An AREVA and Siemens Company

LING AO
2 x 1000 MWe PWR

A success story

FRAMATOME ANP

July 2002: Ling Ao Unit 1 inauguration ceremony chaired by Mr Li Peng

Framatome ANP is the world leader for the design and construction of nuclear power plants and related equipment manufacture. Ling Ao 1 and 2 are the latest 1000 MWe PWR units supplied by Framatome ANP. They were built by CGNPC, the nuclear power utility of the Guangdong Province in China.

The two units were successfully commissioned in 2002, two months ahead of schedule, and have been operating at full power since then: Unit 1 has recorded an outstanding availability of 100% during the first year of operation. This performance proves that the Ling Ao units have benefited fully from the evolutionary approach developed in France which combines unique operating feedback with substantial R&D and innovation programs.

The project was carried out in very close cooperation with the customer and Chinese partners, thereby helping to enhance the self-reliance of the Chinese nuclear industry.

The outstanding success of this project illustrates the soundness of Framatome ANP's principles:

- Continuously improve plant design with innovative techniques and methods,
- Invest in intensive R&D programs and fully integrate the experience gained from operation of a large number of Nuclear Power Plants,
- Be strongly committed to partnerships with its customers and local partners,
- Undertake to implement comprehensive technology transfer programs.

July 2003

1 - LING AO PROJECT

Ling Ao Nuclear Power Station is a 2 x 1000 MWe PWR plant located at Ling Ao Village on the Dapeng Peninsula to the east of Shenzhen. The Power Station is 1.2 km from the Daya Bay Power Station, and 45 km from downtown Shenzhen. The Ling Ao site can accommodate two additional 1000 MWe units.

The owner is LANPC (Ling Ao Nuclear Power Company), a wholly-owned subsidiary of CGNPC, created on October 4, 1995.

Ling Ao Nuclear Power Station has adopted internationally proven nuclear power technology with Daya Bay as its reference power station, while incorporating substantial technical improvements to further enhance the safety and reliability.

The Nuclear Islands supplier is Framatome ANP France and the Conventional Islands are supplied by Alstom, while BOP (Balance of Plant) is procured by the owner directly from both domestic and international markets.

LANPC is fully responsible for project management. All the civil construction work and most of the erection work is being undertaken by Chinese companies.

PROJECT SCHEDULE

Key Activities and Date	Unit 1	Unit 2
• Signature of Main Supply Contracts	October 1995	October 1995
• Project Commencement (ATP)	July 1996	July 1996
• First Concrete Pouring	May 1997	January 1998
• Beginning of Nuclear Island Erection	January 1999	September 1999
• Initial Fuel Loading	December 2001	July 2002
• Initial Criticality	February 2002	August 2002
• Grid Connection	February 2002	September 2002
• Commercial Operation	May 2002	January 2003

SUPPLY & ERECTION CONTRACTS

The Framatome ANP scope of work includes:

- the supply of two Nuclear Islands and the initial core fuel load,
- erection of the Primary System,
- technical assistance to CNI 23rd Company, the main erection contractor,
- and a comprehensive transfer of technology.

Through the Nuclear Island Supply Contract, Framatome ANP has developed a localization program with Chinese industry to progressively achieve Chinese self-reliance in nuclear equipment manufacturing.

Framatome ANP has also implemented a self-reliance program aimed at transferring knowledge and skills covering all Nuclear Island erection activities to the CNI 23rd Company.

PROJECT IMPLEMENTATION

For the Ling Ao project, the reference work schedule envisaged a period of 62 months between first concrete and start of commercial operation for both units. From fuel loading for Unit 1, work was ahead of schedule and commercial operation occurred 48 days early, on May 28, 2002. Unit 2, for which the planned work schedule was eight months behind that of Unit 1, followed in the footsteps of Unit 1, and was also well ahead of schedule: provisional take-over was signed by the customer 3 months earlier than planned.

This outstanding achievement is the result of close cooperation between LANPC and Framatome ANP. Specific measures, which were decided on the basis of the experience gained during the construction of Daya Bay power station, contributed to the smooth implementation of the project. For this purpose, a technical liaison clause allowed a direct link between the main erection contractor, CNI 23rd company, and Framatome ANP as Nuclear Island Supplier. All technical and work schedule issues were addressed through this direct link.

Another key point was the establishment of an overall project schedule by LANPC and Framatome ANP at the very beginning of the project. This time schedule integrated design, supply, erection and commissioning activities and took into account the different interfaces and constraints between the main construction activities: equipment supply, civil works, erection and testing. This allowed the delivery on site of the documents and equipment in an order compatible with construction zone hand-over by the civil works contractor and the erection of subsystems in compliance with the requirements of the startup test schedule.

Framatome ANP developed a comprehensive time schedule supported by powerful scheduling software interfaced to the other project management tools, with more than 15000 tasks and 3000 milestones.

EVER-IMPROVED COMPETITIVENESS

Framatome ANP’s competitiveness has been forged on more than 90 units built around the world.

In France, the pace of commitments made in the 70s for the domestic nuclear program required the design of standardized products. From series to series, the design gradually evolved, integrating the experience feedback gained during construction and operation of all the preceding plants, while retaining enough flexibility to take into account the diversity of sites and changes in safety regulations.

The economic advantages have been mainly achieved by:

- standardization (series effect),
- sustained pace of construction (low manufacturing costs due to bulk orders, reduced construction time),
- improved components and reactor design (experience feedback, new technologies),
- reduced generation costs (fuel cycle, maintenance, availability and radiation exposure).

2 - TECHNICAL DESCRIPTION

TECHNICAL DATA

Power	
NSSS rated thermal output	2905 MWth
Gross electrical output	990 Mwe
Reactor Containment	
Type	Single Containment Prestressed concrete + steel liner
Inside diameter	37 m
Wall thickness	0.90 m
Overall height (from ground level)	59.4 m
Overall internal volume	60000 m^3
Overall internal free volume	50000 m^3
Reactor Core	
Core rated thermal output	2895 MWth
Core damage frequency	5 x 10^{-6} reactor-year
Number of fuel assemblies	157
Total weight of Uranium	72.5 t
Rod cluster control available locations (equipped with CRDMs)	61
Main Primary System	
Number of reactor coolant loops	3
Number of CRDMs	61
Reactor coolant system operating pressure	155 bar
Reactor coolant temperature at RPV inlet	292.4°C
Reactor coolant temperature at RPV outlet	327.6°C
Steam generator tube material	Inconel 690
Steam pressure at SG outlet at nominal power	≥ 67.1 bar
Steam flow rate	1614 kg/s
Steam humidity at SG outlet	< 0.25%
Reactor coolant pump type	Model 100
Reactor coolant pump nominal flow	23790 m^3/h

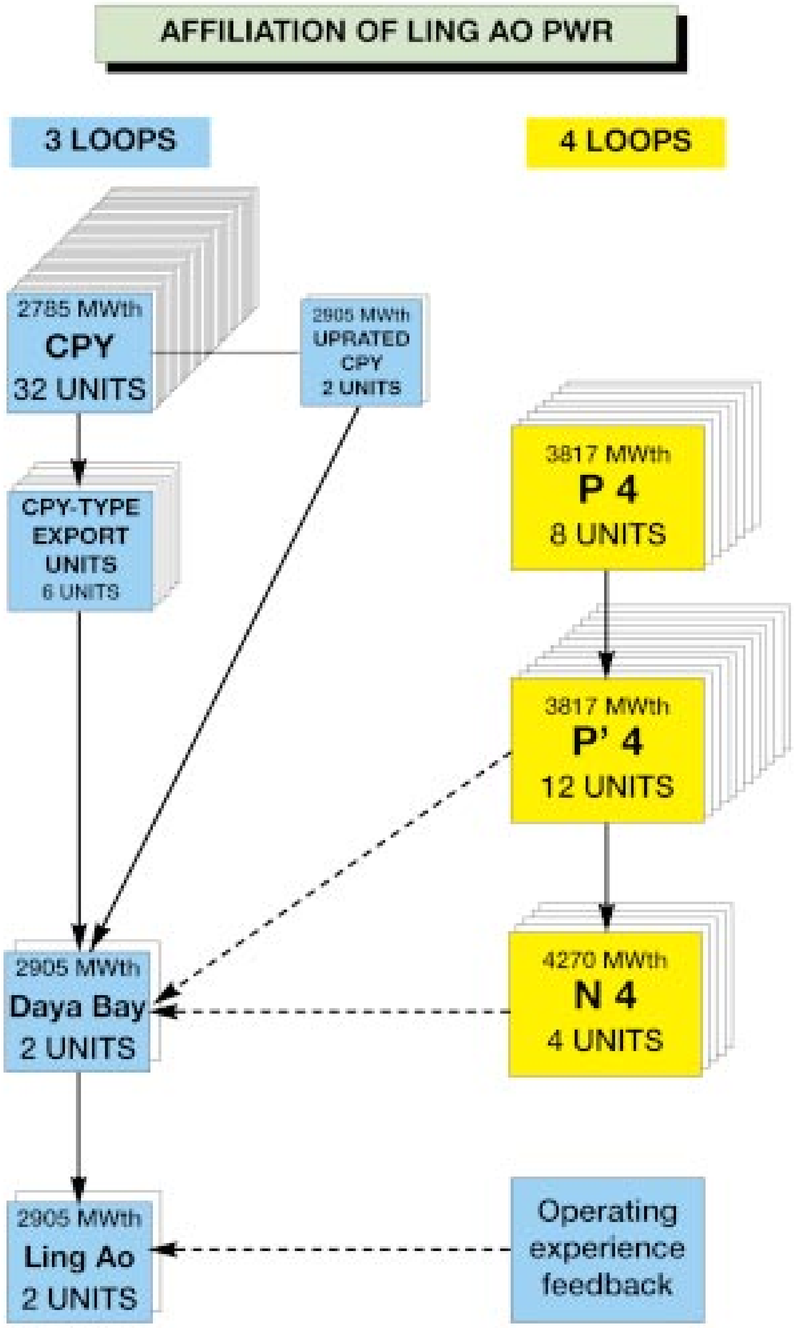
DESIGN BASIS

The design of the Ling-Ao plant is based on Daya Bay Units 1 & 2. It includes improvements resulting from operating experience of French Nuclear Power Plants.

The French Design and Construction Rules (RCC) covering the system design, mechanical components, electrical components, nuclear fuel, fire protection, civil works and Surveillance Rules for Mechanical Components of PWR Nuclear Islands in operation (RSEM) applied between the owner, the designer and the manufacturers enhance the standardization effect and facilitate the technology transfer.

Moreover, the model 55/19 steam generator, the model 100 primary pump, the advanced fuel assemblies and the advanced incore system, provide the reactor with important design margins which guarantee safety and performance targets.

These margins may be used by the plant owner to increase fuel cycle length, optimize power output and improve the fuel management scheme.

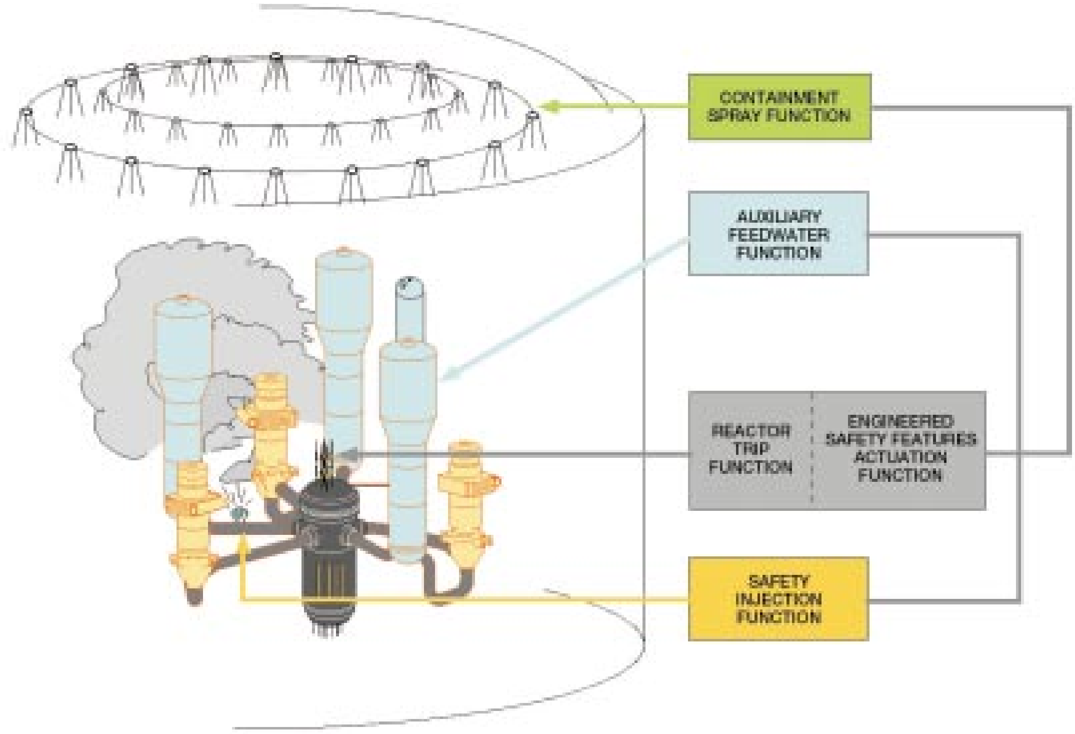


SAFETY

In accordance with the "defense in depth" concept, the design is based on a deterministic list of events, ranging from normal conditions to highly unlikely accidents, including more stringent design criteria backed up by operating experience.
In addition, improvements were introduced at Ling Ao for core damage prevention. For example:

- preventive and mitigating features in order to reduce risks in the shutdown state in the event of loss of the Residual Heat Removal System or spurious increase in reactivity (boron dilution),
- startup Steam Generator Feedwater system separate from Emergency Feedwater system, reducing the risk of total loss of Steam Generator feedwater,
- new reactor trip breaker design (improved Anticipated Transient Without Trip - ATWT) increasing the reliability of the reactor trip system following a transient requiring its actuation.

In 1999, a complete core damage frequency analysis was reperformed on the basis of the new equipment reliability data bank accumulated on French Nuclear Power Plants up to the end of 1997, and taking into account the technical features of the Ling Ao product and Probabilistic Risk Assessment basic rules.
The corresponding calculated core The corresponding calculated core damage frequency was 5 x 10^{-6} per reactor year.



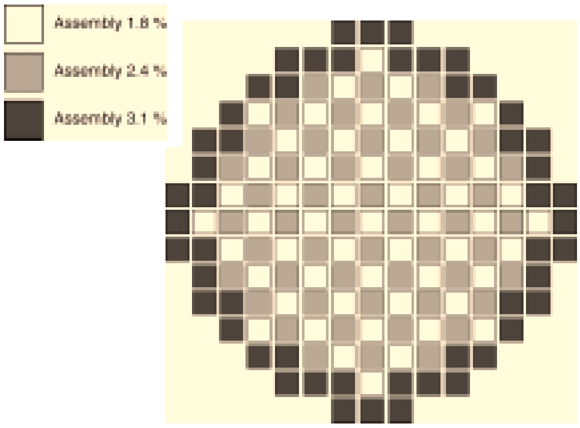
Beyond design basis accidents

The Ling Ao design takes into account the total loss of redundant systems and thus the probability of severe hypothetical accidents resulting in core degradation has been significantly reduced by implementing:

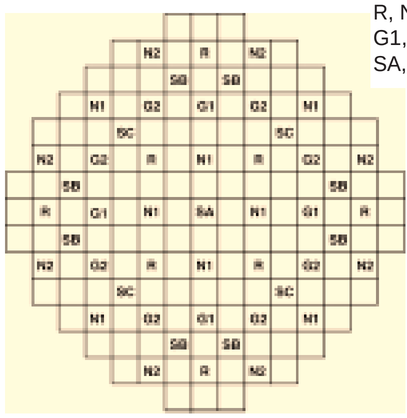
- an improved man-machine interface,
- specific procedures (H procedures), associated with specific items of equipment, such as hydro-test pump turbine generator set, reciprocal backup between safety injection pumps and containment spray pumps,
- futhermore, if all implemented means fail to cope with an accident which results in core melt, specific procedures associated with dedicated hardware, such as sand bed filters, are provided to mitigate such highly improbable severe accidents.

REACTOR CORE

The core is composed of 157 fuel assemblies. Fuel management will evolve with the introduction of AFA 3G fuel assemblies with a view to extending the fuel cycle to 18 months.



First Core Fuel Load Pattern



R, N1, N2 : Black RCCAs
G1, G2 : Gray RCCAs
SA, SB, SC : Shutdown groups

First Core Control Rods Pattern

18-MONTH FUEL CYCLE FOR DAYA BAY

To improve the economics of plant operation and optimize fuel management in reactor cores, GNPJVC made the decision to change from 12-month to 18-month fuel cycles with improved fuel management performances.

Long cycle operation requires higher fuel enrichment and performance levels with improved cladding material and enhanced thermal-hydraulic performances.

The fuel selected for this advanced fuel management strategy was the most advanced and proven design, AFA-3G with mid span mixing grids and M5 alloy as the cladding material.

Today, all objectives set have been reached. Yibin Fuel Plant (YFP) in China manufactured the AFA 3G assemblies for the 9th reload on time and cooperation with NPIC and GNPJVC in engineering self-reliance has been successfully implemented.

AFA 3G fuel assembly

Ling Ao 1 - Fuel loading authorization ceremony

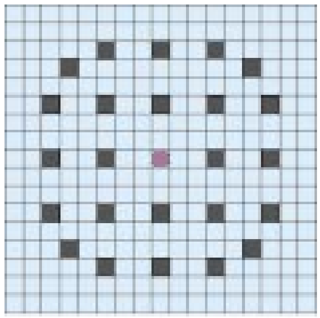
Mode "G" for excellent operating flexibility

The Ling Ao units incorporate the "mode G" reactor control capability for increased and optimized manoeuvrability. The principle of this reactor control mode is to compensate for the effects of power variations using control rod movements only, whereas boration/dilution is only used to compensate for longer term changes in reactivity due to xenon poisoning or fuel burnup changes. Dedicated "gray" control rod banks with reduced absorption capacity are used to limit power distribution disturbances and an independent high absorbing rod bank provides the fine adjustment of core reactivity and axial power shape.

With the high degree of flexibility provided by mode G, utilities can better respond to grid power demand and can optimize the revenue generated when plants are operated in a deregulated electricity market.

Operating Flexibility

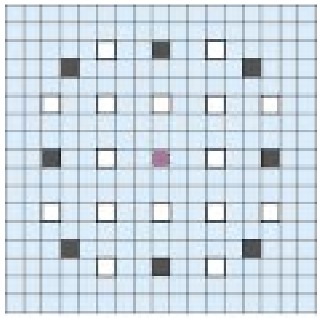
Fuel Assembly with Black Rods



24 (B4C + Ag - In - Cd) rods

Instrumentation thimble

Fuel Assembly with Gray Rods



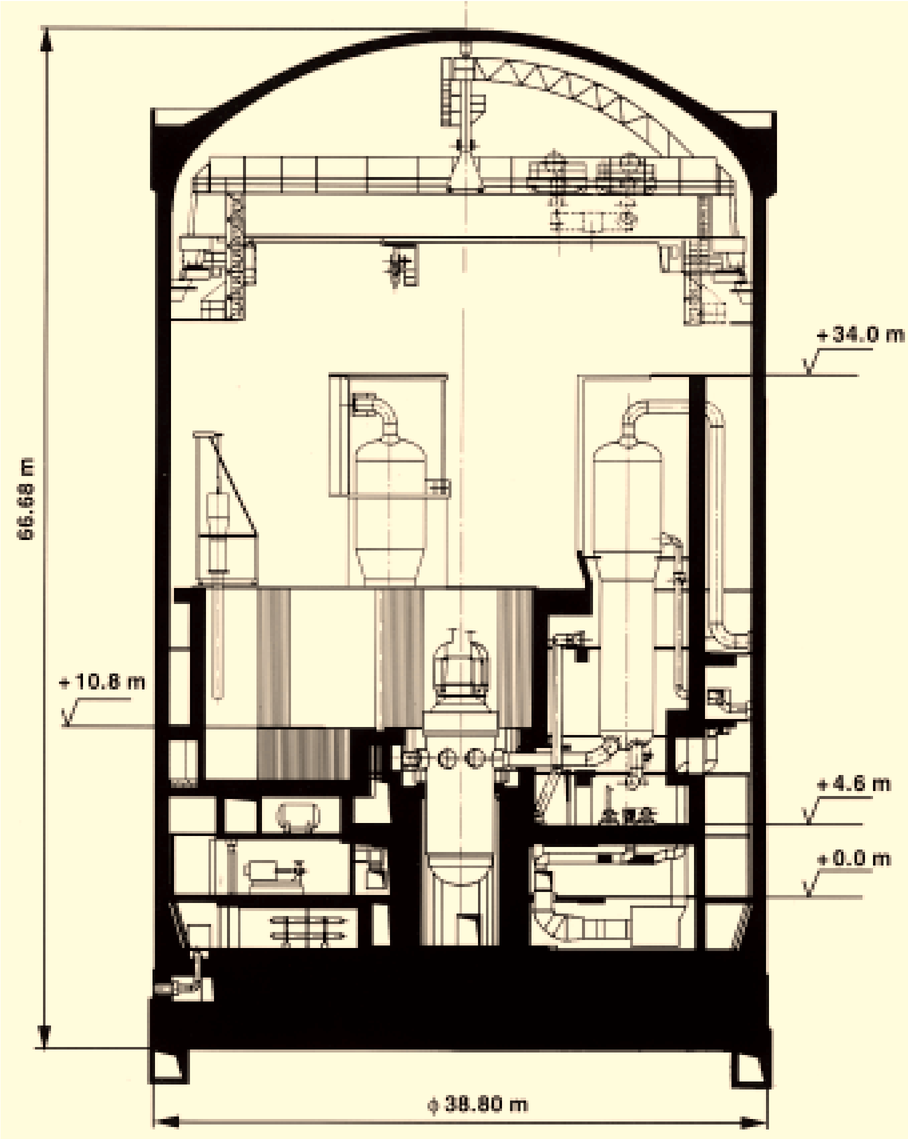
8 (Ag - In - Cd) rods

16 steel rods

Instrumentation thimble

Fuel assembly and shipment container

OVERALL ARCHITECTURE OF LING AO



Reactor building

The general layout of the Ling Ao plant is based on a twin-unit concept and takes into account the applicable requirements concerning radiological protection and circulation of operating personnel, fire protection, access for maintenance and other safety rules.

The cylindrical **reactor building,** has a single containment made of prestressed concrete with an inner metal liner. A cylindrical structure inside the reactor building supports the main reactor coolant system, protects and separates redundant trains, and forms protective bunkers for equipment such as steam generators, reactor coolant pumps, reactor pressure vessel and feedwater lines.

The design also includes recirculation sumps with a large filtration capacity.

The reactor building has an equipment hatch located at operating floor level, used for bringing heavy components into the building during construction, using the polar crane.

The **electrical building** houses, on the upper floor, the Instrumentation and Control Systems and the main control room.

From a safety standpoint, the design of the entire nuclear island ensures physical separation between units and between redundant trains of each unit, protection against internal flooding, division into fire protection areas, and protection against external explosion, airplane crash, earthquakes and tornados.

The adjacent **fuel building** houses the fuel handling and storage system equipment. The safeguard auxiliaries are housed on the lower floor.

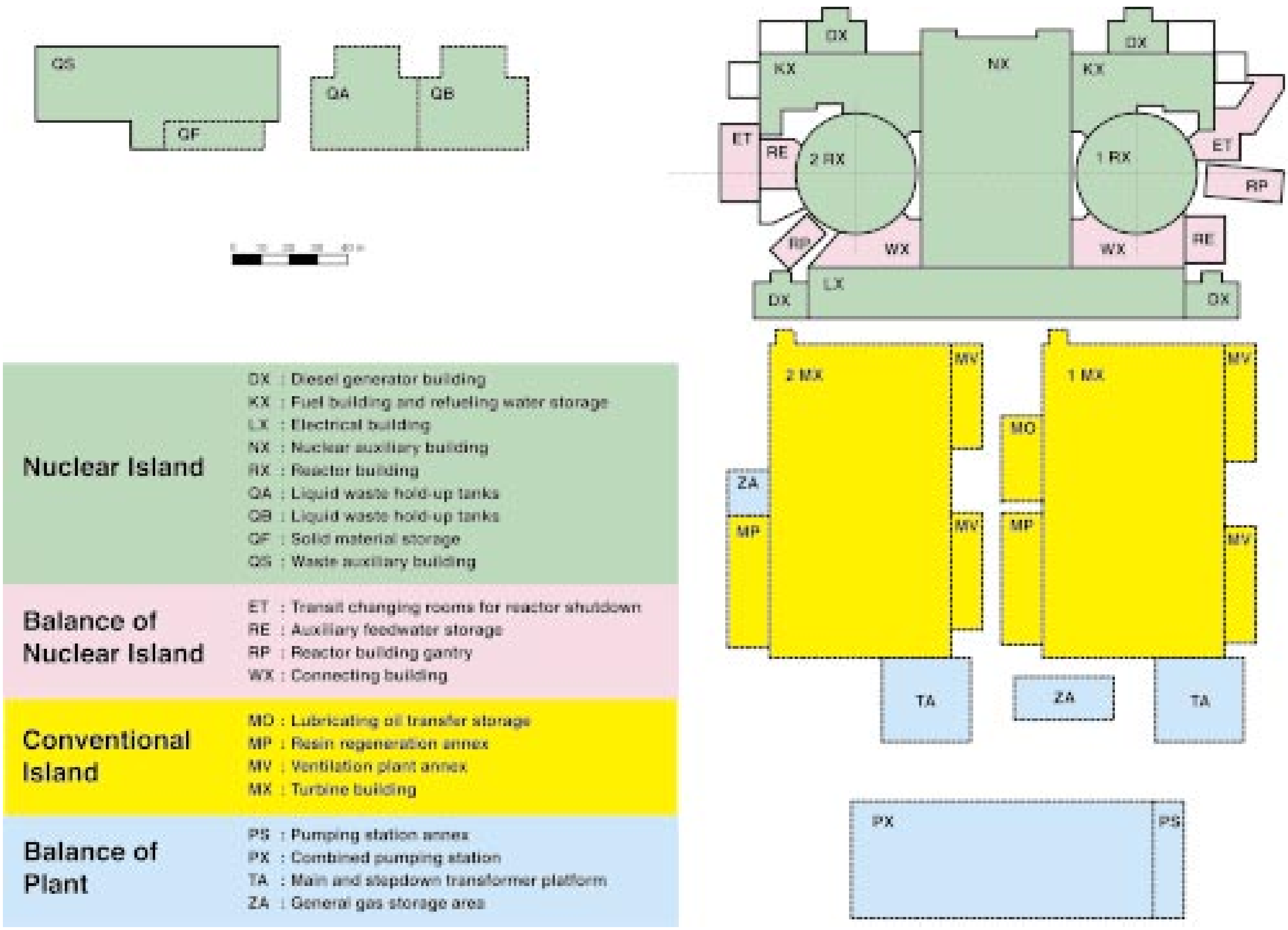
The **nuclear auxiliary building** houses the reactor auxiliary systems equipment. It also contains radioactive waste storage and treatment facilities as well as the required ventilation and handling equipment.

The **nuclear pumping station** is connected to the nuclear island by an underground seismic-resistant gallery.

The balance of plant includes all other buildings and facilities necessary for operation.

TWIN-UNIT CONCEPT

The twin-unit concept applied by Framatome ANP for its 1000 MWe units consists in having two units share a single nuclear auxiliary building. As well as reducing the quantity of civil works, some equipment and systems such as waste processing and boron acid production are common to the two units. This particular design reduces construction and maintenance costs and contributes to the competitiveness of Framatome ANP's 2 x 1000 MWe units.



Plot plan

Reduction in radiation exposure

Improved maintainability with reduced radiation exposure is an important feature of Ling Ao design with improvements such as:

- plant layout,
- extended design life of critical parts by improved equipment design,
- reduction in the number and duration of maintenance and inspection tasks, by reducing the number of welds.

The layout improvements involve extensive separation between radioactive and non-contaminated systems, easy access to steam generator channel heads and reactor coolant pumps, and optimization of facilities and areas used during unit shutdown.

The improvements made to equipment to reduce radiation doses include geometrical modifications to facilitate decontamination and the use of materials that release very few corrosion products. All Nuclear Steam Supply System components are passivated on the primary side surface.

REACTOR COOLANT SYSTEM

The reactor coolant system consists of the reactor pressure vessel, reactor internals, vessel head equipped with CRDMs and three loops. Each loop comprises a steam generator, a reactor coolant pump and reactor coolant pipes. The pressurizer is connected to one of the loops.

Reactor Vessel

Consistent with the core size, the inner diameter of the reactor vessel is 4m.

The reactor vessel is built with a number of welded forged parts clad internally with two layers of stainless steel.

The reactor vessel houses the reactor internals and reactor core.

The Ling Ao reactor vessel incorporates the following improvements:

- use of forged hollow ingots to improve the metallurgical properties of the material in the vicinity of the reactor vessel cladding,
- base material with lower impurity content, resulting in significant reduction in reference nil ductility transition temperature (RNDTT) at the end of life, thus increasing the margin with respect to brittle fracture,
- upper head adapters and bottom head penetrations made of Inconel 690 alloy for better resistance to stress corrosion.

Reactor Internals

The reactor internals guide the reactor coolant flow from the inlet nozzles of the reactor vessel downwards, then up through the reactor core. The reactor core is housed in the lower reactor internals.

The upper internals incorporate the "inverted hat design" for the guide tube support plate. The control rod cluster guide tubes incorporate improved latest generation guide tube pins.

Ling Ao 1 Reactor vessel transportation

Lower internals

Control Rod Drive Mechanisms (CRDMs)

A control rod drive mechanism consists of an electromechanical jack in which three magnetic coils, acting on latch arms, initiate step-by-step movement of the drive rod and cluster. The mechanism is seal-welded to an adapter, which is incorporated into the reactor vessel upper head. The coils are enclosed in a housing and are easily removable.
Jeumont Industrie is the Framatome ANP fully owned subsidiary for CRDM and reactor coolant pump manufacture. Cumulated production exceeds 4500 CRDMs and 220 reactor coolant pumps.

Reactor Coolant Pumps

The model 100 pump for Ling Ao incorporates improvements such as: radial discharge, single piece casing and removable diffuser.
The hydraulic design for the impeller diffuser ensures improved efficiency.
The thermal barrier enclosure is bolted rather than welded, and is removable.
The pump diffuser is also removable.
The cartridge design of the shaft seal system has also been improved to provide easier access during inspection and maintenance and to reduce replacement time.

Over Pressure Protection Upgraded System (OPUS)

The Ling Ao pressurizer, provided with three separate relief lines, is equipped with the overpressure protection upgraded system (OPUS), developed by Framatome ANP to address the TMI issue.
When inventory makeup of the reactor coolant system becomes necessary, the valve lines can be forced open by the operator using electromagnetic actuators to perform feed and bleed.
OPUS consists of three tandems of pilot-operated safety valves with the first valve serving as a safety or relief valve and the second in series as an isolation valve which closes in the highly unlikely case of the safety valve failing to close after opening.
OPUS provides comprehensive pressure relief and overpressure protection for all types of PWRs.
The main advantages of OPUS include:

- compliance with the single failure criterion due to the tandem concept,
- remote manual opening and closing in post-accident conditions,
- qualified feed and bleed operation and improved set-point accuracy,
- reliability of valve closing and leaktightness,
- capability for periodic testing of set-points and operability without valve dismantling.

More than 60 units currently operate with OPUS.

OPUS valve

Lower internals

Pressurizer manufactured in China

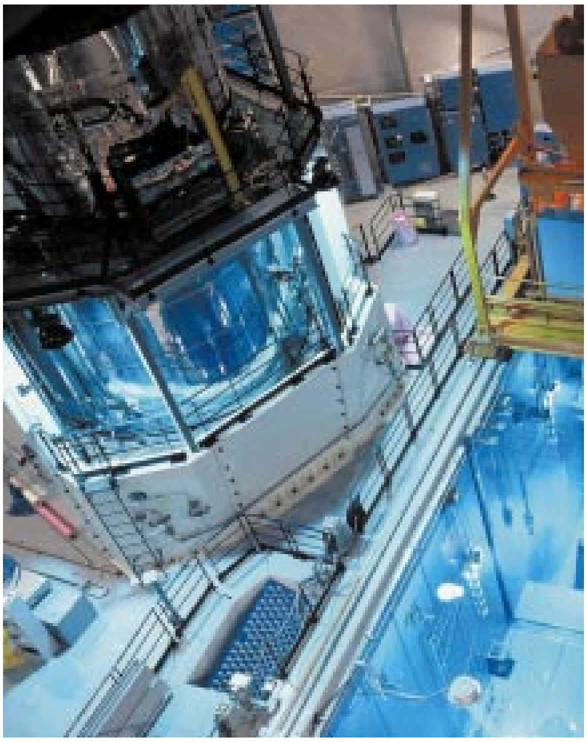
Steam Generators

The Ling Ao Steam Generators are of the 55/19 type: 5500 m^2 of heat transfer area and 19.05 mm outside diameter tubes. Their design incorporates advanced features to provide the owner with optimum performance and enhanced reliability and availability:

- reduced number of pressure vessel welds using:
  - a one-piece hot spin upper dome including an integral steam outlet nozzle,
  - a one-piece forged conical shell with cylindrical ends,
  - a one-piece forged primary head with integral nozzles and manways,
- enlarged heat transfer area ensuring a steam pressure of at least 67.1 bar at the SG outlet,
- ultra-efficient moisture separation equipment permitting a 0.10% moisture carry-over content to be obtained,
- optimized flow velocities above the top of the tubesheet minimizing low flow velocities and boiling areas and thus precluding excessive sludge deposits,
- improved tube material, tube supports and tube-to-tubesheet junction precluding tube damage encountered in the past:
  - thermally-treated alloy 690 tubing to avoid water stress corrosion cracking and provide the best margin against the various forms of potential secondary side corrosion,
  - 13% chromium stainless steel tube support plates with quatrefoil flat lands broached corrosion-resistant holes minimizing denting, dry-out and excessive wear,
  - optimized anti-vibration bars (AVB) installed layer after layer allowing the tube-to-AVB clearances to be reduced and excessive wear to be precluded,
  - two-shot, high-pressure hydraulic expansion reducing the residual stresses in the hydraulic expansion transition zone.

Steam generator & pressurizer

Steam generator installation



Installation in reactor building

Reactor vessel handling

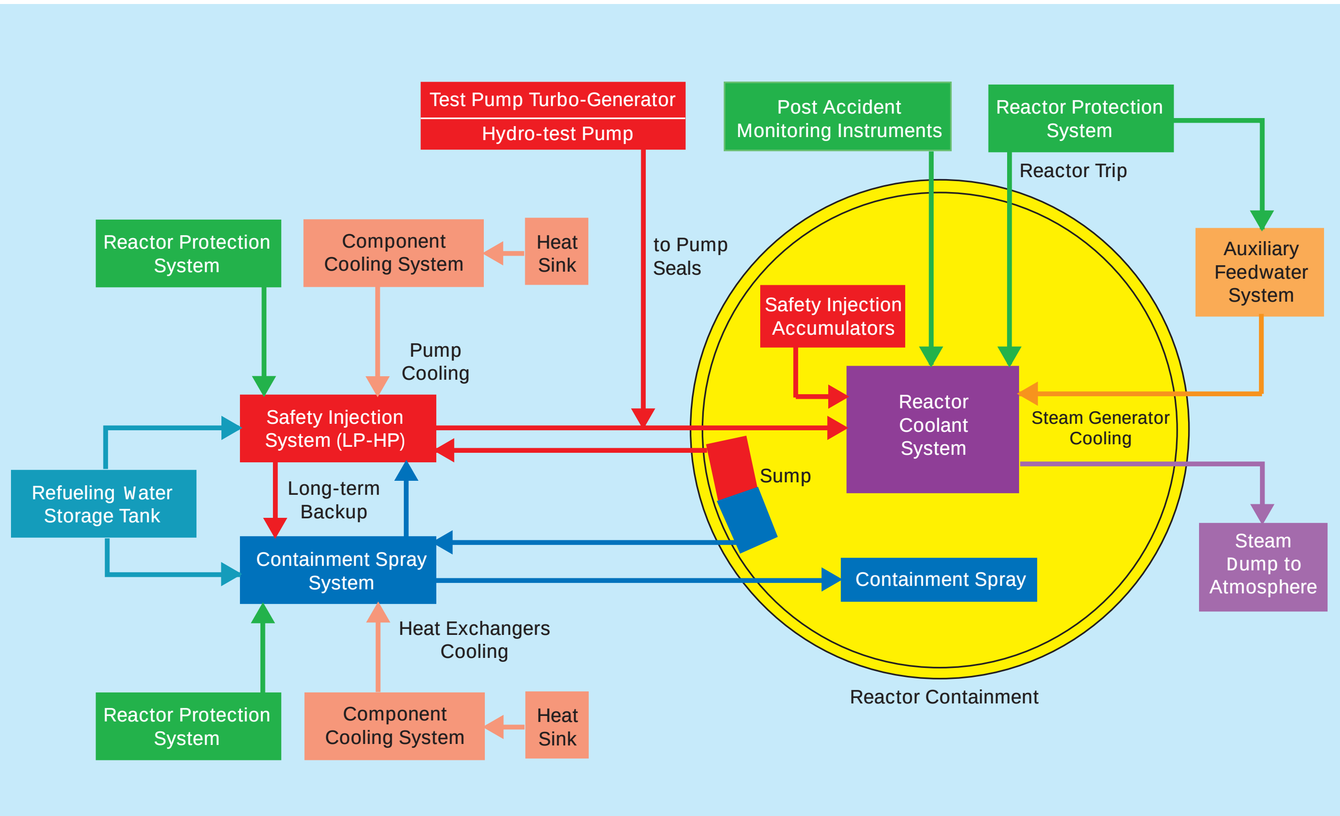
REDUNDANT SAFETY SYSTEMS

The general organization and design of the safety systems adhere to the "two-train" concept: each system includes two totally separate 100% redundant sub-systems or "trains", plus diversified backups to handle beyond-design-basis accidents.

Safety Injection, Containment Spray and Auxiliary Feedwater Systems

The main function of the safety injection system is to cool the core in the event of a leak in the reactor coolant system.
The system consists of two identical trains, each with one high-head pump and one low-head pump, capable of injecting cold borated water into all three loops, together with three accumulators on the cold legs.
The charging pumps of the chemical and volume control system are safety classified and perform the high-head safety injection function. The containment spray system which, in the event of an accident, removes heat from the containment to the heat sink, consists of two identical trains, each with one pump, one heat exchanger and two spray rings.
The hydrotest pump, which is shared between two units, is also used to ensure continuous water injection to the reactor coolant pump seals in the event of total loss of electrical power. The electrical supply to this pump is provided by a turbine-generator set (one for each unit) fed from the steam generators.
The containment spray and low-head safety injection pumps are cross-connected to allow long-term mutual backup in the event of total loss of either system.
The auxiliary feedwater system removes heat from the reactor coolant through the steam generators via the steam dump to atmosphere, in the event of unavailability or failure of the main and startup feedwater system.

Reactor safety systems



NUCLEAR AUXILIARY SYSTEMS

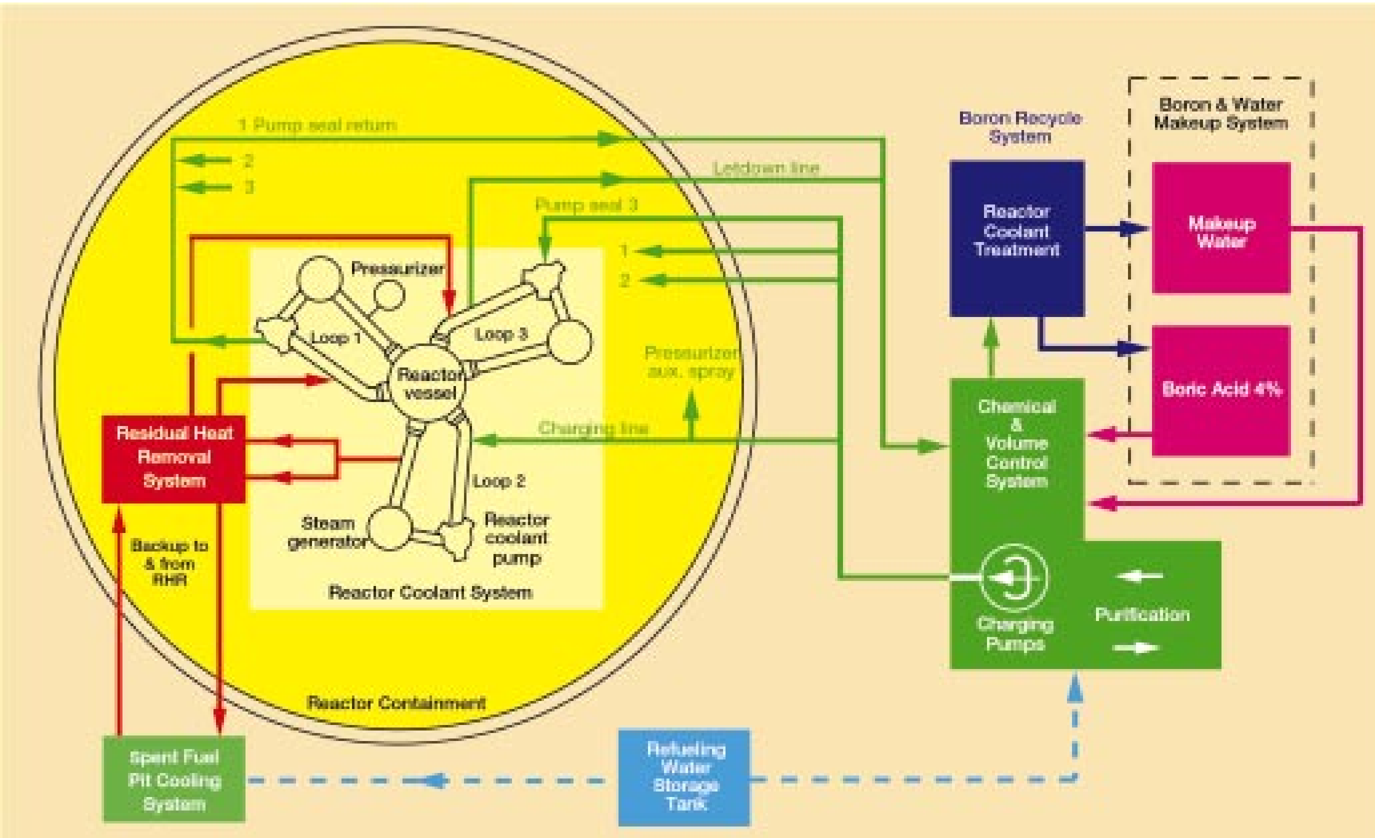
Chemical and Volume Control System

The chemical and volume control system ensures reactor coolant volume, chemistry and reactivity control during normal operation.
Three safety-classified, physically separated, redundant charging pumps (one for train A and two for train B) are provided for charging and water injection to the reactor coolant pump shaft seals. They also ensure high-head safety injection during incidents or accidents.
The three-pump configuration allows maintenance to be carried out on one charging pump while the unit is in operation.
The charging pump and boric acid pump power supplies are backed up by the diesel generator sets.

Residual Heat Removal System

The residual heat removal system removes residual heat from the core during normal shutdown or in certain accident conditions, once a sufficiently low pressure is reached. It consists of two 100% capacity pumps and two 100% capacity heat exchangers.
The system is installed in the reactor containment so that leakage is confined in the event of pipe break.
The spent fuel pit cooling system provides an additional backup.
Moreover, total loss of the residual heat removal function is considered in the safety evaluation. If this happens, heat is removed either by the steam generators or by using the reactor cavity and spent fuel pit cooling and treatment system.

Reactor auxiliary systems

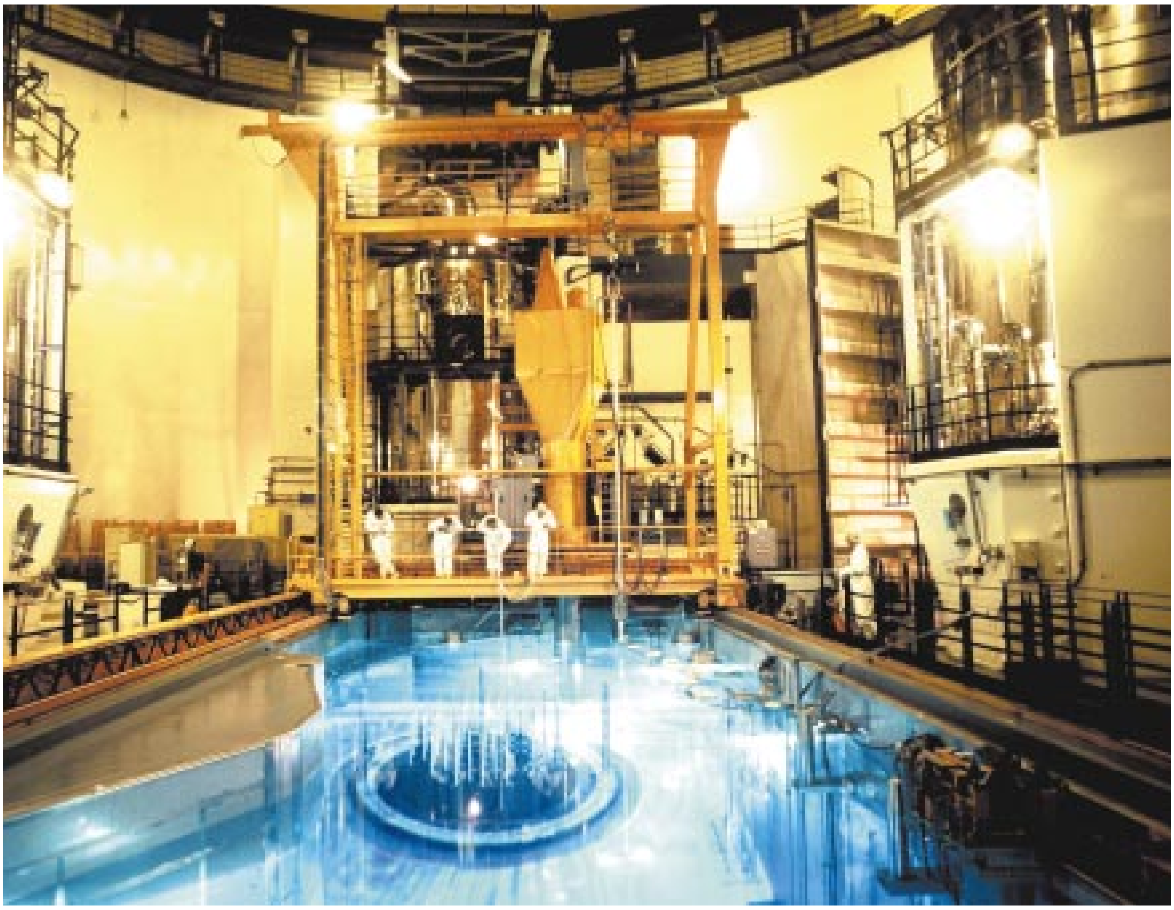


Fuel Handling and Storage System

The fuel unloading/reloading operations constitute the critical path of the plant outage. Particular attention is paid to the fuel handling system since its performance contributes directly to reducing outage time. The fuel handling system includes, notably, the fuel manipulator crane, the fuel transfer device and the spent fuel bridge.

The Ling Ao units are equipped with high density storage racks capable of storing more than 1200 fuel elements in two regions: region 1 for new fuel and region 2 for spent fuel. The arrangement of the racks and the low pitch between the storage cells is optimized. A powerful neutron absorber is used for rack fabrication. The storage capacity permits storage of spent fuel elements for 20 years of plant operation, plus one normal reload of new fuel and one complete core should forced unloading be necessary.

The fuel storage rack design is also compatible with 18-month cycle fuel management and fuel enrichment up to 4.5%.



Fuel loading - Fuel manipulator crane

Waste Treatment Systems

Waste treatment systems, shared by two units, have been designed to provide the most appropriate response to environmental releases according to laws, rules and regulations. Improvements made to French Nuclear Power Plant waste treatment systems have been introduced at Ling Ao. They are supplemented by improvements resulting from operating feedback from the Daya Bay units. The waste handled by the liquid waste treatment system has been reduced by 3000 m^3 per year and the amount of liquid releases by about 100 m^3/year/unit due to rerouting of the aerated water from the primary system.

Reactor Cavity and Spent Fuel Pit Cooling and Treatment System

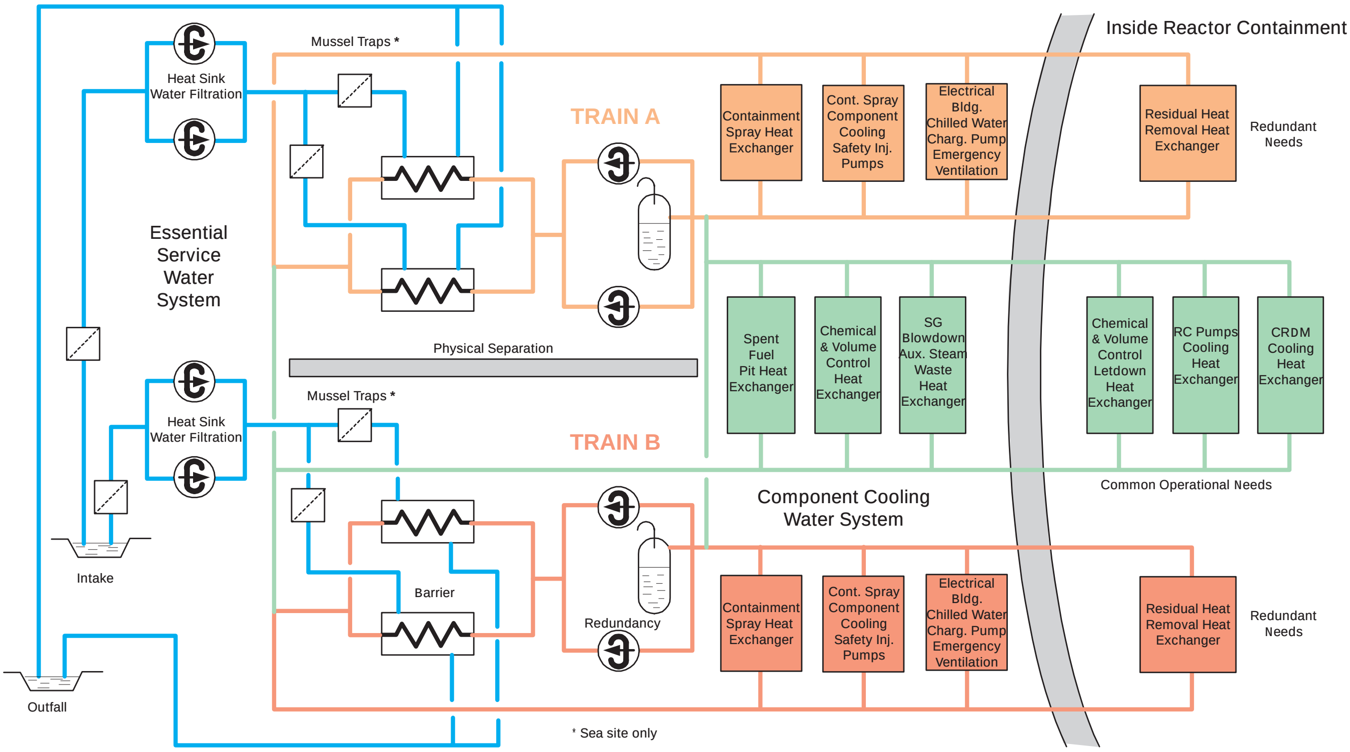
This system removes residual heat from the spent fuel storage pit. It comprises two redundant pumps and two redundant heat exchangers.
The necessary redundancy for maintenance/repair is ensured by the thermal inertia of the spent fuel pit water.
This system can also provide functional redundancy of the residual heat removal system.

Component Cooling and Essential Service Water Systems

The component cooling system removes heat from auxiliary and safety systems. It consists of two redundant safety trains comprising two redundant pumps and two heat exchangers. Maintenance can therefore be performed on the active components at any time.
The ultimate heat sink is ensured by the essential service water system which includes two redundant safety trains comprising two redundant pumps.

Component cooling heat exchanger

Cooling water systems



Construction of dome

INSTRUMENTATION AND CONTROL SYSTEMS (I&C)

The Ling Ao instrumentation and control system replicates the well-proven and reliable I&C organization of the reference plant. This means that the plant is mainly operated through conventional control means and automated systems. Significant improvements have been introduced such as state-of-the-art computer systems which contribute to optimised and ever safer operation of the plant.

Control Systems

In addition to the "mode G" reactor control, the key features of the Ling Ao control functions include:

- automatic turbine load shedding from full to house load operation without reactor trip to reduce downtime after a grid fault,
- automatic steam generator level control from 0 to 100% full power,
- the feedwater system is not tripped after reactor trip, preventing steam generator transients,
- automatic operation for power variation, including at low load, by simultaneous operation of the turbine bypass and the control rods.

Process Computer System

The system is designed to provide the operators with assistance during normal plant operation but also with guidance during post-accident phases. The process data are collected by programmable controllers distributed in different buildings, processed and then presented to the operator through user-friendly graphic workstations integrated into the control room desks. Numerous functions are available to the operators, including:

- synthetic overview of plant status,
- automated system surveillance,
- alarm reduction,
- historical data management,
- post-accident operating procedure guidance.

High performances have been achieved by using up-to-date processing techniques based on internationally recognised standards such as the Unix operating system with a window-based graphic interface and a fast Ethernet communication bus. Redundant architecture has been adopted at all levels of the system to ensure uninterrupted operation of the process computer system. The server and data acquisition controllers are organized in a dual hot-standby configuration and communication networks comprising of redundant ring buses that are automatically reconfigured in the event of loss of communication.

Computer system during commissioning test

Protection System

The protection system is designed to automatically trip the reactor and actuate the engineered safety features when plant parameters exceed the pre-determined operating limits. The system comprises 4 independent groups of instrumentation, signal processing units which issue partial trip signals when parameters exceed threshold values.

Two independent coincidence trip logics combine the partial trip signals, generally in a 2-out-of-4 logic to issue the reactor trip or safeguard system actuation signals. This logic is implemented in a maintenance-free solid-state technology, recognized for its very high reliability.

Nuclear Instrumentation System

This system measures the reactor flux level using ex-core neutron detectors. These measurements are used both by control and protection systems and over the source, intermediate and power operating ranges. The nuclear instrumentation system is 1E qualified and intermediate range channels fulfil post-accident adverse condition requirements.

Power range detectors are multi-staged with thermal neutron collimating features. The output signals are then used by a digital processing unit to compute on-line LOCA margins, from the axial distribution and actual rod position. A terminal located in the control room is used by the operators for optimized plant operation within the safety limits.

Rod Control System

The rod control system actuates the CRDM to position the control rods inside the reactor core. Static electronic switching units that are cycled and sequenced by digital controllers regulate the CRDM power supply currents. These controllers have built-in surveillance features to detect any internal malfunction of the rod control system and then to take the counter-measures to prevent inadvertent rod drop.

The rod control system also includes the rod position indication system which is used to monitor the actual rod position.

Nov. 7, 2001 - France's Finance Minister, Chinese Authorities and the AREVA Chairman in the Ling Ao 1 Control Room

Control Room

The unit is normally operated from the main control room that is protected against earthquakes, missiles, radiation, contamination, fire and sabotage. In the unlikely event of complete unavailability of the main control room, a remote shutdown panel allows the operators to bring the plant back to safe shutdown conditions.

The Ling Ao control rooms benefit from ergonomic studies and improvements resulting from operating experience of similar units. The human factor has been considered in the design of the control desk and computer screen display: clear color coding rules, consistent functional grouping of control means and indicators and operator guidance through computer displays.

Comprehensive post-accident monitoring instrumentation is available to the operator including:

- reactor vessel level indication system,
- core cooling monitor using core exit thermocouple,
- radiation monitoring system.

The process computer also provides the operator with powerful guidance in the implementation of the post accident procedures. These functions which are referred to as the safety panel, include:

- assistance in selecting the applicable procedures,
- identification of the initiating event,
- continuous surveillance of the plant safety parameters,
- automatic surveillance of safeguard system status, availability and configuration,
- automatic surveillance of electrical power supply sources,
- monitoring of the performance of safety injection.

The technical support centre located in the vicinity of the main control room is designed to host a team of experts in the event of an emergency to assist the operating team. Any plant information can be accessed from computer terminals located in the technical support centre to help the experts in their diagnosis without disturbing the operation.

TIANWAN

Framatome ANP is the supplier of the instrumentation and control systems of Tianwan nuclear power station.

Tianwan Nuclear Power Station, located in China (400 km north of Shanghai), includes two Russian designed VVER-1000 Model “NPP 91” units. Unit 1 is scheduled to go on line in December 2004, with Unit 2 following one year later.

The plant owner, Jiangsu Nuclear Power Corporation (JNPC) decided to equip Tianwan exclusively with an advanced digital instrumentation and control system and in 1998 selected Framatome ANP and Siemens with the global TELEPERM I&C platform. TELEPERM represents the most modern technology of its kind presently available on the market and already has numerous applications.

All I&C systems requiring nuclear qualification, such as the reactor protection system, are implemented using the digital I&C platform TELEPERM XS. This platform benefits from a generic qualification making it possible to reduce the licensing time and efforts. It has also received approval from the US Nuclear Regulatory Commission (NRC).

Operational I&C is implemented using the TELEPERM XP process control platform. This system also provides operation and monitoring functions and makes it possible to operate the plant directly from a computer workstation.

3 - SINO-FRENCH CO-OPERATION

In 1986, Framatome ANP signed a contract with GNPJVC for the design and supply of nuclear islands for the two 1000 MWe PWR Daya Bay nuclear power units. In addition to the supply contract, Framatome ANP actively participated in construction in collaboration with CNI 23rd Company, and provided the customer with major technical assistance for the commissioning of the plant.

The official inauguration of Daya Bay Nuclear Power Plant took place in February 1994. Since then, this plant has consistently recorded impressive annual operating results year after year and has already received several awards.

The Daya Bay power plant is owned by Guangdong Nuclear Power Joint Venture Co. Ltd. (GNPJVC), which was established by China Guangdong Nuclear Power Holding Co. Ltd. (CGNPC) and Hong Kong China Light and Power Co. Ltd.

Construction of Daya Bay Nuclear Power Plant constituted a major success in the development of nuclear energy in China. For the second step, Ling Ao, the Chinese authorities and CGNPC wished to combine the execution of the project with extensive efforts focused on technology transfer and acquisition of technical autonomy to facilitate China's future nuclear power program.
To meet these expectations, Framatome ANP undertook an ambitious localization and self-reliance program within the framework of the nuclear island supply contract.

The localization program was implemented in various ways through joint ventures, technology transfer agreements and technical assistance, and it focused particularly on the highly technical nuclear equipment. The localization ratio targeted in the contract was achieved, with all locally manufactured equipment delivered on schedule and with quality levels identical to the highest nuclear standards.

The Ling Ao supply contract already included a self-reliance program to the benefit of LANPC teams, mainly in the field of project management, engineering work and startup activities. This was then extended in September 1997 to technical assistance, combined with an ambitious self-reliance program for CNI 23rd Company. The aim of this program, which focused on the development of self-reliance capabilities, was to transfer to CNI 23rd Company, Framatome ANP's knowledge and know-how in the area of nuclear island erection including primary system construction, so as to facilitate the implementation of China's future nuclear power program. The assessments performed for this self-reliance program, together with the results obtained during the Ling Ao project implementation phase, demonstrate the full success of this program.

Over the past 10 years, cooperation between the Chinese and French nuclear industries has been developing within the framework of several technology transfer agreements. These agreements cover a wide range of technologies relating to the design, construction, operation and maintenance of nuclear power plants. Implementation of these technology transfers has produced positive results:

- design and construction of Qinshan phase 2,
- fuel manufacturing factory in Yibin,
- implementation of 18-month fuel management at Daya Bay,
- joint venture for maintenance services, etc.

The outstanding achievement of the localization, self-reliance and technology transfer programs proves the ability of Framatome ANP to support the long-term policy of the customer and the Chinese Authorities and contributes to the sustained development of the Chinese Nuclear Industry.

LOCALIZATION OF EQUIPMENT MANUFACTURING IN CHINA

The Ling Ao project represents a major step in the development of the Chinese nuclear industry manufacturing capability. To help meet this objective, the localization program implemented by Framatome ANP has been focusing on major nuclear components with a very high technical content, mainly for the second unit in order to make the necessary investments and carry out the required qualification programs.

As early as 1995, Framatome ANP began selecting Chinese suppliers on the basis of their industrial capability, their potential for meeting the highest applicable standards and their willingness to establish long-term cooperation. This process was conducted by Framatome ANP engineering and procurement groups and its own manufacturing organization was highly involved. The localization program was then implemented in different ways through technology transfer, joint ventures and technical assistance, including direct assistance from French factories to Chinese factories.

The extensive industrial know-how and experience of Framatome ANP as a plant and component designer, but also as a component manufacturer with its own factories, has played a determining role in the successful completion of the localization program. The Framatome ANP team has been working closely with Chinese workers and technicians to transfer the necessary know-how, train them and assist them in the implementation and operation of the quality organization.

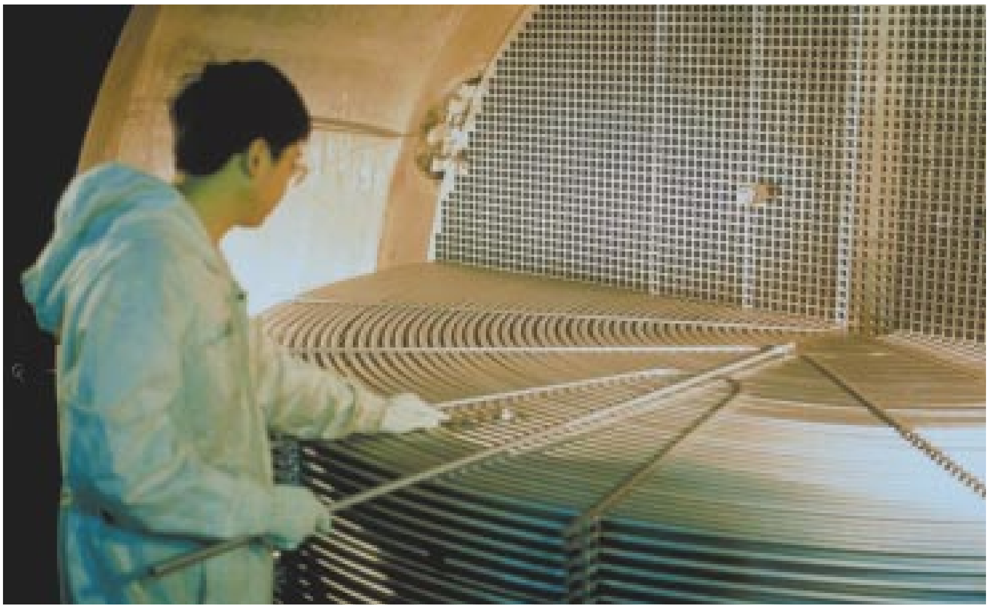
All the components manufactured in China were delivered to the site in compliance with the erection time schedule and without compromising the quality of the manufactured components, by strictly applying the highest nuclear standards.

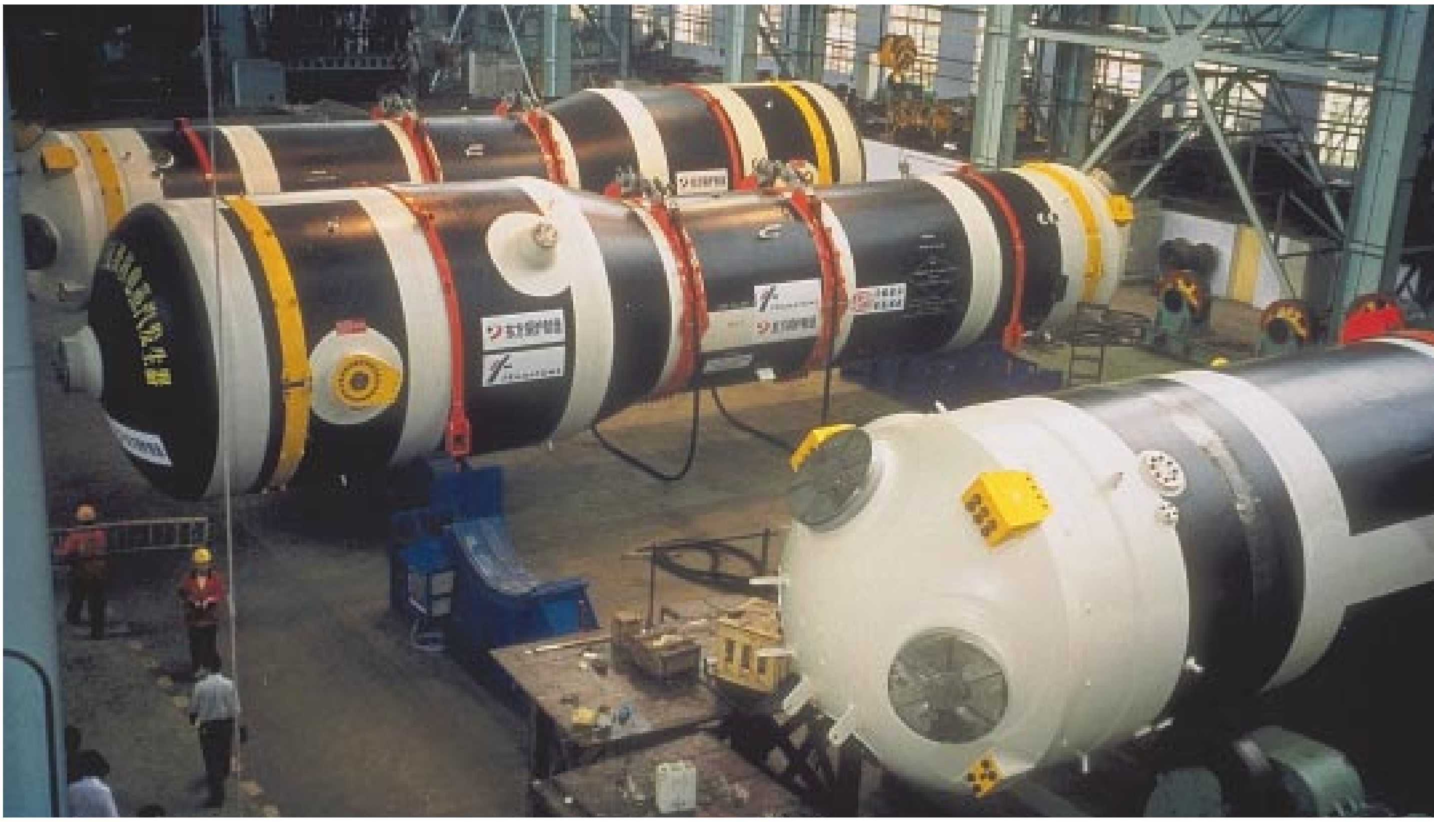
Steam Generators and Pressurizer

Dongfang Boiler Group Co. Ltd. (DBC) is a subsidiary of Dongfang Electric Corporation (DEC) located in Zigong and Deyang in Sichuan province. DBC has manufactured key components for the second unit of Ling Ao including:

- one complete steam generator,
- two SG upper parts and assembly of upper part and lower part,
- one complete pressurizer,
- three accumulators, and
- one complete boron injection tank.

Steam generator tubing and installation of anti-vibration bars in China





Fabrication of steam generators in China

Reactor Internals

Shanghai No.1 Machine Tool Works has manufactured a large part of the reactor vessel internals for the second unit of Ling Ao including the lower support columns, lower instrumentation columns, tie plates and base plates, formers and baffles. It also assembled the lower reactor internals and the assembly of the upper and lower reactor internals.

Shanghai No.1 Machine Tool Works has also manufactured all the control rod guide tube upper parts for Ling Ao Unit 2 and carried out final assembly of the lower parts.

Lower internals core support plate

Fabrication of reactor internals in China

Localization of Equipment

China Xi'an 524 Factory
Manufacturing of Fuel Transfer Device, Fuel Handling Tools, Sipping Test Container (LA2)
New Fuel Storage Cells and Tools (LA1 & 2)

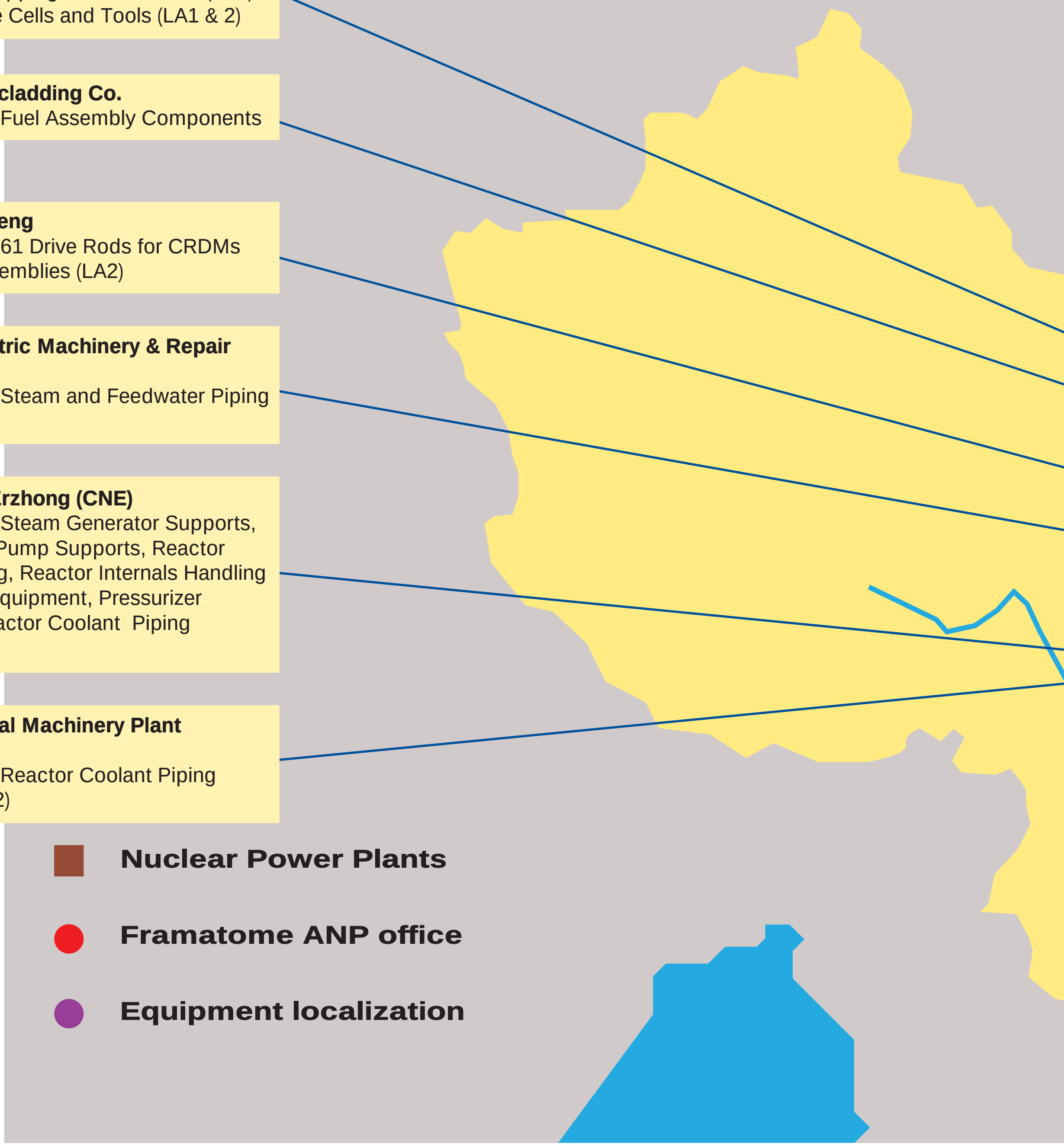
Northwest Zircocladding Co.
Manufacturing of Fuel Assembly Components

Shanghai Xian Feng
Manufacturing of 61 Drive Rods for CRDMs and 61 Latch Assemblies (LA2)

Changzhou Electric Machinery & Repair (CEMR)
Manufacturing of Steam and Feedwater Piping (LA1 & 2)

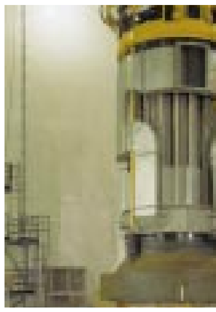
China National Erzhong (CNE)
Manufacturing of Steam Generator Supports, Reactor Coolant Pump Supports, Reactor Vessel Lifting Ring, Reactor Internals Handling and Supporting Equipment, Pressurizer Supports and Reactor Coolant Piping Supports (LA2)

Sichuan Chemical Machinery Plant (SCMP)
Manufacturing of Reactor Coolant Piping Components (LA2)




Cable trays


Steam piping


CRDMs

Manufacturing in China

Shanghai Cable Works
Manufacturing of Power and Control Cables (LA1 & 2)

Shanghai Power Equipment Co Ltd
Manufacturing of Tanks, Demineralizers and Heat Exchangers (LA1 & 2)

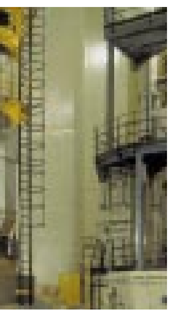
Shanghai Gaotai Rare & Precious Metals (SGTC)
Manufacturing of Fuel Assembly Components

NingBo Zhenzhua Electrical Equipment Factory
Manufacturing of Cable Trays (LA1 & 2)

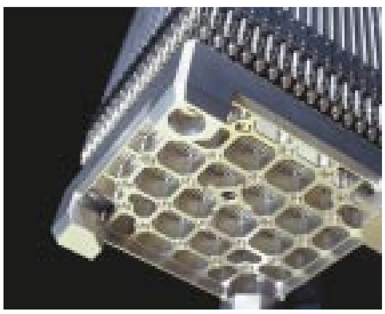
Zhenjiang Electrical Equipment Factory
Manufacturing of Cable Trays (LA1 & 2)

Yibin Nuclear Fuel Element Plant
Manufacturing of Fuel Assemblies

S&T joint venture - CNI 23rd Co & SPIE (France)
Manufacturing of Stainless Steel Auxiliary Piping (LA1 & 2)



Accumulators



Fuel assembly

SELF-RELIANCE

Erection

The cooperation between the Chinese Nuclear Industry 23rd Construction Corporation and Framatome ANP started more than 10 years ago, during erection of the Daya Bay nuclear islands.

This cooperation was further developed during erection of the Ling Ao Nuclear Island. CNI 23rd Corporation was the main erection contractor for the nuclear islands. Framatome ANP was responsible for main primary system erection and provided technical support to the CNI 23rd Corporation to make it completely self-reliant in all erection and field design activities. The self-reliance program was set up between the partners for both scopes of work - Nuclear Island erection work (CNI 23rd Corporation scope) and the primary system erection work (Framatome ANP scope), and focused on the following activities:

- technical management:
  field design, delegations to the CNI 23rd Corporation for the engineering works, procedures and end-of-erection reports,
- project coordination: preparing, updating and managing the different project schedules, external site coordination with civil works (room hand-over),
- implementation of the works with specific technology as well as equipment parts and material management, documentation management, quality control and schedule control.

Framatome ANP's expatriates were integrated into the CNI 23rd corporation organization with assigned Chinese counterparts. Regular and important technical exchanges were established throughout the project implementation period through correspondance, technical meetings, documentation exchanges and technical audits.

The long-term cooperation relationship and the technical liaison established between CNI 23rd Corporation and Framatome ANP made it possible to solve all technical issues rapidly and resulted in smooth progress of the erection work ahead of schedule.

TECHNOLOGY TRANSFER

Nuclear Island Design: Qinshan phase 2

In July 1992, Framatome ANP signed a Cooperation Agreement with CNNC, transferring the Nuclear Island technology implemented for the Daya Bay nuclear power plant to Chinese design and engineering institutes. BINE and NPIC were the two institutes designated to receive the nuclear island technology.

This Cooperation Agreement was implemented through two successive work orders signed in 1992 and 1996. More than 110000 pages of documentation and 7000 drawings, as well as computer codes, were transferred to the Chinese institutes. In addition, Framatome ANP welcomed about 220 Chinese engineers to France for training and meetings and provided technical assistance services in China.
The direct application of this technology transfer agreement is the design and construction of the Qinshan 2 plant which consists of two 600 MWe units built in Hayan in Zhejiang Province.

Extended Nuclear Island Cooperation Agreement

In October 1995, Framatome and EDF signed a technical transfer agreement with CGNPC which gives the Chinese Nuclear Industry access to all the Framatome ANP and EDF technology used to build plants in France, up to the latest N4 plant series.

Qinshan phase 2: 2 x 600 MWe

Nuclear Fuel Technology Transfer to China

Fuel assembly

The first cooperation agreement in the fuel area was signed in May 1991 between China Nuclear Energy Industry Corporation (CNEIC), a subsidiary of the China National Nuclear Corporation, and Framatome ANP and involved several institutes and companies under the authority of the China National Nuclear Corporation. The Nuclear Power Institute of China (NPIC), located in Chengdu, was commissioned to design the fuel assemblies and reloads, and the Yibin Fuel Plant was put in charge of operating the AFA 2G fuel assembly production and fabrication facilities.

As a result of this technology transfer, the Yibin Fuel Plant has been successfully manufacturing all the fuel reloads needed by the two Daya Bay units since 1994, with NPIC performing the engineering work for the fuel management and safety assessments of the reloads. Furthermore, in 2001 and 2002, the Yibin Fuel Plant delivered the first cores for both units of Qinshan Phase 2.

In order to reduce the kWh cost, GNPJVC decided, at the end of 1998, to shift from 12-month to 18-month fuel cycles. A new fuel technology transfer for the localization in China of **AFA 3G** fuel assembly design and manufacture was set up between NPIC and the Yibin Fuel Plant and Framatome ANP. NPIC carried out a large part of the engineering studies for Daya Bay’s 18-month fuel cycles with advanced AFA 3G fuel assemblies and the Yibin Fuel Plant now delivers **AFA 3G** reloads for Daya Bay and Ling Ao.

Framatome ANP is transferring its **cladding tube** fabrication technology to two Chinese companies, Shanghai Gaotai Rare & Precious Metals (SGTC) and Northwest Zircocladding Co. Ltd. (NWZ) with final qualification scheduled for 2003. Framatome ANP's subsidiaries, FBFC and CEZUS, are participating actively in the transmission of their technology to their Chinese counterparts.

This proves the huge amount of work and the progress made by Chinese institutes and industries in a space of few years to **master nuclear fuel technology.**

NUCLEAR SERVICES

From the first maintenance services contract signed between GNPJVC and Framatome ANP in 1993, one year prior to commercial operation of Daya Bay Unit 1, the approach to self-reliance in the field of outage work was based on carrying out operations jointly. Supplemented by the appropriate training, it involved a number of simple principles:

- GNPJVC would progressively take more responsibility for the work,
- shadow training of Chinese specialists during work performed in France by Framatome ANP teams,
- priority given to training in real-life situations ("on-the-job training" within integrated teams) over theoretical teaching.

The objective of the program established was to allow GNPJVC to:

- carry out general maintenance operations,
- manage all aspects of plant outages: planning, time schedule, human resources, material resources, dosimetry, etc.,
- achieve self-reliance in all unforeseen maintenance situations.

This program started with the first outage of Daya Bay Unit 1 in December 1994. The effectiveness of the transfer of knowledge can be measured by comparing the situation during the first outage in December 1994 and the latest outage in early 2003:

- for the first plant outage, more than 100 Framatome ANP specialists took part in the work and managed the maintenance operations,
- for the latest outage, only about 40 Framatome ANP specialists were present to provide technical assistance and GNPJVC managed the operations.

Other facts show that the knowledge transfer objectives were achieved:

- the time schedules were met and outage duration is decreasing,
- no major technical difficulties occurred during plant restarting,
- GNPJVC has considerable autonomy in the resolution of technical difficulties,
- the dosimetry linked to maintenance operations is satisfactory,
- availability, averaged for both units, was more than 89% in 2001.

This clearly illustrates that Chinese maintenance personnel have fully understood and are able to implement all general maintenance operations.

In the future, Framatome ANP will cooperate with CNI 23rd company and will transfer its technology in the field of Nuclear Services to localize overall general maintenance even further. Framatome ANP is also cooperating with Chinese Institutes in the field of engineering services (BINE, NPIC) and in-service inspection (RINPO).

Equipment welding control training

Fuel Loading

PLANT PERFORMANCE

Since the start of commercial operation, the Daya Bay plant has continuously recorded impressive annual operating results year after year. In 2001, for the two units, the Load Factor and Capacity Factor reached an average of 86.8% and 89.5% respectively, and the total net electrical output sent to the grid reached 14365 million kWh, the highest level since the start of commercial operation.

In 1999 and 2000, the Daya Bay plant **came first** in the "Safety Challenge" competition organized by EDF for French Nuclear Power Plants, at the same time **ranking seventh** for overall competitiveness in comparison with 106 Nuclear Power Units in operation in the United States.

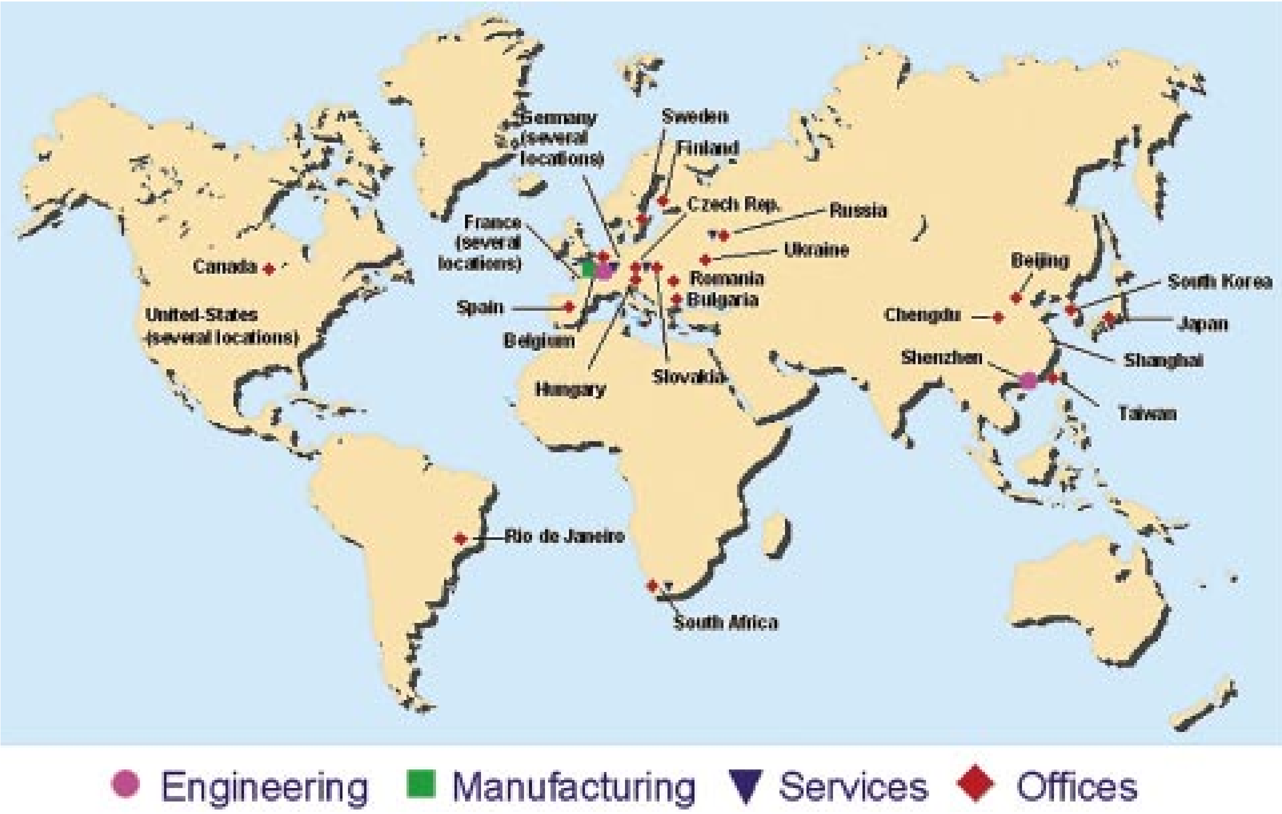
In 1998 and 1999, both units set excellent records of "zero unplanned shutdown"and afterwards less than one unplanned shutdown per unit.

Daya Bay has achieved a constant increase in economic return every year. In 2000, the two units generated 14063 billion kWh with an off-take revenue of US$ 842 million and foreign exchange earnings from the electricity export market reached US$ 590 million, thereby making a considerable contribution to China's economy.

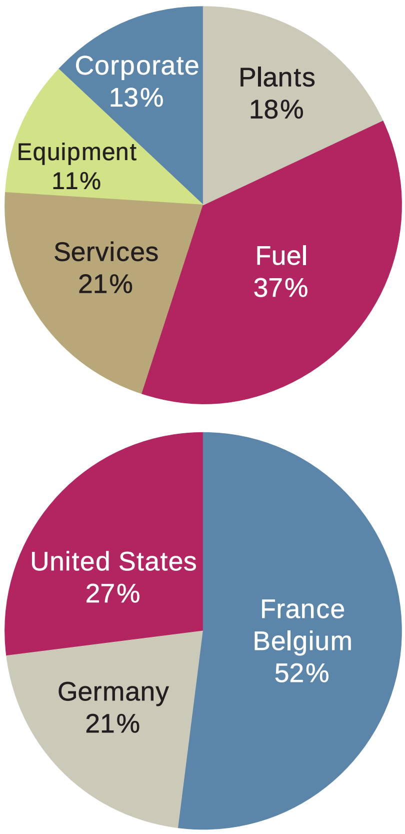
China - Daya Bay 2 x 1000 MWe

4 - FRAMATOME ANP

FRAMATOME ANP - 14 000 EMPLOYEES WORLDWIDE

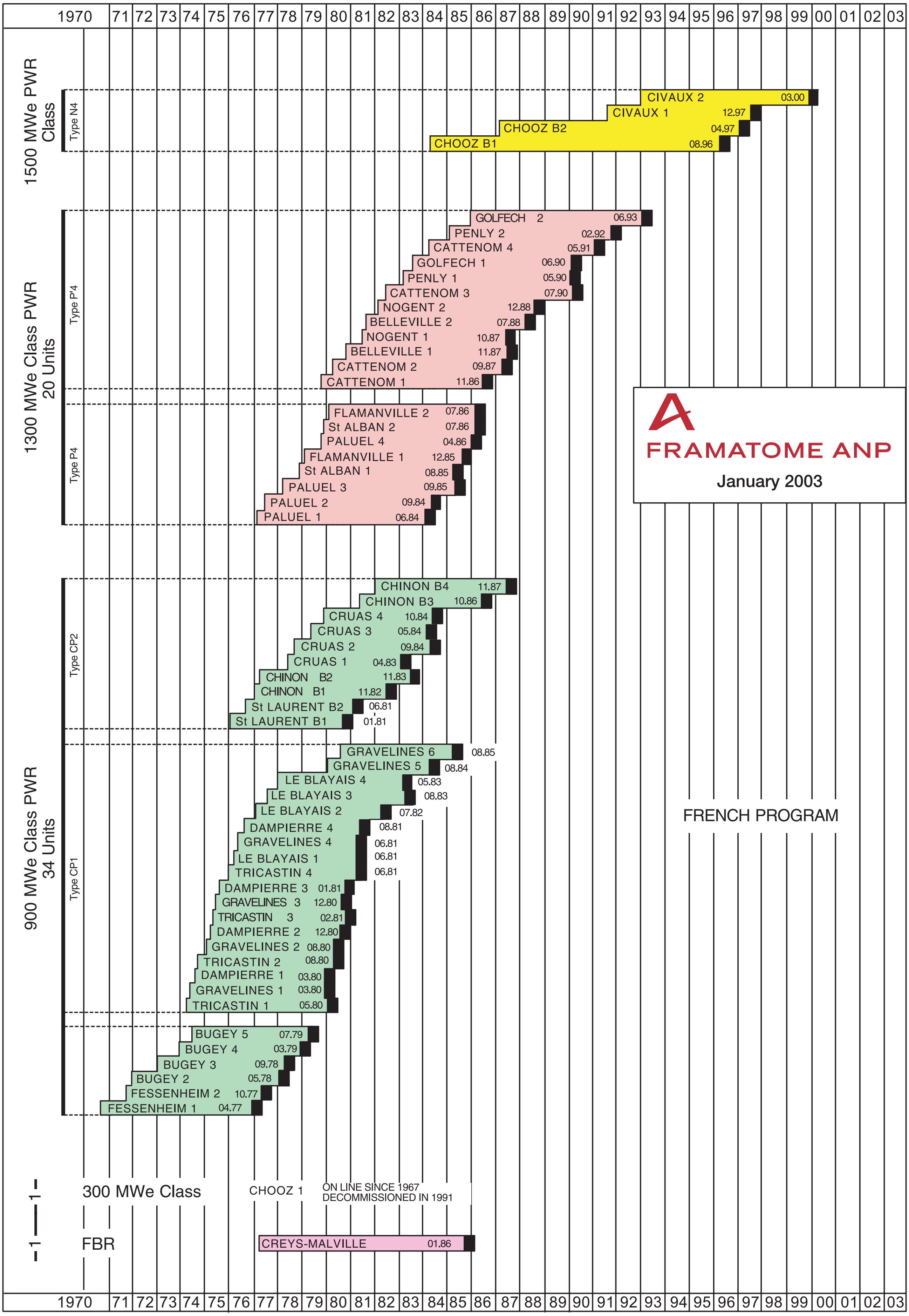


Workforce
Breakdown by sector & by country



Framatome ANP, an AREVA and Siemens company, is dedicated to nuclear power around the world. Framatome ANP provides comprehensive engineering, instrumentation and control, nuclear services, heavy component manufacture, modernization, fuel assemblies for many reactor designs, including those supplied by other vendors, and the development and construction of nuclear power plants and research reactors. Framatome ANP is headquartered in Paris with principal subsidiaries in the U.S. and Germany. In the company, AREVA has a 66 percent share and Siemens 34 percent. Framatome ANP has a total workforce of approximately 14,000 worldwide.

For further information,
visit: http://www.framatome-anp.com



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1500 MWe PWR Class
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CIVAUX 1 12.97
CHOOZ B2 04.97
CHOOZ B1 08.96
1300 MWe Class PWR 20 Units
Type P'4
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PENLY 2 02.92
CATTENOM 4 05.91
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FRAMATOME ANP
January 2003
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1
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CREYS-MALVILLE 01.86
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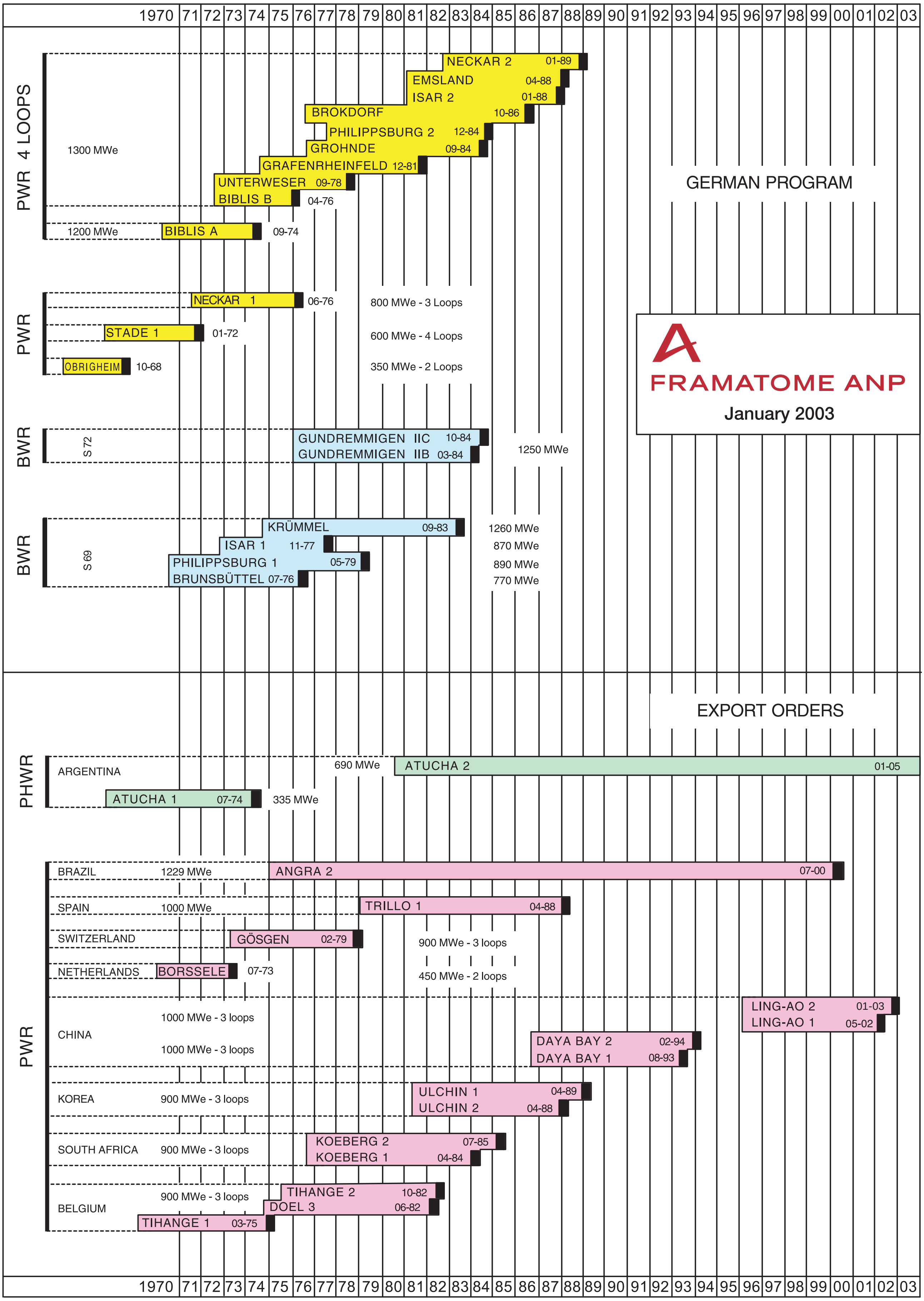
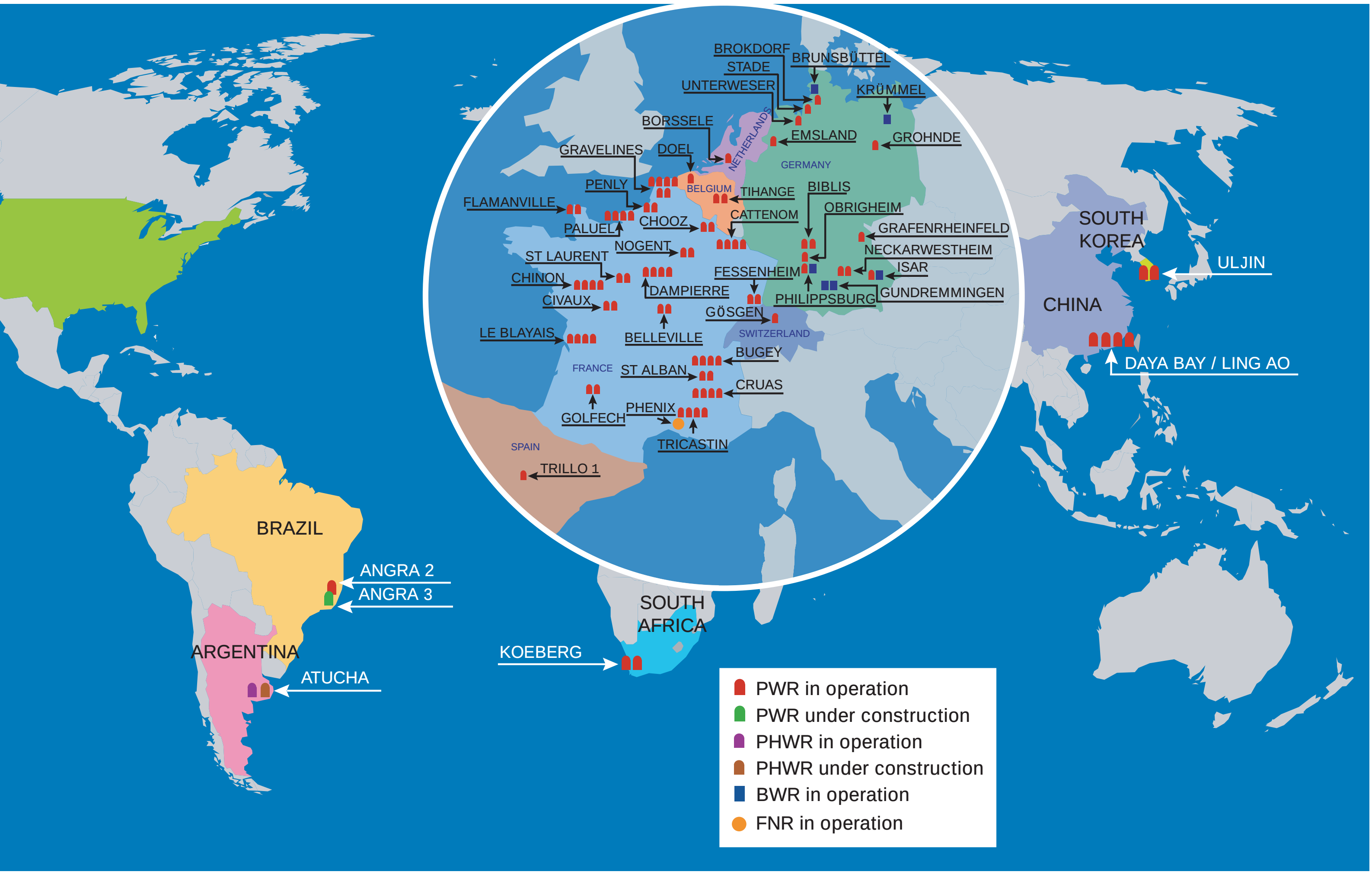
96 NUCLEAR POWER PLANTS



NUCLEAR POWER PLANTS BUILT BY FRAMATOME ANP WORLDWIDE



Ling Ao 2 x 1000 MWe PWR

AREVA, the world leader in nuclear power and connectors, is present in more than 30 countries.
The group's employees provide customers with a full range of products and services for electricity generation and develop connector products and interconnect systems mainly for the communications and data markets.
AREVA brings expertise and technologies for better living to meet the challenges of the 21st century: generalized access to energy and information, preservation of the planet, and responsible stewardship of resources for future generations.

LING AO
2 x 1000 MWe PWR

A success story

FRAMATOME ANP

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