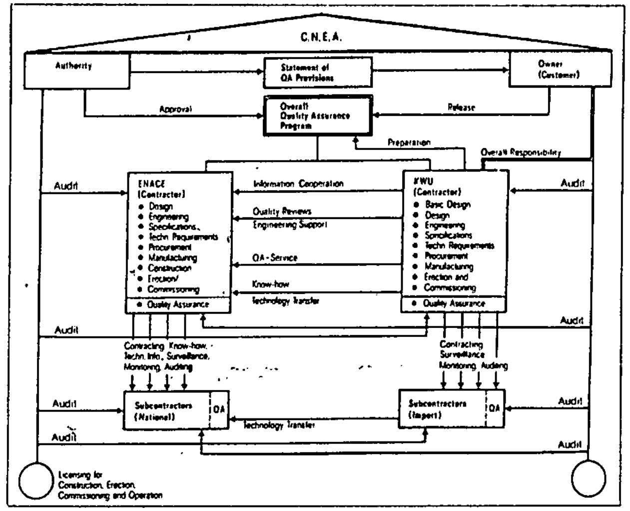


Interaction of quality assurance activities of CNEA and the main and sub-contractors

power plant with a pressurized heavy water reactor (PHWR). The contractual negotiations started immediately and the main CNEA-KWU contracts were signed in May 1980 in Buenos Aires and approved by the Argentine government in July 1981 (see diagram). These include:

- The supply, service and warranty contracts for the 745MWe power plant Atucha II.
- Contracts for the creation of the engineering company Empresa Nuclear Argentina de Centrales Eléctricas (ENACE) which cover the status of ENACE and the shareholder agreements.
- Contracts for nuclear fuel technology covering the technical co-operation agreement on nuclear fuel technology, and guidelines for nuclear fuel supply.

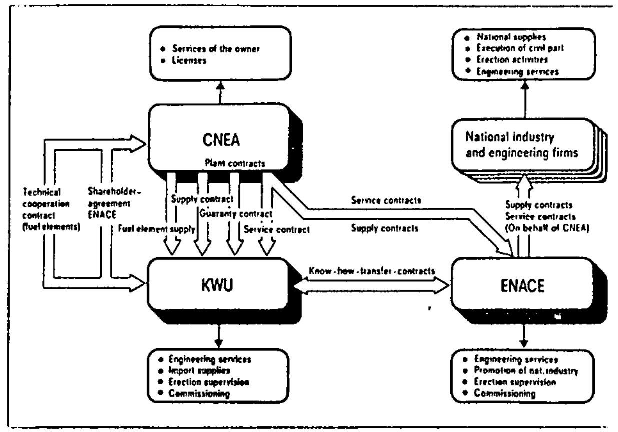
Supply contract. This covers the licensing and quality assurance requirements and hardware supply. The licensing requirements of the Argentine licensing authorities are based on all the criteria in IAEA codes and standards and ICRP 26. German and American standards and regulations, and other pertinent international rules and regulations are only part of the contract when applicable. Because of this diversity of specifications, it was agreed that the contracts should be supplemented by the specifications of the relevant codes and standards from the above. These codes and standards cover all requirements valid in 1979 for the design, construction and operation of Atucha II and have been implemented. The contracts contain the condition that any changes in the state of art or in licensing aspects must be communicated to CNEA and analysed if required for CNEA to decide whether they should be implemented.

The licensing of the plant is based on the above-mentioned requirements and in addition on a risk analysis. The licence is in two parts, the construction permit is granted before the first concrete is poured and the operating licence is granted before the first criticality is reached (filling with heavy water).

Quality assurance for Atucha II will be performed in accordance with IAEA codes and guides and will be executed for the imported part by the independent quality assurance and quality control groups of KWU and for the Argentine part by ENACE. The interaction between the main parties involved is illustrated in the diagram. The licensing authorities and CNEA as client are entitled to perform audits. The quality assurance programme forms part of the licensing documents.

After an extensive analysis of the Argentine suppliers market, CNEA and KWU agreed to a scope of supply which can be produced in Argentina to the specifications laid down in the contracts mentioned above. The balance remaining after accounting for the national supply forms the basis for the supply contract between CNEA and KWU. The delivery of all components and equipment in accordance with the general project schedule has been laid down in a "milestone schedule". This milestone schedule must be up-dated every three months in line with the actual status of the plant. Imports will be delivered under fob conditions to Incoterm 1953 with its 1967 and 1976 supplements.

CNEA and KWU have agreed that, if Argentine industry is able to increase its supply position such additional supplies will be taken out of KWU's scope of supply and the price including overheads of KWU's scope will be reduced on the basis of current offers from subcontractors.



Contract structure for implementation of the Atucha II project

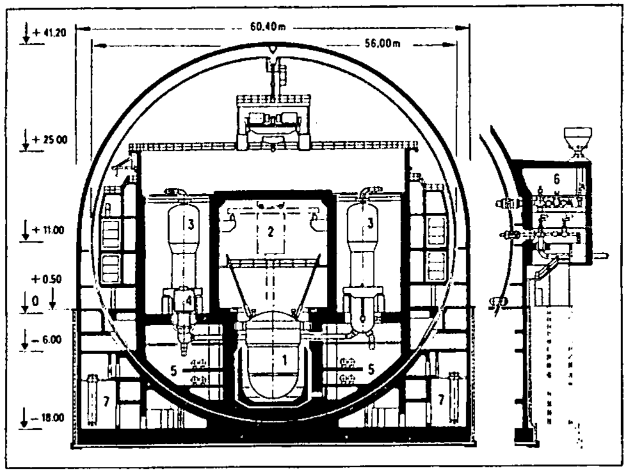
Service and warranty contracts. The service contract between CNEA and KWU includes the complete scope of engineering services for the nuclear power plant, reduced by that part necessary for the procurement, follow-up and quality assurance of the national components. As the build-up of ENACE progresses, this scope of services will gradually be reduced and subsequently, responsibility for the software will be transferred from KWU to ENACE. The volume of services to be transferred can be defined and decided only by CNEA. CNEA governs the build-up of ENACE.

KWU guarantees the gross electrical output, the plant specific heat rate and the heavy water losses for the first two years of operation. Additionally, KWU warrants for four years after handing-over of the plant to the customer that the services performed and the components delivered are free from deficiencies, free from non-conformities and will operate trouble-free and that any repairs necessary will be performed at no cost to CNEA.

ENACE and fuel contracts. The foundation contracts stipulate that ENACE will be the main architect engineer for all nuclear power plants in the Argentine programme. Accordingly the know-how contract between ENACE and KWU includes intensive training services and entitles ENACE to request manpower to act as normal staff members of ENACE on long-term assignment contracts. The percentage of KWU shares in ENACE will be progressively reduced to zero by 1990.

Since 1968 CNEA has been building up its own fuel manufacturing facilities for Atucha I, and KWU has supported this build-up by supplying manufacturing equipment. The recently signed contracts include the assumption of manufacturing responsibility by KWU but the transfer of nuclear fuel manufacturing know-how to enable CNEA to build and operate a fuel factory with sufficient capacity for 100 per cent supply of the reload and first cores for the entire Argentine nuclear programme.

For Atucha II, the contracts between CNEA and KWU are supplemented by the delivery of fuel elements and heavy water by CNEA itself and by about 50 per cent of the component and system deliveries being from Argentine sources. The know-how contracts with ENACE for engineering services and with other Argentine companies for the manufacture of special components form the basis for the further development of Argentine industry.



Reactor building of the Atucha II PHWR

1 Reactor pressure vessel. 2 Refuelling machine. 3 Steam generator. 4 Reactor coolant pump. 5 Moderator cooler. 6 Steam and feedwater valves. 7 Component cooling heat exchanger.

Extensive use of PWR-technology

In the pressurized heavy water reactor (PHWR) of Kraftwerk Union design the core is contained in a pressure-vessel. As a result there are many common features between this PHWR and a pressurized light water reactor (PWR), and it has benefitted from KWU's 150 years of operating experience with LWRS.

The components of the reactor coolant system are fully comparable in design and arrangement with a PWR. The reactor pressure vessel is positioned vertically in the centre of the system. Identical coolant loops, each comprising one coolant pump and one steam generator, are connected to the pressure vessel radially. The system is enclosed in a spherical leak-tight steel containment, designed for full accident pressure, and this containment is protected against external impacts by a reinforced concrete reactor building. The annulus between the steel shell and the protective concrete structure is connected to a special exhausting system that ensures that even under accident conditions radioactivity cannot be released to the environment.

So far there are no main differences to a PWR. There is also one common pressurizer in the system. The PWR-like general design of the reactor coolant system with standardized and proven components and welded joints results in a small and leak-tight high pressure boundary for the heavy water which is used as both coolant and moderator. There is good accessibility to the components for maintenance and in-service inspection. In-service inspections according to internationally accepted codes, with proven methods and equipment, can thus be performed without restrictions.

The pressure vessel, is larger than that of a PWR at equal thermal output and has a different cover: it is penetrated by a large number of nozzles, one for each coolant channel.

The control rod drives are arranged around the periphery of the cover, to allow room for the on-load refuelling machine which operates directly above the vessel cover. The control rods are inserted into the reactor core at angles between 18° and 25°.

As with a KWU-PWR, there are no penetrations of the reactor pressure vessel in the area of the core and below.

The reactor pressure vessel internals, however, are very different from those of a PWR. Because of the neutron physics a larger amount of moderator is necessary compared with a PWR and the fuel has to be concentrated in discrete coolant channels. These are arranged vertically and so there are no problems due to deflections, especially from those induced by earthquakes. The coolant channel closure plugs, which are needed at one end only, are easily accessible for maintenance by lowering the water level.

The coolant channels penetrate a moderator tank, which is located inside the reactor pressure vessel. As the moderator is more efficient for moderation at lower temperatures, the moderator tank is connected to separate cooling circuits via nozzles in the reactor pressure vessel.

Coolant circuit. Each coolant channel contains one 37-rod bundle with an active length of 5300mm. The coolant enters the coolant channels from below and leaves the coolant channels above the cover of the moderator tank and is guided to the outlet nozzles of the vessel. The coolant, having passed through the steam generator, enters the pressure vessel and flows outside the moderator tank downwards to the bottom of the pressure vessel before entering the coolant channels again.

The pressure, but not the temperature, between coolant and moderator is equalized by openings in the cover of the moderator tank. As the pressure difference between coolant and moderator is therefore only small, thin-walled coolant channels can be used. This results in low parasitic neutron absorption and therefore high burnup of the natural uranium fuel. Furthermore, the connection between the reactor coolant system and the moderator system permits the use of common auxiliary systems to maintain the necessary water quality. The number of auxiliary systems can therefore be reduced to a minimum.

The heat generated in the moderator by neutron moderation and heat transfer (5 per cent) is removed from the moderator for pre-heating the feedwater. This is one of the reasons for the high net efficiency (about 32 per cent) of a power plant with a pressure-vessel-type PHWR.

The turbine-generator plant is conventional and only site-dependent features vary. The building layout and arrangement are also identical to those of a PWR as are a great number of auxiliary systems, allowing identical inspection and maintenance methods and equipment.

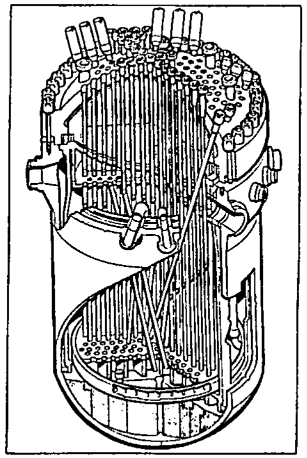
This design of PHWR was first demonstrated as a 57MWe multi-purpose research reactor (MZFR) at the Nuclear Research Centre, Karlsruhe, which went into operation in 1966. The first commercial power plant, with a 340 MWe PHWR of KWU design, was built at Atucha, Argentina, and was handed over in 1974. The power output was increased to 367 MWe in 1977. To date this reactor has shown excellent operating performance with high rates of availability and thereby furnished proof of its full operating reliability. Up to the end of January 1982, Atucha I attained an availability of 82 per cent and a heavy water loss of less than 1 per cent a year. The order for the 745 MWe Atucha II was accepted in October 1979.

The pressure-vessel type heavy water reactor described here has a promising further potential. With the present state of the art the reactor power can be increased to obtain a plant output of 900 to 1000 MWe, without basic changes to the reactor pressure vessel, and an even larger plant size may be expected in the future.

Site conditions. The 745 MWe Atucha II nuclear power plant is situated 110km north-west of Buenos Aires on the south bank of the Rio Paraná de las Palmas a few kilometers away from the community of Lima, Zárate County.

The possible site-specific external impacts were taken into account in the design of the plant, and the following structurers are designed against earthquake, tornado, explosion pressure-shock wave and flood: reactor building, main steam and feedwater valve compartment, fuel pool building, switchgear building, emergency power and chilled water supply building, service cooling water intake structure, service cooling water pump houses, service cooling water pipes, and cable ducts between the reactor, switchgear and emergency power and chilled water supply buildings.

Cooling water discharge is effected by means of a second discharge canal arranged beside the existing discharge canal. Two structures separated from one another and protected against earthquake are provided for service water supply, with the water being extracted directly from the Rio Paraná and from the existing intake channel for Atucha I.



Cross section of reactor pressure vessel

Reactor core design. The design of the Atucha II reactor core follows the design of Atucha I. The 451 fuel channels generate a thermal power of 2052 MW, and 108 MW are generated in the moderator to give a total generated thermal power of 2160MW.

Reactivity control is possible by (a) control rods consisting of steel (grey absorbers) and hafnium (black absorbers); (b) change of moderator temperature within the range of 180°-220°C; (c) moderator and coolant poisoning by the normal operation borating system; and (d) refuelling.

A fast boron injection system for poisoning the moderator provides a second independent and diverse-mode shutdown system.

In line with progress in control of core thermo-hydraulics, KWU reactor plants are equipped with a "condition limitation system" which acts between the normal feedback controls and the reactor protection system. This system keeps the plant variables within the range specified as the basis for safety analysis.

The benefit of the new core protection philosophy is that – in contrast to the past – thermal core design is not obliged to supply DNB margins to allow for undesired power density distributions in the core caused by control rod or fuel assembly manoeuvres. These can now be detected and prevented by the condition limitation system which is of redundant design and physically separated and built to fulfil the same safety requirements as the reactor protection system (see below).

At full power and taking into account measuring tolerances, the reference values for power density limitation and DNB condition limitation are set to ensure that the following technological limits are not violated: a linear heat rate of 598.6W/cm, and a DNB ratio after complete loss of flow of 1.30 according to W3 correlation.

Automated on-load refuelling. The natural uranium reactor makes possible and desirable, with a view to obtaining a high burnup, the shuffling and replacment of the fuel assemblies during power plant operation. The refuelling procedure is performed by a *single* refuelling machine. Normally 1.8 fuel assemblies are replaced in the reactor each full power day.

The fuel assembly transport system is located in the reactor building and in the fuel pool building. The main items of the fuel transport system are: refuelling machine, tilter with supporting structure, fuel transfer tube, fuel pool, and the cor-