

THE FRANCO-GERMAN APPROACH FOR A NUCLEAR POWER PLANT IN TURKEY



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ÖZET

Nuclear Power International (NPI) firması, 1989 yılında, Siemens ve Framatome firmalarının ortaklığı ile kurulmuştur. Böylece, nükleer alanda, her iki kardeş firmanın 100.000 MW'dan fazla kurulu veya ısmarlanmış kapasiteye dayalı deneyim birikimleri bu yeni firmada birleştirilmiştir. Biz, Türkiye'deki olası bir nükleer güç projesinde, Alman Basıncılı Su Reaktör Teknolojisini temel alarak rekabet etmek niyetindeyiz. Yabancı yükleniciler tarafından Siemens, Framatome ve GEC-Alsthom firmalarının bulunacağı bir konsorsyum kurulacaktır. Konsorsyumun yabancı ortaklarına ek olarak, mümkün olan en fazla yerel katkıyı sağlamak için, Türk endüstrisini de teklif paketine dahil edeceğiz. Önceki teklifimizdeki yerel pay, kontrat miktarının % 30 kadarını kapsıyordu.

ABSTRACT

Nuclear Power International (NPI) has been established as a joint subsidiary of Siemens and Framatome in 1989, thereby combining the experience accumulated in both parent companies with more than 100,000 MW capacity installed or on order in nuclear field. We intend to compete in a potential nuclear power project in Turkey on the basis of the German Pressurized Water Reactor Technology. We intend to establish a Consortium which on the foreign suppliers side will include Siemens, Framatome and GEC-Alsthom. In addition to the foreign partners in the Consortium we will include the Turkish industry in our proposal in order to achieve a maximum possible local content, which in our previous proposal was in the range of 30 % of the contract-value.

INTRODUCTION

Nuclear Power International (NPI) has been established as a joint subsidiary of Siemens and Framatome in 1989, thereby combining the experience accumulated in both parent companies with more than 100,000 MW capacity installed or on order in the nuclear field.

The basic objectives of NPI are twofold. In the marketing-field, NPI is in charge of marketing nuclear islands and complete nuclear power plants on the basis of the technologies developed by Framatome in France and by Siemens in Germany.

In the development field, NPI is coordinating the development of a joint Franco-German PWR-design for the future, called European Pressurized Water Reactor (EPR). This development is presently being supported by the utilities and the licensing authorities in both countries. It is expected that nuclear units based on this EPR technology will be under construction by the end of this decade and the technology can be offered thereafter on the international market.

Projects, which will be executed in the near future require a proven, yet up to date technology, which is available in France and Germany today.

SIEMENS EXPERIENCE IN TURKEY

Siemens as one of NPI's parent companies has a long experience in Turkey, the first Siemens Company in Turkey was established in 1927. Today, Simko and Türk Siemens, which represent the Siemens Group in Turkey provide services in almost every branch of electrical and electronic fields with a staff of nearly 4,000 people.

In the power generation and distribution field, Siemens covers a wide spectrum including lignite and gas fired conventional power plants, the latest example being the combined cycle plant in Ambarlı, where Simko was a consortium member providing supplies and erection service.

More specifically, Siemens nuclear technology has been extensively discussed with TEK and TAEK during the contract negotiations between 1982 and 1984 for AKKUYU. During this time, the licensability of Siemens Pressurized Water Technology in Turkey was investigated in detail and finally confirmed. A contract was negotiated simultaneously and all technical and contractual details were agreed upon. Even if this this contract could not finally be signed, we believe that the comprehensive work undertaken during these negotiations represent a valuable asset for any future discussions on a Nuclear Power Plant in Turkey.

NPI'S PROPOSAL FOR A NUCLEAR POWER PLANT IN TURKEY

On the basis of the experience described above, we intend to compete in a potential nuclear power project in Turkey on the basis of the German Pressurized Water Reactor Technology. We intend to establish a Consortium which on the foreign suppliers side will include Siemens, Framatome and GEC-Alsthom. Siemens will be responsible for the design, construction and commissioning of the Nuclear Island, Framatome will be in charge of the important components in the Nuclear Steam Supply System such as Reactor Pressure Vessel, Steam Generators and Pressurizer and GEC-Alsthom will be responsible for the Conventional Island. Thereby we combine not only the extensive know-how and industrial capabilities but also the financing potentials in France and Germany. In addition to the foreign partners in the Consortium we will include the Turkish industry in our proposal in order to achieve a maximum possible local content, which in our previous proposal was in the range of 30 % of the contract-value. Technically, the proposal will be based on the nuclear side on the German "Konvoi" -plants, the latest 4-loop Pressurized Water Reactors commissioned in Germany recently and on the conventional side on the technology of GEC-Alsthom with their outstanding experience in the large nuclear power program in France and in export-projects of the French industry in Belgium, South-Korea, South-Africa and China. In the frame of the International Nuclear Technology Forum, we shall concentrate below on the technical description of the Nuclear Island.

TECHNICAL FEATURES OF THE NUCLEAR ISLAND

With the choice of the Convoy-type 4-loop Pressurized Water Reactor with a thermal output of 3850 MW, resulting in a net electrical output of the plant of approximately 1.360 MW we have combi-

ned the advantage of a technology recently licensed under the very stringent German licensing requirements with the economy of scale of large units which on the one hand appears to be necessary for a competitive energy-generation cost and on the other hand fits to the grid capacity installed in Turkey by the time the plant will be commissioned.

PLANT LAYOUT

The plant layout of NPI's power plant is characterized by a distinction between site dependent and site independent buildings. The arrangement of the site independent buildings is selected so that it fits practically to any site and so that the site dependent buildings can be easily adjusted to particular customer's requirements and local conditions (*see figure 1*).

The reactor building is located almost in the centre of the plot plan, thus keeping interconnecting pipes and cables as short as possible. Good accessibility of the buildings during construction is ensured, however. The arrangement of the reactor building on the axis of the turbo-generator set prevents damage to safety related systems and components by turbine missiles. Moreover, it reduces the length of the main steam and feedwater lines to a minimum. The related pilot operated safety and isolation valves are located immediately outside the reactor building in a special compartment, resulting in a very compact arrangement.

The controlled access area is clearly separated from the non-controlled area and comprises the reactor building and parts of the reactor auxiliary building. Access is provided via only one central access point in the reactor auxiliary building. All secondary systems are arranged in the turbine building but no systems related to nuclear safety are located there.

REACTOR BUILDING

The primary components in the reactor building are installed in an as low as possible position in relation to the ground level. The reactor pressure vessel is surrounded by a biological shield which serves as radiation shield.

The reactor pressure vessel together with the other primary components is surrounded by a freestanding steel containment designed to withstand the accident pressure after LOCA. This freestanding, spherical design provides large laydown space on the operating floor and an easy maintainability and inspectability. The leak rate at test pressure is specified to 0.25 vol %/d, whereas the real leak rates achieved are by several factors lower.

The steel shell itself is surrounded by a concrete containment serving as protection against external events and as radiation shield. The space between both forms the annulus. Its atmosphere can be exhausted via filters, thus reducing the effects to the environment after accidents significantly. The doses to the general public after design basis accidents as calculated for German site conditions are under worst case consideration by a factor lower than the permissible limit values.

The design of this double containment together with the design of the ventilation systems, moreover, provides the accessibility of the containment even during operation, which contributes to short annual outage times. The fuel pool is located inside the containment so that the transport ways of the fuel assemblies during refuelling are the shortest possible ones.

EMERGENCY POWER SUPPLY BUILDINGS

In the design of the KONVOI plants, following the German licensing requirements, external events have to be considered. This led to a clear separation of the switchgear, emergency power supply and emergency feed functions in different buildings (*see figure 3*). Each of these buildings is divided into four identical sections, one for each redundancy. The interconnecting pipes and cables are run in physically separated ducts. As a consequence of this strict separation of functions, only the emergency feed building, beside the reactor building itself, is needed to be protected against external events.

The application of this strict separation philosophy furthermore led to a very high redundancy of emergency power diesel generators. The normal emergency power grid, the so-called D1 net, is supplied by four large diesel generators with 50 % capacity each. It serves all safety related functions.

In addition, four smaller diesel motors drive directly the emergency feedwater pumps and are connected to generators serving the so-called D2 net, also following the 4x50 % principle. They are located in the emergency feed building, thus being protected against external events. This building also includes the safety related switchgears and the emergency control room.

THE REACTOR COOLANT SYSTEM

The reactor coolant system of KONVOI plants consists of four identical main coolant loops. The main technical data of the reactor coolant system are given in figure 4. The reactor pressure vessel is the fixpoint of the primary system. It is made of seamless forged ferritic rings with austenitic cladding. The utilization of forged rings as base material leads to the omission of any longitudinal welding.

A large water gap reduces the neutron flux to the RPV material in order to ensure a long and safe life time of this component. All penetrations, for the control rod drives as well as for the incore instrumentation are located at the closure head, so that not bottom penetrations are required. By that, any leakage below the level of the main coolant nozzles can be ruled out (*see figure 5*).

The design of the steam generators probably is the most outstanding feature of our plants (*see figure 6*). The heating tubes are made of the material Incoloy 800, a material which has proven the best operating results.

Not only the material selection is decisive for the operating performance of the steam generators, also the design contributes significantly. The heating tubes are welded to the tubesheet on the primary side and are twice roller-expanded avoiding the formation of a crevice on secondary side. They are supported by tube support grids made of austenitic steel. These so-called egg-crate tube supports consist of two rows of bars which are arranged in two planes at an angle of 120°. This design

provides wide flow cross-sections and prevents the deposition of impurities causing damages to the tubes, known as denting. Furthermore, proper water chemistry specifications for the primary and secondary circuit, harmonized with the materials involved on both sides, have to be kept.

All these precautions in connection with extensive inservice inspection with especially designed manipulators led to outstanding operating results concerning the integrity of the steam generator heating tubes, so that the probability for a primary to secondary leak could be significantly reduced for nuclear power plants equipped with steam generators manufactured according to our specification.

The main coolant pumps are single-stage centrifugal pumps. As shaft seals three identical hydrodynamic seals are used which can be replaced without the necessity of motor removal. The material selection for these seals as well as for the bearings was done under the consideration to reduce the use of antimony to a minimum, thus contributing to an as low as possible radiation exposure to the operating personnel. A special nitrogen operated stand-still seal is provided in order to prevent loss of coolant in case of unavailability of reactor auxiliary systems.

The main coolant lines as well as all other primary components and in addition the secondary side shell of the steam generators are fabricated from forged materials under high quality requirements, so that longitudinal welds are omitted and the number of circumferential welds is reduced to a minimum. This leads to a reduced scope of inservice inspections and in line with that to shorter outage times and again to reduced personnel exposure. Also the replacement of cobalt base alloys in the primary circuit by other hard facing materials has contributed to the reduction of personnel exposure.

For the main coolant lines as well as for the main steam and main feedwater lines inside containment, the LBB-concept (leak before break) is applied which on the basis of careful material selection, load analysis, inservice inspections and high quality of the manufacturing process excludes a catastrophic failure of the pressure boundary. On the basis of the LBB concept, only a 0.1 A break has to be considered as design basis (except for the emergency core cooling system and for the containment design, where still a 2 A break is considered) and leads to the omission of pipe whip restraints. By the avoidance of pipe whip restraints the personnel exposure to the operating personnel accumulated for inservice inspection work at the main coolant loops is reduced by a factor of about 5, since the whip restraints need not any longer to be dismantled and reassembled for inservice inspection work.

SAFETY ASPECTS

The safety systems are designed to reliably shutdown the reactor and keep it in a safe subcritical condition and to remove the residual heat on a long term basis under upset conditions or postulated accidents. The single failure postulate implies a degree of redundancy of $n + 1$. In order to avoid additionally operational restrictions and to allow unrestricted repair, maintenance and testing during normal operation, one additional redundancy is added, resulting in a $n + 2$ system configuration (see figure 7).

This $n + 2$ requirement leads to a safety system configuration of $4 \times 50\%$ for the most challenging design basis accident. Each train of the safety systems is directly assigned to one main coolant loop. The safety trains are functionally and physically separated or structurally protected in order to limit the effects of common cause failures, such as fire or flooding.

The emergency core cooling and residual heat removal system takes over cooling of the reactor core in the event of a loss of coolant accident. The high pressure injection system is able to make-up small coolant losses by injection of borated water from the borated water storage pools into the hot legs of the primary circuit.

The low pressure residual heat removal pumps compensate larger losses of coolant and remove the decay heat in the long term. The trains inject into both, the hot and the cold leg of the primary circuit. The same concept applies for the eight accumulators of which always one is directly assigned to one hot or one cold leg, respectively. This combined injection has been proven very effective in various experimental investigations performed in world-wide cooperation.

Another safety system provided in this design, which is a rather unique one in comparison to competing designs, is the extra borating system. It is also built-up in four independent trains directly assigned to the four main coolant loops. It injects borated water at high concentration into the primary circuit to make-up small primary system leakages. It is furthermore used as a second, independent shutdown system, of special value in the course of Anticipated Transients Without Scram (ATWS).

The same design philosophy as above applies for the emergency feedwater system on the secondary side which is also a four train system. Each train is directly assigned to serve one steam generator in case of loss of main feedwater. It should be emphasised that the heat removal via the secondary side is a very important feature of the nuclear power plant design described in this paper, since the reliable and fast heat removal via the steam generators avoids the necessity of feed and bleed operation on primary side for the mitigation of design basis accidents. This is an additional reason for the provision of a very reliable startup and shutdown system with two 100 % pumps, feeding feedwater into the steam generators from the feedwater tank during operational startup and shutdown and during various transients and accidents.

Another very important factor contributing to the high safety standard of our nuclear power plants is the careful design of the man-machine interfaces. For the mitigation of accidents a reliable event identification is mandatory. After this identification, event oriented countermeasures have to be taken. In order to enable the operator to perform a careful analysis, he should be provided with enough time to avoid decisions and actions under time pressure. Therefore the so-called 30-minute-criterion is applied, which means that all actions for the mitigation of any accident are initiated automatically for the first 30 minutes after onset of an accident. Only after this period of time manual countermeasures by the operators are required.

Probabilistic risk assessments have shown that the overall frequency for accident sequences beyond design basis is about $1,4 \times 10^{-6}$ /year, which is in comparison with other internationally discussed design conditions for future plants, an outstanding good figure. The failure of all relevant safety functions contribute to this figure almost to the same extent, so that a well balanced safety concept was realized. Further consideration of plant internal emergency operating procedures, preventive and mitigative accident mitigation measures reduce the probability of severe radioactive releases to the environment further to below 10^{-7} /year (see figure 8).

CONSTRUCTION AND OPERATING EXPERIENCE

The three KONVOI plants constructed in Germany from 1983 through 1989 were built with an average construction time of about five years (*see figure 9*). The excellent operating experience obtained with these plants so far shall be shown using two very indicative figures. The first is the relative time the plants were connected to the grid. German plants are better characterized by this figure than by the load factor, because some German plants contribute to load follow operation in the European grid. For the KONVOI plants an average service time factor of about 90 % was achieved calculated from first grid connection to the end of 1992 (*see figure 10*).

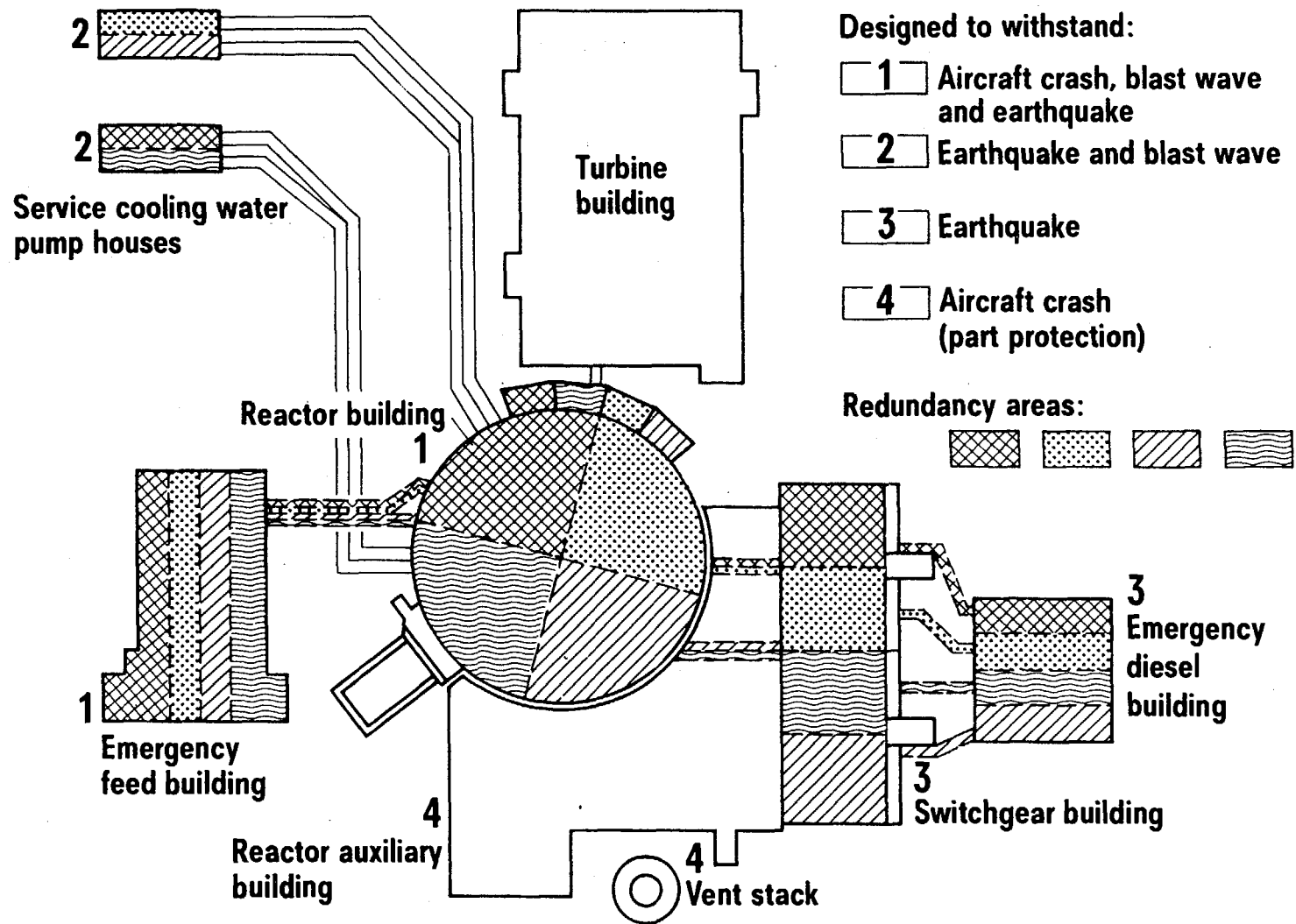
A second very important operational figure demonstrating the high quality of the design with regard to radiation protection is the personnel exposure to the operating personnel. The KONVOI plants have reached here an average figure of less than 0.3 mSv/year (*see figure 11*).

CONCLUSION

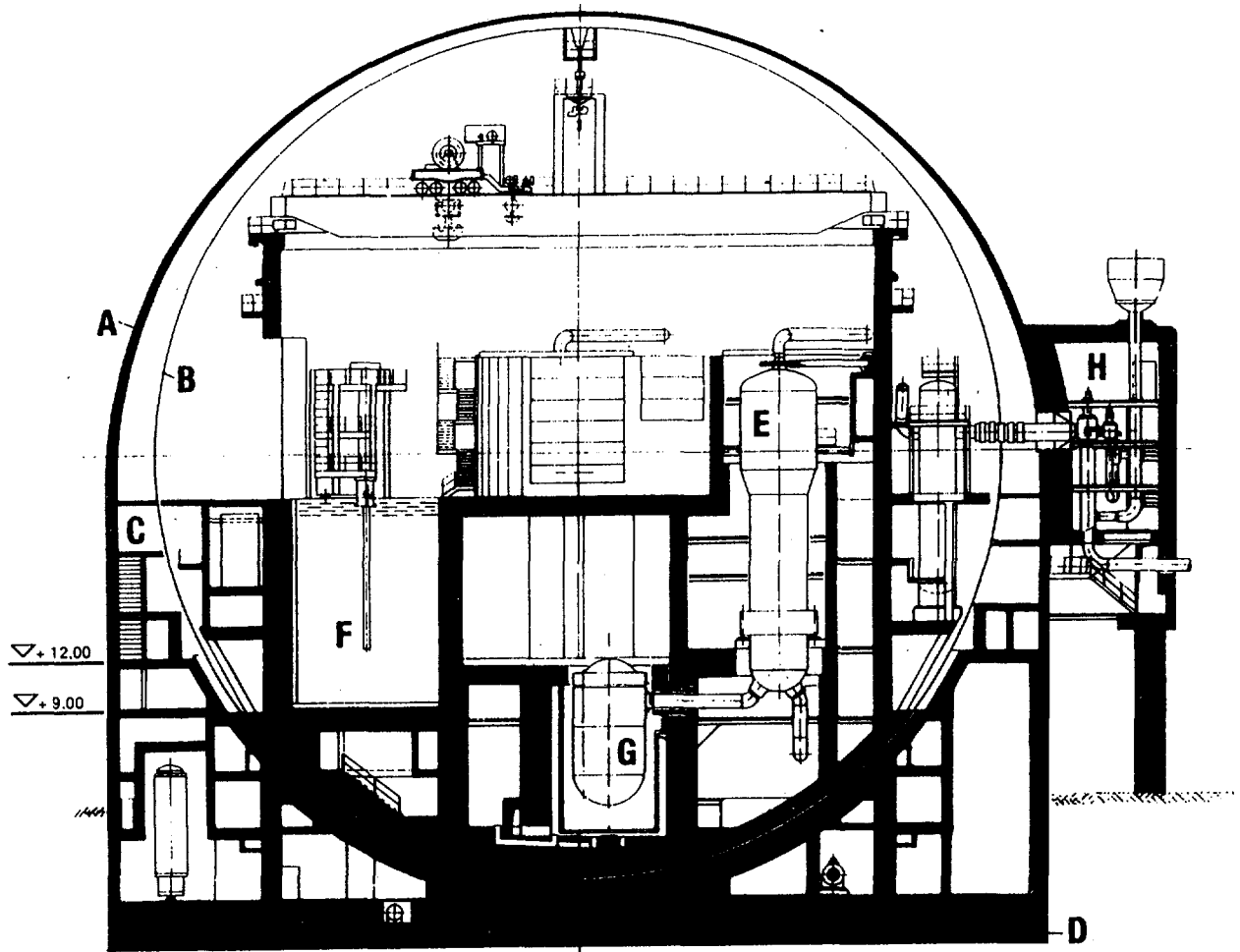
In case Turkey intends to introduce nuclear energy NPI together with their parent companies Siemens and Framatome are prepared to establish a strong consortium in which, besides Siemens and Framatome, GEC-Alsthom and Turkish companies will participate. The technology offered by this consortium would rely on the German PWR-technology for the nuclear part of the plant. This technology has been extensively discussed during the negotiations for the AKKUYU project and has proven its licensability in Turkey. For the conventional side of the plant GEC-Alsthom, the supplier for the French conventional islands, will be responsible.

With this technology, we are able to offer the state of the art in Pressurized Water Reactor Plants. The capabilities and the strength of the partners involved will ensure an efficient implementation of the project.

Fig-1



Building Protection Status and Redundancy Areas for a 1300 MW Convoy PWR Nuclear Power Plant



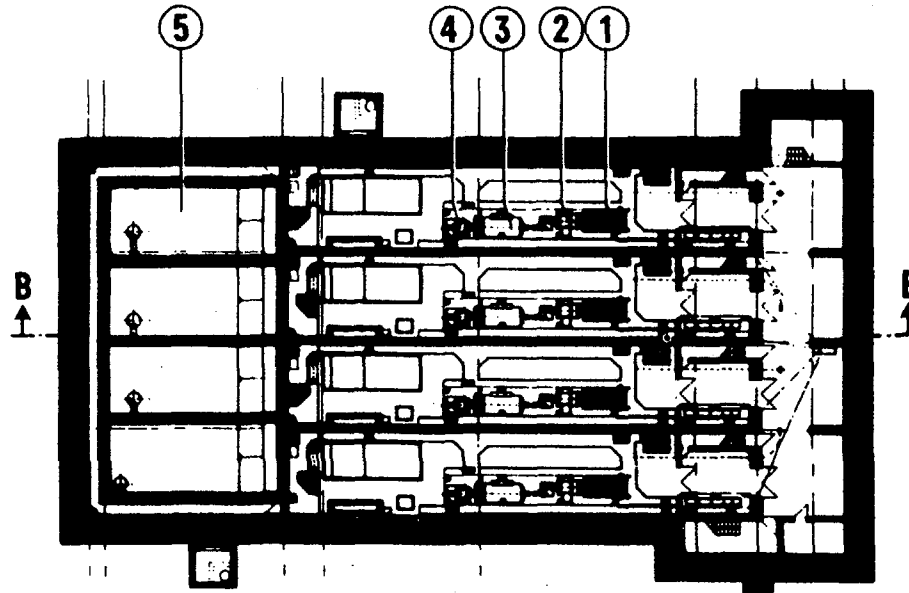
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|--------------------------------------|----------------------------------|
| A Concrete containment | E Steam generator |
| B Spherical steel containment | F Fuel pool |
| C Annulus | G Reactor pressure vessel |
| D Base plate | H Main valve compartment |

PWR

Reactor Building Cross Section

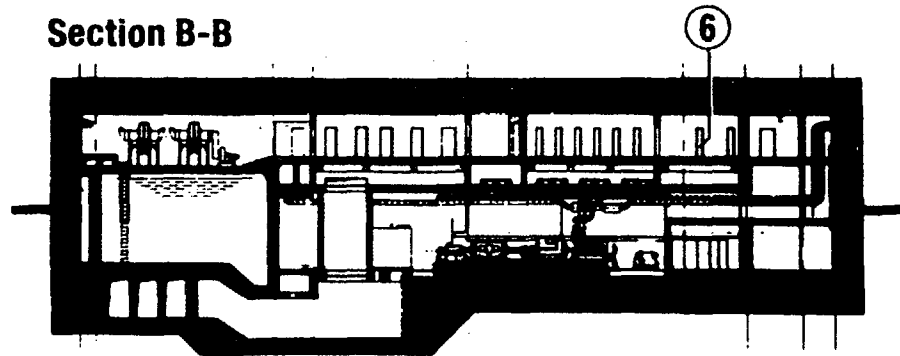
SIEMENS
KWU/N221
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Fig-2



- 1 Diesel Engine**
- 2 Generator**
- 3 Gear**
- 4 Emergency Feed Pump**
- 5 Demineralised Water Pool**
- 6 Remote Shutdown Station**

Section B-B



67
FIG-3

**Emergency Feed Building
KONVOI**

Power

Thermal Reactor Output	3,850 MW
Gross Electrical Output	1,447 MW
Net Electrical Output	1,377 MW

Reactor Coolant System

Number of Coolant Loops	4
Reactor Operating Pressure	158 bar
RPV Inlet Temperature	291.8 °C
RPV Outlet Temperature	325.2 °C

Reactor Pressure Vessel

Inside Diameter	
Cylindrical Shell	5,000 mm
Height	12,362 mm
Weight	507 Mg

Steam Generator

Height	21,300 mm
Diameter	4,812 mm
Tube Material	Incoloy 800

Reactor Coolant Pump

Type	single stage centrifugal pump
Discharge Head	89.6 m
Design Flow Rate	4.969 kg/s

Pressurizer

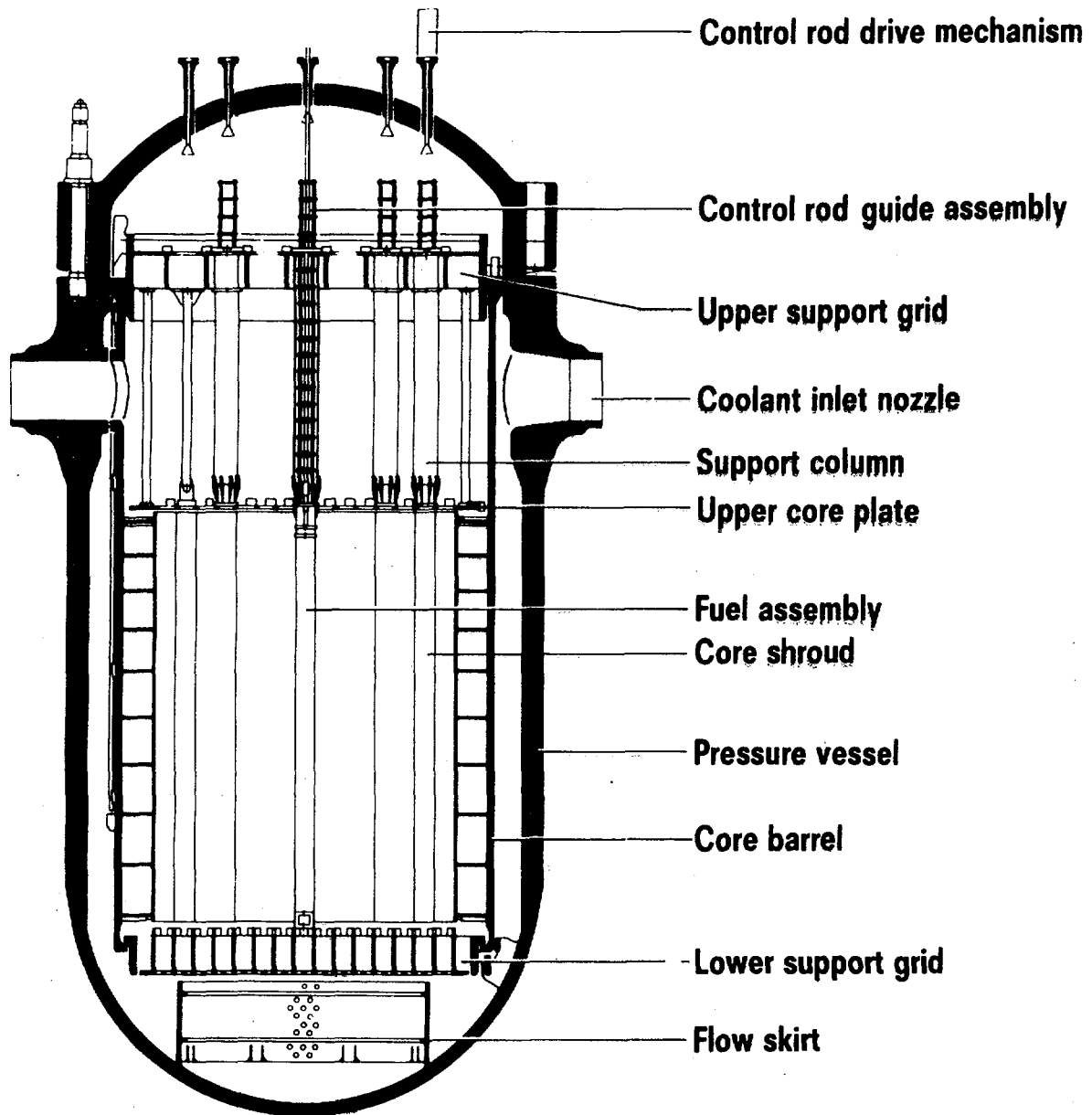
Volume	65 m³
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Containment

Diameter	56 m
Design Pressure	5.3 bar
Design Temperature	145 °C

**NPI PWR 1400 MW, KONVOI,
Main Technical Data**

NPI-ME/Laverenz
SF/0161/ofsubpre-3
April 16, 1992



Reactor Pressure Vessel and Internals

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Fig-5

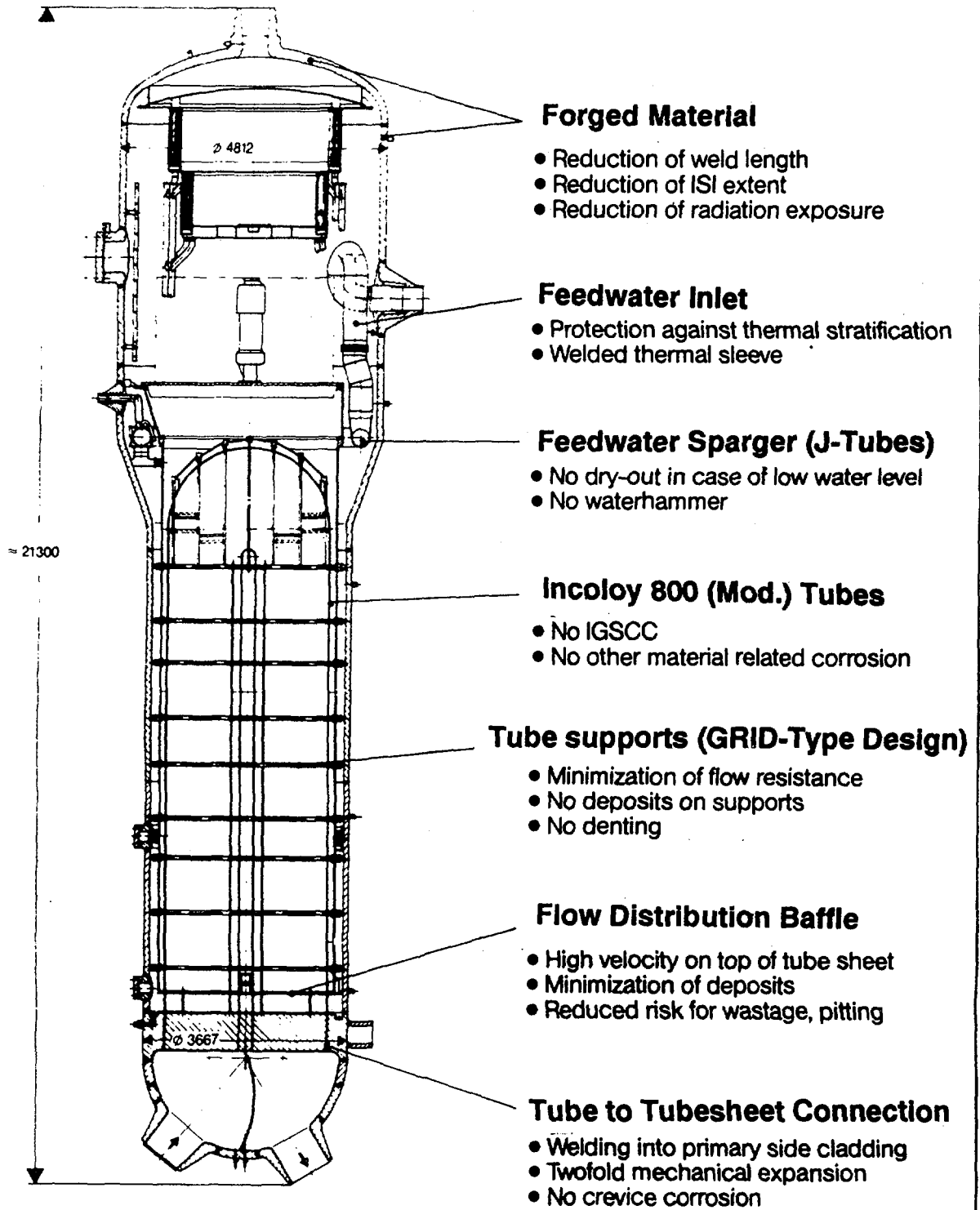


Fig-6

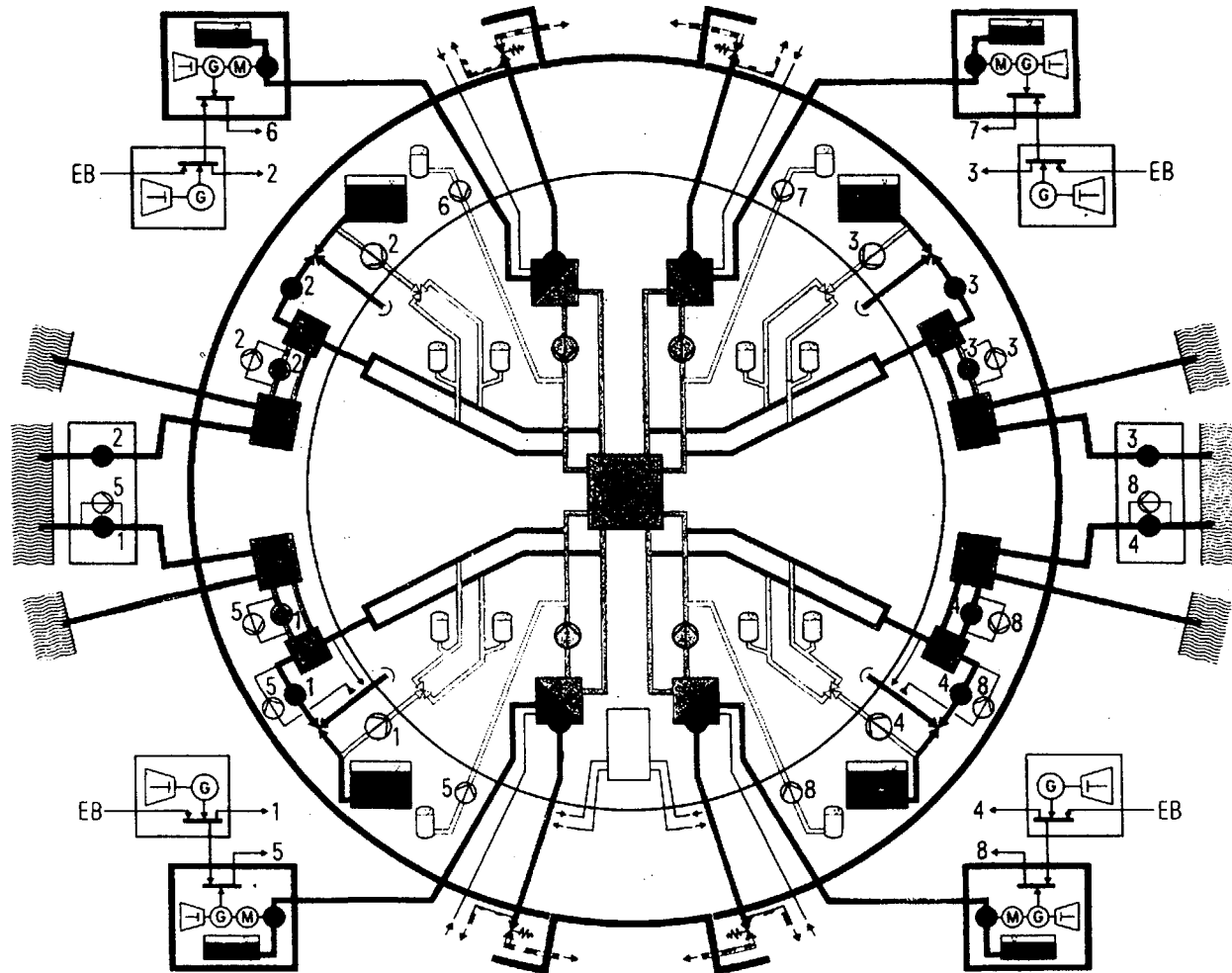
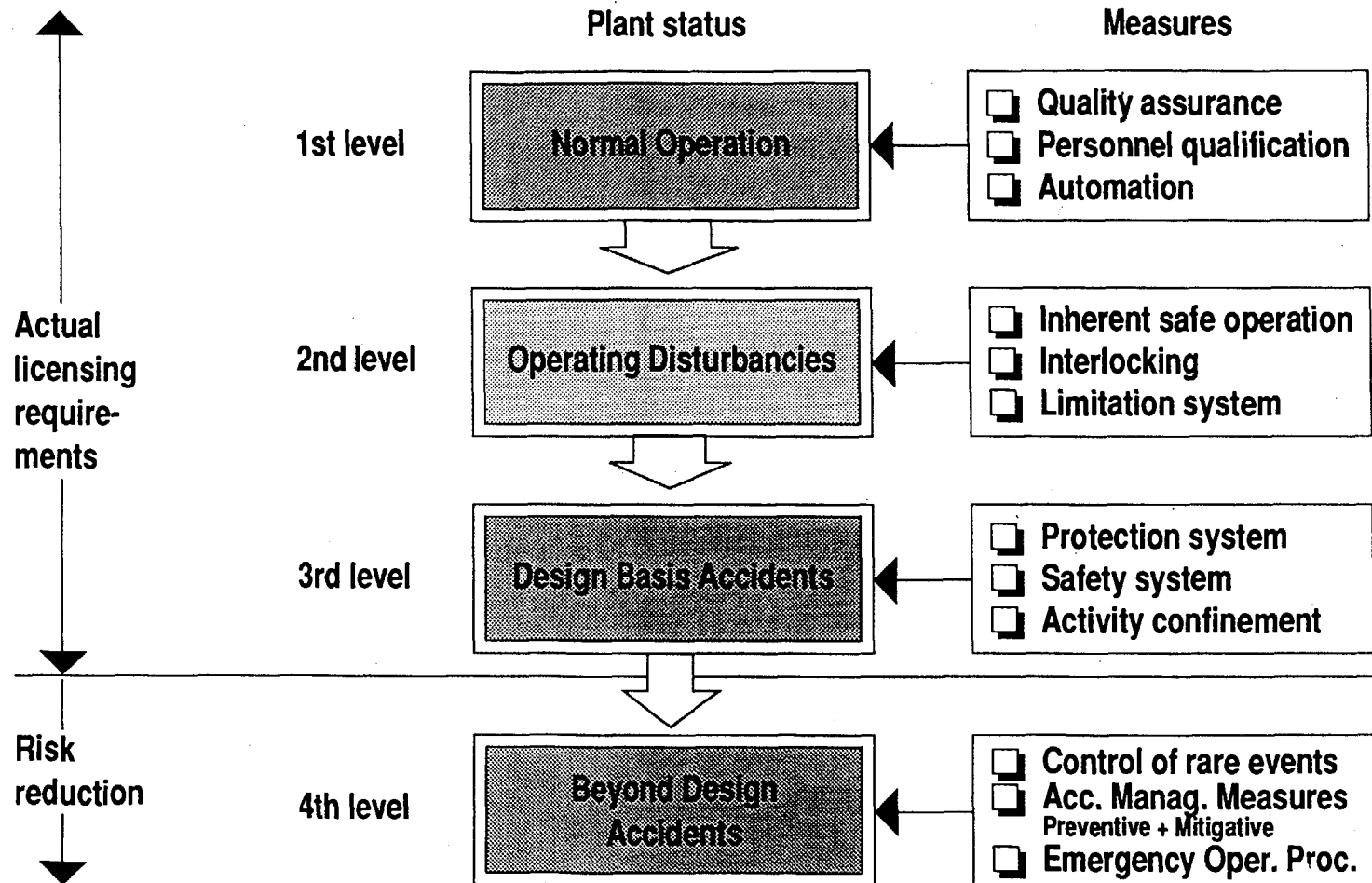


Fig-7

71

DWR 1300 MW Not- u. Nachkühlung 4-Strang Konzept
Emergency Core Cooling Chain 4-Train Concept

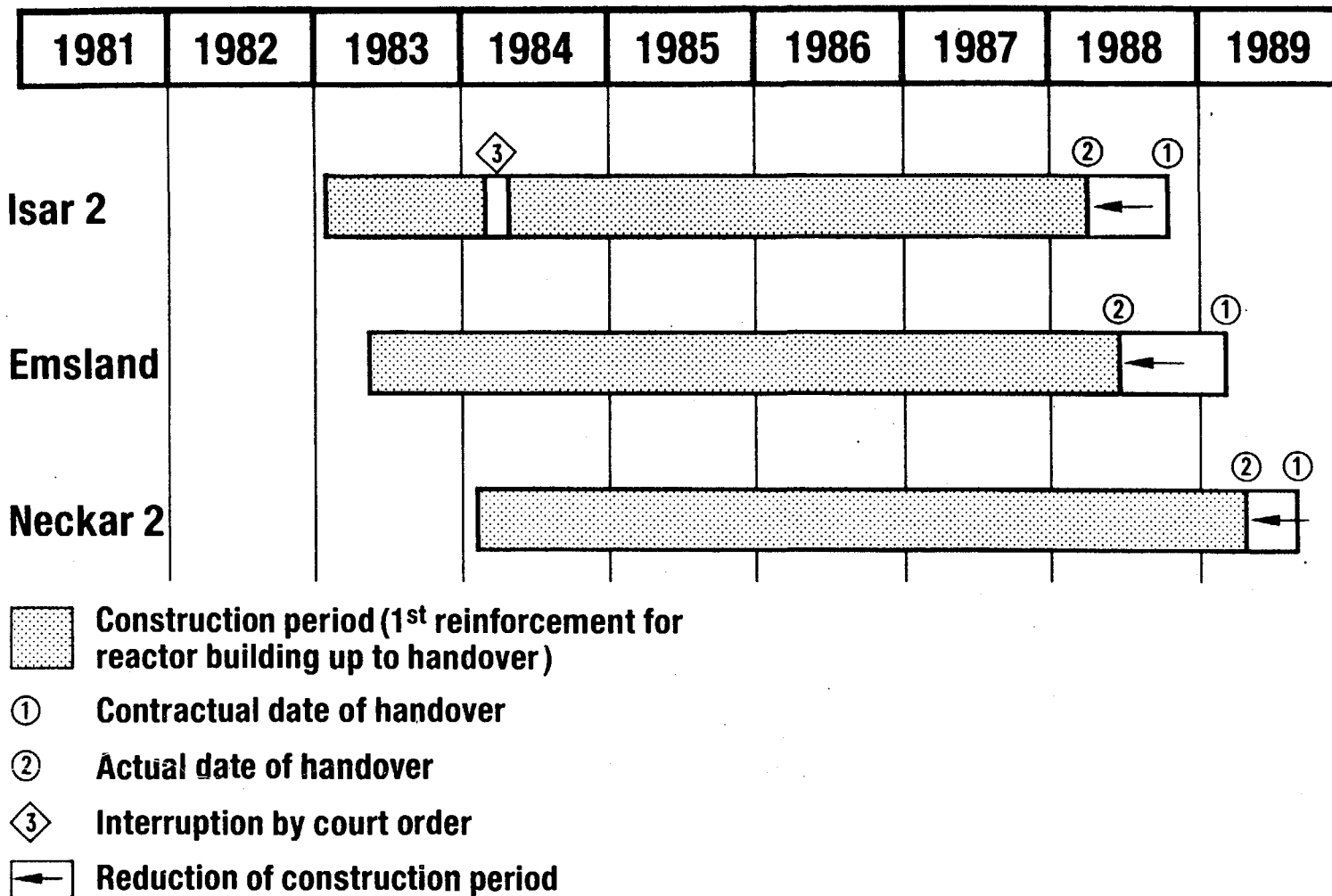
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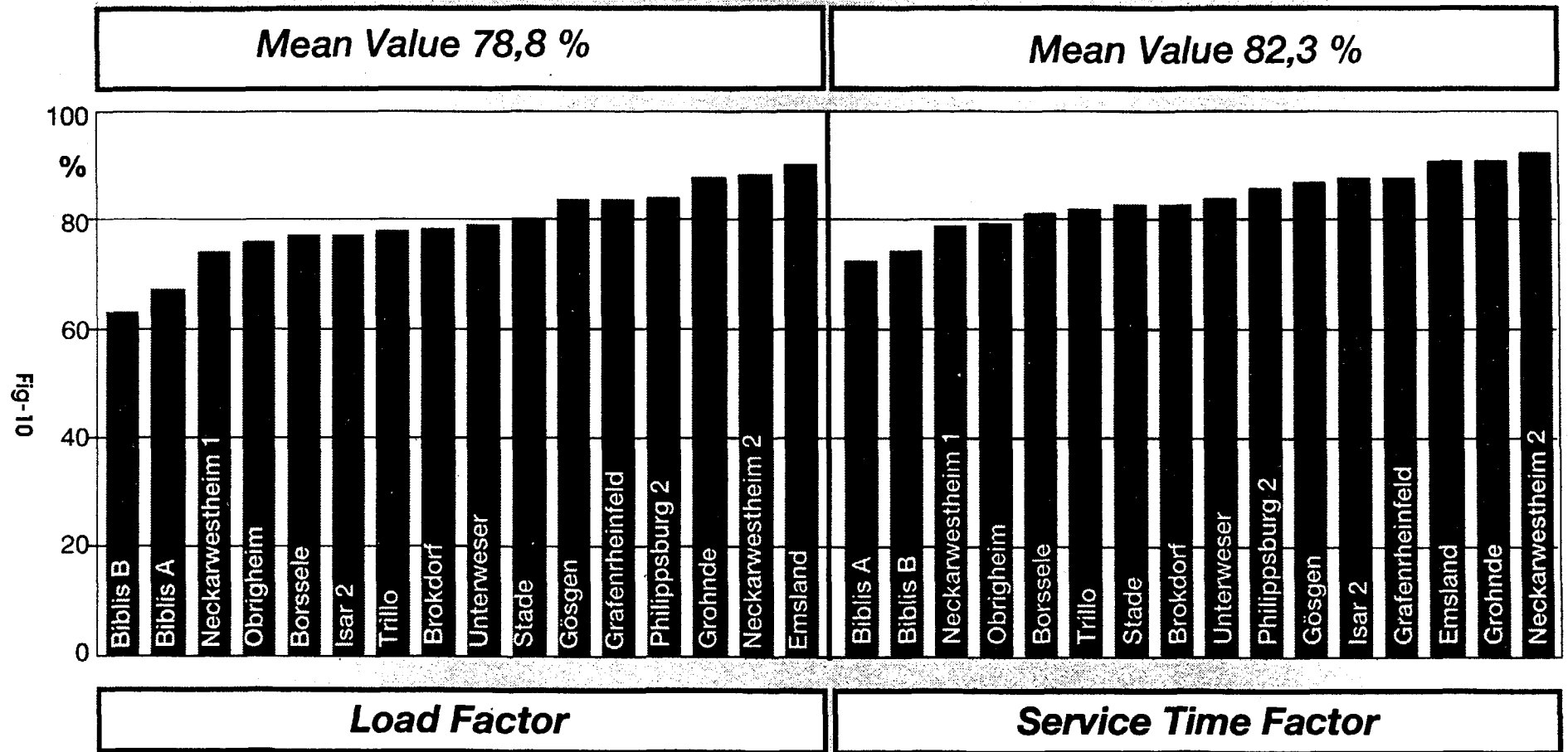
Fig-8

Multilevel Concept of Plant Safety



73 Fig-9

Time Schedule for Convoy Plants



Cumulative Load Factor and Service Time Factor of Siemens-PWR-Plants from Commercial Operation up to December 1992

75

Fig-11

