features such as:
- Graded pressure and directed air flow, that is, containment pressure below atmospheric pressure and pressure of component rooms below pressure of accessible areas of containment.
- Extensive radioactivity monitoring.
- Appropriate treatment of the exhaust air via Hepa filter and activated carbon filter.
- Sufficient recirculation capacity.
- Separation of operating rooms and equipment rooms and additional separation of H_2O and D_2O compartments in the auxiliary building.
- Protection against fire hazards by means of fire dampers.
- Standby units for substitution of the operating units in case of failure (automatic switchover)
- Building isolation during accident conditions by means of suitable isolation dampers.

To increase the reliability of all important drives and valves, actuators are connected to independent emergency power trains, the required coolers being supplied from redundant chilled water equipment.

Accident analysis. The analysis of all postulated loss-of-coolant accidents shows that the maximum clad temperatures does not exceed the range between 600°C and 1000°C, thus being far below the limit of 1200°C internationally taken as the design basis for the emergency core cooling systems. These results were calculated without taking credit for heat transfer by the steam generators.

For the licensing of the PHWR plant Atucha II the Argentine authority required a risk analysis to be performed to demonstrate that the risk arising out of accidents satisfies a pre-determined risk criterion, and that the safety concept is adequately selected, primarily on the basis of a deterministic criterion.

The methodological procedure and component evaluation were selected by analogy with the two "classical" risk analyses: WASH 1400 and, in particular, the German Risk Study (GRS) which serves here as the reference study. The reference plant for the GRS is a KWU 1300MW PWR (Biblis B, 1976).

The results for the probabilistic risk analysis for the PHWR-plant show:
- The risk is very low for both KWU-plants, the LWR and the PHWR
- The values for the PHWR plant are somewhat smaller than those from the reference plant of the GRS. Considering the lower power of the PHWR plant and the date and model uncertainties the risk is within the same order of magnitude.

Active engineered safeguards:
Shutdown control elements
Fast boron injection system (second independent shutdown system)
Moderator system
Residual heat removal system
Service cooling water system for the assured plant
Nuclear component cooling system
Safety injection system
Accumulator injection system
Containment isolation
Reactor building annulus air extraction system
Isolation of the reactor coolant system and of the moderator system
Isolation of the main steam and feedwater lines
Main steam atmospheric dump station
Leakage make-up pumps
Emergency power supply system

- Even if conservatively estimated error bands are taken into account to cover data and model uncertainties, the limit criterion specified by the Argentine authority is still met. The analysis confirms, that the design of Atucha II is adequately selected and that the plant fulfills the licensing requirements imposed in this context.

The PHWR, which needs no enriched uranium, is preferred by developing countries. It is the principal item in the German nuclear co-operation programme, which as described in the next section, provides for a complete transfer of design, manufacturing and operating technology. Bearing in mind the improved utilization of nuclear resources obtained by the good neutron economy of heavy water reactors and the adaptability of the pressure-vessel type PHWR to other fuel cycles, such as tandem cycle PWR-PHWR, or thorium fuel cycle, the PHWR will occupy a justified place in the production of nuclear power in the future.

08.82.11

Good experience of technology transfer

From its creation in 1951 up to 1964, the Comisión Nacional de Energia Atómica (CNEA) developed the capability required to be able to promote and support the construction of nuclear power plants in Argentina. This capability was mainly based on human resources that throughout those 13 years were dedicated to the solution of scientific and technological problems related to nuclear energy, and was demonstrated in the construction of several research reactors and in later projects.

In 1965 a feasibility study was undertaken by CNEA for the first nuclear power plant to be built in the country. In 1968 the call for tenders and the evaluation of offers was carried out by CNEA. Based on CNEA's advice the government approved the construction of the 367 MWe Atucha I, a pressure-vessel type PHWR using natural uranium. The Atucha I power plant started operation in 1974 and the local contribution to its construction amounted to 33 per cent by value.

The technology transfer involved in this initial Argentine experience of a nuclear power plant can be summarized as follows:
- Training of local industry to meet strict and severe quality control standards.
- Training of scientific personnel in the solution of practical problems related to the commissioning of a nuclear power plant.
- Development of the technical capability to assume the responsibility for operating and maintaining a nuclear power plant.
- Training in the fabrication and inspection of fuel elements.
- Acquisition of managerial experience in areas such as planning and control, organization and personnel.
- Theoretical and practical experience in the field of licensing.

During the construction of Atucha I, the second nuclear power plant, Embalse, a 648 MWe pressure-tube type PHWR using natural uranium, was approved in 1973. At present, Embalse is being commissioned and the local participation in its construction has risen to 58 per cent by value.

As is shown in the table, local participation has considerably increased and at present the technological capability acquired can be summarized as follows:
- Training of local industry in the detailed engineering, erection and supply of nuclear quality components and systems.
- Increase in the capability of scientific and technical personnel through a technology transfer agreement with the main contractor.
- Practical training of personnel in detailed engineering and special erection work.
- Improved capability in fuel element fabrication.
- Increased experience in contractual relationships and technical-administrative organization.
- Acquisition of capability in the procedures of quality assurance audits.

– Increase in capability in supervising and controlling the work of main contractors and subcontractors.

New engineering company. The scientific, technological and managerial experience attained through the first two Argentine nuclear power plants made it possible to avoid a "turnkey" contract for the third one. For this, Atucha II, the role of architect-engineer is being undertaken by a new national engineering company as mentioned earlier, in the section on contracts.

The company was set up in 1981 with the following main objectives:

- To perform all engineering services needed to implement nuclear power plant projects to be installed principally in Argentina. Such engineering services comprise the management of the infrastructure, as well as preliminary planning, plant planning and layout; design, project management, procurement and follow-up; supervision of construction and erection, including commissioning, training of personnel; and back up assistance for operation and maintenance of nuclear power plants.
- To render technical assistance to owners or operators of nuclear power plants in Argentina, in line with the execution of the Argentine nuclear plan. Such assistance will be rendered preferably through the delegation of personnel to the respective owners or operators, or through service contracts covering activities such as those described above.
- To promote the use of Argentine engineering and components in the nuclear projects to be built in Argentina.

So far the activities of the company have been directed to the procurement of local supplies, project and site management, quality assurance and the formation of different engineering groups. Today the company carries out these activities through its technical, commercial, industrial promotion and assistance directorates, and the project and quality assurance departments. It is engaged in the transfer of technology and know-how from the Federal Republic of Germany both for the efficient performance of its present activities and for the development of the project for the fourth nuclear power plant in Argentina. The success of this transfer process requires the co-operation of the shareholders and the integration of the German personnel assigned to the enterprise (about 50 at the present moment) and the Argentine personnel (about 400).

With the development of ENACE, it will be possible to consolidate the national potential for the construction of nuclear power plants, assigning clearly defined roles to the different sectors involved:

- CNEA will remain the client and operator.
- ENACE will design the nuclear power plants and will be their architect engineer.
- Private industry will supply the components, including the heavy ones, will do the detailed engineering and will be responsible for erection.

National participation in Argentine power plants

	Reference standard NPP	Atucha I	Embalse	Atucha II
	%	%	%	%
Electromechanical supplies	60	9	24	27
Erection	17	9	16.1	16
Civil works	15	15	15	15
Engineering	8	0	3.2	4
	100	33	58.3	62

Manufacturing technology. There are already numerous precedents for the transfer of manufacturing technology from German industry to Argentina with its own high standard of industrialization. For this reason more-or-less close contacts already exist between several German and Argentine companies concerning the manufacture of equipment for thermal power plants, hydro-electric power plants, and chemical and petrochemical plants. The construction of nuclear power plants in Argentina entailed, in addition, the manufacture of components to special rules, standards and specifications.

Since 1968, with the construction of Atucha I, Argentine industry has been participating actively in the manufacture and erection of numerous components such as heat exchangers, pressure vessels and tanks. The equipment manufactured at that time was for requirement categories 3 and 4, which are at the lower end of the requirement category scale, which begins with requirement category 1, i.e. equipment forming the reactor coolant the pressure boundary. This demonstrates the willingness and ability of the Argentine design and manufacturing engineers to acquaint themselves with German rules and to manufacture to specifications.

With Atucha II, the participation of the Argentine industry will be considerably greater, and in the course of the project nuclear components for requirement category 1, such as the site weld between the upper and the lower sections of the reactor pressure vessel, the steam generators, the pressurizer and three of the four moderator coolers, and the accumulators, will also be manufactured in Argentina.

Thanks to the flexibility of the Argentine design and production engineers in co-operation with their German partners, the conversion necessary in some cases from ASME Code to German standards did not present any major problems. The progress of the components in production indicates that for Atucha II also Argentine industry will deliver on schedule and in the required quality.

Power plant engineering. The principal item of the Argentine-German nuclear co-operation is the transfer of the power plant engineering technology to the joint Argentine-German engineering company ENACE. The challenge here lies in the fact that simultaneously with the implementation of a large-scale project, such as Atucha II, the engineering potential must be established and built up. The advantage of tying a plant-related technology transfer to the setting-up of a company is that the build-up can be carried out to fixed dates and before actual project work is started. Also with the performance of engineering activities, the progress of technology transfer is measurable.

The potential for power plant engineering in Argentina is composed partly of already existing capabilities and partly of various joint German-Argentine specialized groups of engineers, which include project management. These groups consist of German and Argentine engineers in the ratio of approximately 1:5 initially. Some of the Argentine engineers spend six to 18 months in KWU project groups in Erlangen, while others are being familiarized with special engineering fields using KWU's on-the-job-training.

In parallel and within the scope of the so-called transfer of documents agreement, drawings, reports, specifications, working procedures, and process specifications which will be needed for the independent construction of nuclear power plants in the future are being transferred to ENACE. Already this year, extensive fields of the engineering are being transferred from KWU to ENACE.

The similarity of the PHWR with the PWR facilitates the transfer of technology between German industry and Argentine industry. □