SERVICE & FUEL
Nuclear Power Plant Services · Power Generation Group · KWU · Nuclear Fuel Cycle

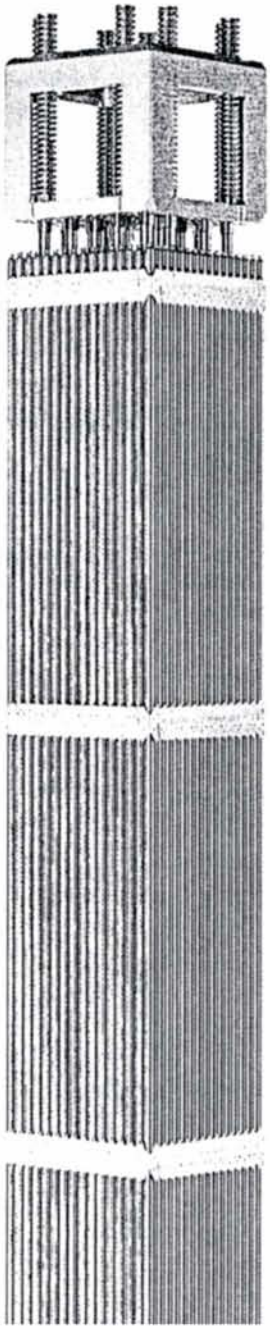
FOCUS X5 and HTP X5 – A New Generation of Higher-Enrichment PWR Fuel Assemblies

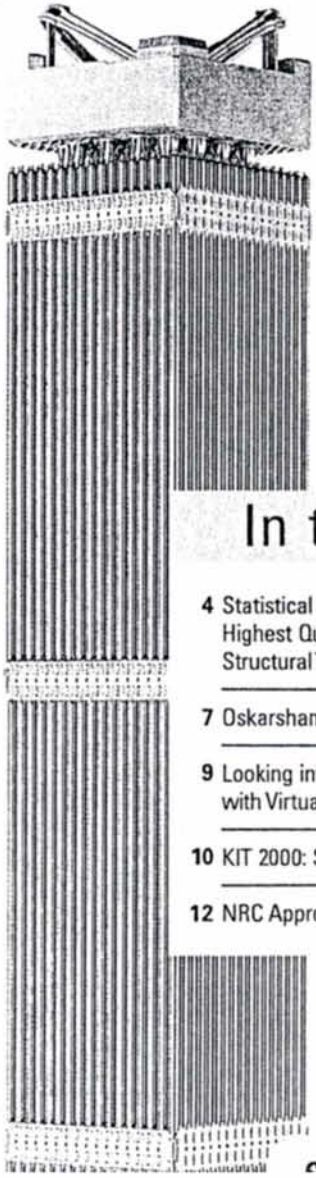
Optimum fuel utilization and maximum fuel assembly reliability are key factors for reducing nuclear fuel cycle costs and thus enhancing the competitiveness of nuclear power. Two of the main objectives pursued in fuel assembly development are therefore to employ higher-enriched fuel and to ensure high operational reliability of the fuel assemblies in reactors with demanding power histories.

Designed for Enrichments up to 5 w/o U235

Our new fuel assemblies FOCUS X5 and HTP X5 for pressurized water reactors (PWRs) are designed for enrichments of up to 5 w/o U235 (hence the "X5" which stands for "extended to 5 w/o U235"). They are based on our service-proven FOCUS and HTP product lines and permit fuel assembly burnups of around 70 MWd/kgU and fuel rod burnups of up to 75 MWd/kgU.

The main difference between these two product lines is that they are equipped with either FOCUS spacers or HTP spacers in the active zone of the fuel assembly. Our irradiation experience with these fuel designs now covers 2800 FOCUS fuel assemblies inserted in 17 PWR plants and 2500 HTP fuel assemblies in 15 plants, both in Germany and abroad. The main features characterizing the FOCUS spacer are its conventional spring-and-dimple fuel rod support configuration and its use of split vanes for enhanced coolant mixing. In the HTP spacer the fuel rods are supported along four pairs of continuous lines, with coolant mixing being effected by curved internal flow channels.





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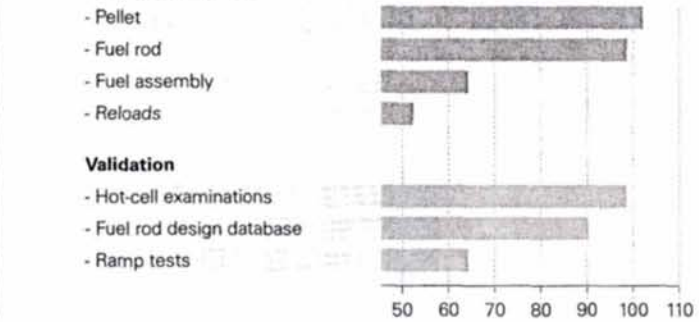
Design Concept Allows for Customization

The material of the cladding tubes is selected in consultation with the plant operator to meet specific plant requirements (such as target burnups, licensing requirements and/or planned operating modes). For rod burnups up to between 55 and 60 MWd/kgU, PCA-2a and PCA-2b throughwall cladding tubes are employed. DUPLEX (DX) tubes are the right choice for even higher burnups. The DX ELS0.8b cladding tube variant has been in use since 1989. The more recently developed DX D4 cladding allows rod burnups in the range of 70 MWd/kgU to be attained. We have also developed modern cladding tubes for even more demanding service conditions which are presently being put through an extensive demonstration and lead test program to verify their suitability for burnups in excess of 75 MWd/kgU.

The irradiation of lead fuel assemblies to high burnup levels plays an important role in verifying the reliability of new fuel designs, components and materials. The experience thus gained minimizes the risk associated with the operation of high-burnup fuel.

Siemens' High-Burnup Experience



Our standard DUPLEX cladding tube variants DX ELS0.8b and DX D4 already cover a very wide range of burnups. The DUPLEX variants DX HPA-4 and DX Zr2.5Nb developed for even more demanding service conditions are currently in the testing phase.

Suitable Cladding Tube Materials

Potential Rod Burnup (MWd/kgU)	Cladding Material	Number of Inserted Fuel Rods	Number of Plants	Maximum Rod Burnup (MWd/kgU)
Reloads				
55–60	Modified Zry-4	110000	12	52
65–68	DX ELS0.8b	480000	12	75
70–73	DX D4	21500	5	70
Leads				
>75	Zr1Nb	1400	4	80
>75	DX Zr2.5Nb	1500	4	80
>75	DX HPA4	1000	1	90

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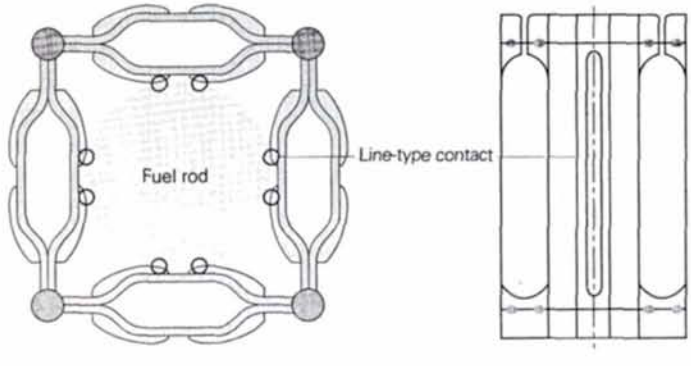
The all-zirconium HTP spacer supports each fuel rod along four pairs of continuous lines, providing a large grid-to-rod contact surface that ensures optimal resistance to fretting. The curved internal flow channels improve coolant mixing and enhance thermal hydraulic per-

HTP Spacer Fuel Rod Support Concept



Enhancements Targeted at Minimizing Risk

For our latest generation of PWR fuel assemblies, the service-proven FOCUS and HTP spacers have been specifically enhanced – drawing on our past operating experience – to ensure safe operation to high burnups together with a very high degree of reliability. Spacer growth has been reduced in the case of the HTP spacer, and the related margins in the FOCUS spacer have been further increased. New developments also include, for example, introduction of the advanced materials PCAm and HPA-4 as well as design improvements such as widening of the slots in the strip intersections. These modifications have been backed up by FMEAs (failure mode and effects analyses).

Greater Margins for Even Higher Operational Reliability

In both the FOCUS X5 and HTP X5 fuel assemblies, an innovative spacer design is used for the bottommost spacer which is subjected to particularly severe loads during reactor operation. This new spacer represents a further development of the HTP spacer. The only differences are that it has straight flow channels for coolant mixing instead of curved channels (which are unnecessary in the bottom spacer) and is made of Inconel instead of Zircaloy.

The HTP spacer's high resistance to fretting has been demonstrated, for example, through its use in core locations with local flow anomalies that place severe demands on rod support. No damage has been observed on HTP fuel assemblies inserted at these locations. This can be attributed to the fact that the HTP spacer supports each fuel rod along eight continuous lines of contact, providing the highest resistance to fretting available anywhere in the world.