESWS. The modification completely solved issues of silt sediment and frequent filter chock-up caused by open cycle design of ultimate heat sink, moreover, enhanced the system safety.

2) Design of reactor containment personnel airlock improved.

3) According to Qinshan NPP's experience, we redesigned the primary loop filter cartridge replacement device and other equipment items. The new design played an important role in the plant safety and reliability escalation.

4) In respect to procurement of conventional equipment items, the first priority was given to the quality products fabricated by the qualified manufacturers with advanced technique. The practice escalated the reliability and availability of the plant.

### 3.3 Technical innovations in the construction Chashma 300 MWe Nuclear Power Plant Projects (C-1 Project & C-2 Project) in Pakistan

Construction conditions of Chashma NPP projects are entirely different from those of domestic nuclear power plant projects. High temperature, very little humidity and great temperature difference are Chashma site features. According to features of Chashma site and specialties of local environment, we keep improving our construction techniques and methods, and have made quite some innovations in the construction management.

**3.3.1** De-watering work technique of on large areas of sandy sedimentary formation adjacent to the operating nuclear power plant

Chashma Nuclear Power Plants Complex is seated on a site of sandy sediment formation of 200 m in thickness with high groundwater table at −8.0 m. Due to big outcome of groundwater and quick permeability of sandy soil, de-watering construction is very difficult especially when you have to de-water to −16.0 m and maintain the low water level for over 400 days. After many calculations and tests, we successfully solved the issue of C-1 Project de-watering on large area of sandy soil by selecting proper de-watering spots, adjusting groundwater pumping outcome, conducting real time measurement of de-watering depth, and preparing standby power source with adequate capacity.

How to arrange C-2 Project de-watering work is a new problem before us. C-1 plant plunged into its commercial operation many years ago and sediment of its buildings and structures is in a stable way. The crow flight distance between foundation pit of C-2 NI and C-1 turbine-generator building is less than 80m. The large scaled de-watering project adjacent to C-1 plant would definitely induce groundwater table inclination and how to avoid the uneven sediment of C-1 plant became a greatest problem in C-2 de-watering work. We have studied many de-watering project construction schemes, and ruled out the possibility of building water insulation wall due to the thick sandy formation with quick water permeability. The only feasible scheme was water priming method. Prior to the start of de-watering project, we have conducted a vast amount of experiments and tests for accurate control of relationship between groundwater table gradient variation and water priming volume. With the exception of building observation wells in C-2 construction site, we have added quite a few observation wells and water priming wells in C-2 plant area for monitoring the groundwater table variations and adjusting water pumping and priming accordingly. Adjustment has also been made to the profile of de-watering spots to let the groundwater table be declined to the direction of C-1 plant as far as possible and maintained a smooth groundwater table descent at C-1 side. Thanks to the implementation of the corrective construction scheme, C-2 de-watering project succeeded and the actual measurement of uneven sediment of C-1 plant turbine generator building caused by de-watering project of C-2 was 1.5 mm, which was much lower than the maximum design tolerance limit of 70 mm.

**3.3.2** Mass concrete construction and its cracks prevention technique

How to ensure that there is no structural cracks appeared after mass concrete casting in a meteorological condition of high temperature, little humidity and large day-night temperature difference is really a technical problem. The C-2 Project mass concrete construction has been proved up to top quality without any structural cracks appearance (even hair cracks were seldom observed). The Owner thought highly of the mass concrete construction quality. The achievement is due to the following effective measures taken in the course of construction.

1) Accurate thickness calculation of each layer concrete in the laminated concrete casting work.

2) Correct selection of water-cement-aggregates-sand ratio in concrete batching process.

3) Strict control of concrete moulding temperature and vibration process.

4) Real time measurement and control of concrete internal temperature rise and speed of temperature drop.

5) Strict control of concrete curing process

**3.3.3** Construction modularization try

Based on the domestic nuclear power projects and C-1 project construction experience, we actively started the construction modularization in installation of reactor containment barrel steel lining, steel brackets, reactor dome steel lining, pipe lines, steel structures, etc, the practice has been proved an ideal construction method in giving effective control of construction progress and quality and minimizing the complicated cross works and overhead works.

The optimum construction scheme, accurate arrangement of construction sequence and computerized management mode enable the complicated work to be done in a modular blocking way by processing route from workshop prefabrication to the site assembly, especially for materials machine shaping like blanking, boring, edge cutting, etc. which used to be done on the site.

The advantage of construction modularization is obvious. Compared with working condition in the open air at site, workshop provides a good and convenient working condition as well as advanced machines and inspection facilities for sophisticated fabrication of products. Quality control to products finished in the workshop can be more efficient. As most of construction members are prefabricated in the workshop, work quantity at assembly stage will be lessened, and the practice benefits both project quality and project progress controls. For example, thousands of linear meters of radial and vertical weld seams have been reduced by using broad steel plate material, as length of each prefabricated member became longer and the originally designed 13 layers of reactor containment steel lining changed to 10 layers. Another example, all the pre-installation works on the steel lining including electric penetrations bushing installation, welding bevels and grooves machine shaping, metal surface sand blasting and rustproof painting, etc. were done in the workshop first then shifted to the site in integrated modular forms. The remaining site assembly works were prefabricated mudulars lifting, fitting, positioning, aligning plus welding. The practice significantly reduced overhead welding work quantity, minimized weld seam length and improved product visual quality.

C-2 Project construction modularization is still in its fledging stage, but it gives us a new conception in the construction of nuclear power plant projects. The methodology has the practical significance in our work efficiency escalation, construction period reduction, and effectively control of project cost and quality. More and more new generation of nuclear power plants have adopted this methodology in their construction.

## 4 Active and steady promotion of indigenous capability in nuclear power equipment items supply

People devoted to nuclear power career of China are seeking the indigenous capability in nuclear power equipment items supply for long. Thanks to the efforts in the past 20-odd years, great progress has been made in this aspect. CZEC has also made its outstanding contributions to localization of nuclear power equipment items.

Localization of nuclear power equipment items is a decision making issue rather than a technical one. For a long time, certain western countries have monopolized most of market share in nuclear power equipment items supply by using their technical superiority. They have set blockade on us in accessing to nuclear equipment fabrication information and technology by taking various excuses. We have to rely on the western countries to obtain certain key equipment and components, although we have taken command of nuclear power plant design.

The western countries have imposed sanctions against Pakistan from the very beginning of its nuclear power development program implementation, and forbidden sales of nuclear power key equipment items and components to Pakistan. Started from C-1 Project, based on its guide line of "Breaking the blockade of the western countries, providing nuclear power equipment items and components by self-reliance, and making full preparation for the consequent risks", CZEC had made huge amount of investment to technical researches and development activities of nuclear power equipment items and components. Along with the design institutes and manufacturers, we had removed numerous obstacles standing in the way of equipment fabrication. In C-1 Project, CZEC initially made breakthrough in the localization of the following equipment items and components and exported them to Pakistan:

Reactor Pressure Vessel (RPV) and its metal insulating layer;

250 t polar crane;

Reactor coolant pump casing and motor;

Process instrumentation;

Complete set assembly of reactor core neutron flux monitoring system;

Gas Insulated Switchgear (GIS);

Nuclear power plant computing system;

Equipment hatch;

Mechanical snubber;

Remote control crane

The successful development and exportation of the above mentioned China made equipment items and components had made the first step towards the way of developing China's indigenous capability in nuclear power equipment fabrication and explored a new procurement channel of nuclear equipment items and components for nuclear power plant projects both at home and abroad.

Compared with C-1 Project, the execution of C-2 Project Contract was more difficult when sanctions from the western countries against Pakistan turned to even sterner by specifying the application scope and enhancing the surveillance of "Certificate of the End-User". Certain countries even rejected to sell civil vehicles and construction machinery to Pakistan for its nuclear power projects. Under the circumstance, CZEC has resolutely made the following decisions.

1) To procure China made equipment items and components as far as possible so long as the safety and quality requirements could be met the design specifications;

2) To actively support the domestic manufacturers with potential capability to research and develop the required products for quickening pace of nuclear power equipment items and components localization process in China;

3) To take full advantage of available results in domestic products research and development to meet requirements of nuclear power plant exportation and strengthen CZEC's competitive capability in the international market of nuclear power exportation.

The implementation of above mentioned decisions enabled CZEC to overcome technical and administrative difficulties, and bravely undertook responsibilities for risks rising from project progress and quality controls in the consequence of initial development of equipment items and components. Thanks to the efforts of CZEC, remarkable progress in the following equipment items and components domestic fabrication has been made for C-2 Project.

Main pipe material and fabrication;

1E class emergency diesel generator unit;

Main feed water pump unit;

1E class electric penetrations;

Reactor water level monitoring system;

1E class medium-voltage switch cubicles;

Reactor top cables;

Dual-fuel boilers

The exportation of the above mention China made equipment items and components filled the notch of C-2 Project, moreover, demonstrated the updated fabrication capability and competitive capability of China. Successful experience in procurement of nuclear power equipment items and components for CZEC's export nuclear power plants has paved way for utilization of the China made products in nuclear power plant construction both at home and abroad. Nowadays, the domestic nuclear power plants under construction have all placed order of reactor pressure vessels, polar cranes, etc. with manufacturers in China.

Up to the end of 2008, procurement of C-2 Project major equipment items and components completed, and 86 % of the total value of order placing contracts has been settled by RMB currency in the consequence of utilization of China made equipment items and components. When calculation is on set of equipment, the percentage goes even higher. Compared with the utilization level of China made equipment items and components in domestic nuclear power plants in operation and under construction, Chasham nuclear power plants in Pakistan are a cut above them.

## 5 General contractor of nuclear power export projects

General contracting is the prevailing management mode in the construction of nuclear power plants. As a general contractor and in turn key mode, the professional engineering company is to be responsible for all the construction and management work including design, equipment procurement, civil and installation works, commissioning (or coordinating commissioning), which are to be sublet or subcontract to other professional subcontractors or the Owner in most of cases. The respective work scope, responsibilities and obligations as well as the corresponding rights of general contractor and its subcontractors are to be defined in the form of economic contract. The general contracting mode has the advantages of high profession integration and high work efficiency but less working staff. When the plant is in commercial operation, how to settle those management employees recruited in the plant construction stage is always a headache to all the owners of the running plants, however, in the general contracting mode, the practice of letting general contractor serve as sensible interim owner is welcomed by most of plant owners.

CZEC is the first professional company designated by CNNC for undertaking overseas nuclear projects in turn key mode. The successful completion of 871 Projects and 911 Projects in Algeria and C-1 and C-2 Projects in Pakistan demonstrated CZEC's rich experience and outstand achievement in construction and management of the overseas nuclear projects. In the execution of project management, CZEC constantly summarizes its experience, absorbs the advanced new management conceptions, enhances the quality of its working staff and improves its management ability. CZEC has gradually established a nuclear project general contracting management system with its own characteristics.

### 5.1 Studies in establishment of new project general contracting mode

In China nuclear industry circles, CZEC is the trail blazer and pioneer in executing project general contracting mode in nuclear project construction. After signing the 871 Project Contract, CZEC initiated the general contracting mode for implementation of the contract and subletting design, civil and installation works, commissioning and training activities to its subcontractors. CZEC took the overall responsibilities for project management and equipment procurement. CZEC designated equipment suppliers/subcontractor after making comparison of their capability, and defined responsibilities, obligations and the corresponding rights by signing contracts with subcontractors. The general contractor had the overall responsibility for the project progress, quality and cost controls to the Owner, subcontractors were responsible for the project progress, quality and cost controls in the respective work scope and accepted CZEC's management and coordination.

Compared with the project distractive management mode adopted in nuclear facilities construction for long, introducing project contract generating mode to nuclear facilities construction was quite an advanced thinking. In the pre-project stage, some people viewed that senor leaders of the Ministry of Nuclear Industry should be the chief commander of the project, and project work should be assigned to the concerned functional departments or bureaus for implementation, and CZEC was only responsible for liaison with the concerned authorities of Algeria. After demonstrated its elaborated planning and explained its thinking in details, the senior leaders of the Ministry of Nuclear Industry was finally convinced and agreed the proposal of constructing 871 Project in general contracting mode submitted by CZEC, however, confined by the old practice, 871 Project work steering group had also established for further strengthening the leadership and coordination of the project work. Although the Ministry of Nuclear Industry had well-disciplined and experienced construction and installation teams, although subcontracts were signed between them with CZEC, administrative instruction of senior leaders were playing important role in project problem solving as these teams were not able to immediately accept the contract management. Nowadays, people would say the so-called general contracting mode adopted in 871 Project was still in its undeveloped form mixed by general contracting mode and administrative instruction mode.

No matter it is a failure or a success, introducing the general contracting mode to 871 Project initiated the CZEC's first try in breaking the old conception of planning management system that had dominated the development of China nuclear industry in the past 20-odd years, and managing the project by means of signing economic contracts. The interim general contracting mode adopted in 871 Project enabled CZEC as well as other enterprises engaged in nuclear projects to have their initial but valuable experience. The management work of 911 Project had made a progress by introducing the tender bidding mechanism, and further emphasizing the seriousness of the contract.

### 5.2 General contracting management of C-1 and C-2 Projects in Pakistan

CZEC's project management of C-1 and C-2 Projects is a successful example of general contracting mode application. In respect of C-2 Project, CZEC's project management level has been upgraded to a new level i.e. management conception and planning, contract preparation and performance, establishment of management measures and process controls, etc. are all in line with the requirements of modern project management and requisites of international nuclear power plant projects construction management system. The description of project general contracting management practice in the construction of Chashma nuclear power plants in Pakistan is as follows.

1) Establishing Chashma Nuclear Power Plant Project Management Organization and designating the Project General Manager with full power of project organization and contract implementation. Establishing functional departments according to management work delimitation (Technical Management Department, QA Management Department, Project Progress Management Department, Contract Management Department, Information Management Department, etc.)

2) According management work requirements, establishing CZEC's Site Management Office and Shanghai Procurement Office respectively responsible for site construction and equipment procurement management. Establishing necessary functional departments under the Site Management Office and Shanghai Procurement Office. The managers of Site Management Office and Shanghai Procurement Office are responsible to the General Manager of CZEC.

3) Subletting design, civil and installation works, commissioning to designated subcontractors. CZEC Shanghai Procurement Office is responsible for equipment procurement.

4) Fully introducing tender bidding mechanism in project work sublet. With the exception of the design and commissioning subcontractors, all the other subcontractors or suppliers are to be selected from the strongest bidders.

5) Establishing nuclear engineering system, preparing Quality Assurance Program for the Construction Period of the Plant, issuing QA declaration, working out Program Procedures and Management Procedures, conducting QA management and QA audits to all subcontractors and suppliers, and preparing non-conformance management and disposal procedure.

6) Fully implementing contract management and preparing the complete, detailed and executable subcontract text for implementation.

7) Establishing project budget management system, working out detailed project budget, setting year/quarter/month budget management targets for expenses control, preparing budget adjustment and review/approval procedure against off-budget payment.

8) Preparing complete, effective and executable management procedures and work-oriented procedures for implementation, conducting inspection, modification and supplement to these procedure bon the regular or irregular basis to let them enable to cover all the management works and behaviors.

9) Adopting advanced management methodology and management software, conducting categorized management and dynamic management to project construction schedules, enhancing subcontract settlement management, computerizing the combination of tangible work quantity and imaginary progress schedule for synchronizing payment settlement with actual work achievement and imaginary progress schedule.

10) Introducing internal quality surveillance mechanism motivated by a highly responsible attitude to the project quality (although the Owner did not employ the independent surveillance organization, the General Contractor had employed a professional surveillance organization for quality surveillance implementation).

11) Establishing smooth communication channel with the Owner, accepting the Owner's inspection and surveillance. Establishing periodic general manages' coordination meeting and monthly site managers' coordination meeting system to effectively solve problems raised in the course of contract implementation and timely coordinate actions accordingly.

The above mentioned measures enable us to give effectively control to project construction quality, progress and investment, realize the accurate management of the project to the satisfaction of the Owner.

**Author**

Mao Xiaoming, male, was born in 1952 and graduated from Shaanxi Machinery College in 1978. He is a senior engineer of professorship and a specialist in machine fabrication and nuclear equipment. Mr. Mao Xiaoming enjoys the special subsidization from the State Council. He has been granted with the honors of working model as a young and middle aged specialist with outstanding contributions to the nuclear industry development of China. Now he is the General Manager of China Zhongyuan Engineering Corporation (CZEC). As a responsible person, he has engaged in many important projects in China including Qinshan Nuclear Power Project Phase I and quite some large petrochemical projects. He has been conferred with the Science and Technology Prizes Class I for two projects, Class II for three projects and Class III for one project respectively by the Nuclear Industry Ministry.

During construction of the Pakistan Chashma Nuclear Power Plant Phase I, thanks to his efforts in developing the indigenous capability of nuclear equipment fabrication, 40-odd equipment items including Reactor Pressure Vessel (RPV), Lifing Jigs, Polar Crane, Reactor Coolant(RCP) Pump Motors, Pump Case, Process Control and Instrument System, etc. were initially and successfully fabricated by self-reliance. His technical experience enabled him to solved quality problems of RPV nozzle forgings and installation quality problem related to RPV main stud hole No.48. During construction of the Pakistan Chashma Nuclear Power Plant Phase II, he has organized six research groups and realized localization of the Emergency Diesel Generator, Reactor Main Pipings and Electrical Penetration Assembly, which were used to be imported from the third countries.

He worked as the leader of specialist group and solved the RPV quality problem discovered in in-service inspection of C-1.