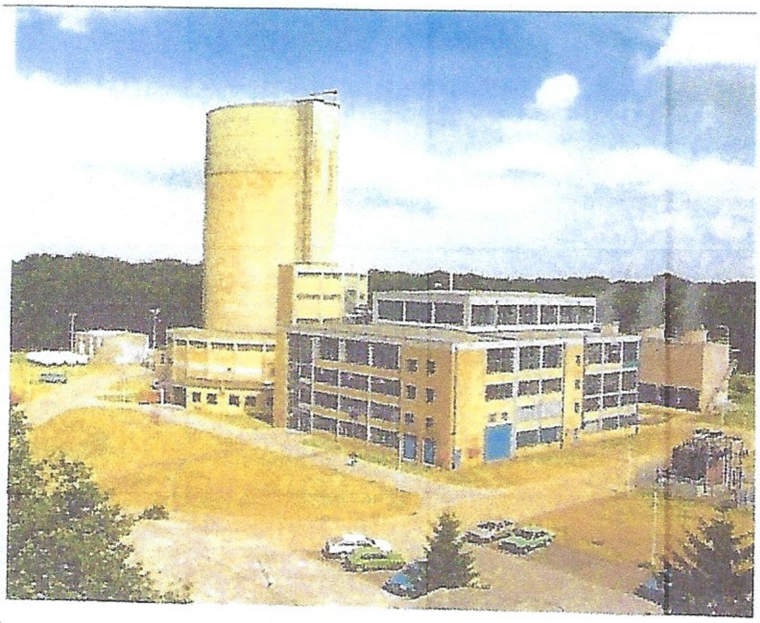
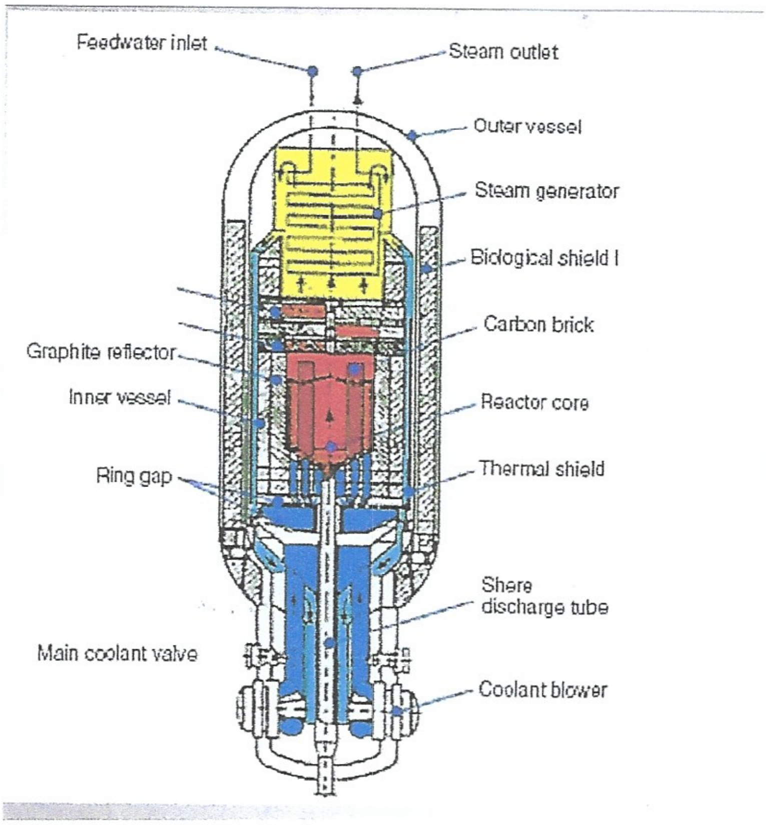


The AVR as Small Modular Thorium

Very High Temperature Reactor
(SMTVHTR)

Experiences-Design-Safety-Fuel Cycle

Dr.-Ing. Urban Cleve



The AVR as Small Modular Thorium Very High Temperature Reactor.

Experiences – Design – Safety – Fuel Cycle

Abstract AMNT 2019

Urban Cleve
Ex CTO of BBC/Krupp

As young engineer in the power plant department of Brown Boveri, Dr. Schulten had the idea to design nuclear power stations without major risk. The following requirements must be accomplished:

- A negativ temperature coefficient had to avoid a MCA;
- Ceramic materials for core construction and fuel elements;
- A homogemous mixture of nuclear fuel and graphite had to be able, to use uranium and thorium as breeding material.
- The produced high temperature heat shall be the basis for production of electricity, drinking water, hydrogen, ect.
- A relatively simple plant, which could be operated in developing countries, to cogenerate electricity and heat.
- Helium used as cooling gas;

The AVR GmbH was established in 1959 and orderd in 1960 to construct the new experimental power station /Fig.:1/ by BBC/Krupp GmbH, which was founded by Brown Boveri and Krupp, mainly through the initiative of Dr. Berthold Beitz, to develop Schultens ideas. (1;2;3;)

Start of the design began in 1960, first criticality reached in 1966, and start of power production in 1967. The AVR was in operation for 22 years and had to be shut down in 1988 by order of the Government. (4;)

No safety incidents occured during that time.

The main design features are:

- Thermal power — 46 MW:
- Electric power — 15 MW
- Steam conditions — 505 °C /72 bar

- He-Cooling gas temperature: 950°C / 10,8 bar;
- Fuel: Triso coated pebbles;
- Power production: 1,6 x 10^{10} kwh;
- Availability: 67.2% average up to 92%

The high availability shows the quality of design of the complete power station with all components including: the new graphite construction, the steam-generator, the blowers, the fuel recycle system and all major components. The combined installation of the pebble bed core and the heat exchanger in one pressure vessel was very important for safety reasons.

The most important experience gained only in the AVR and THTR-300 was first fueling and operation using Pebbles with Triso coated particles, the German development, containing Uranium, Thorium as breeding material and Plutonium. They proved from the beginning as extremely safe and reliable nuclear fuel. /Fig.:2;/ The operation with Triso coated Pebble-Fuel-Elements by continuous charging and measuring of each single pebble makes it possible to keep the NPT. (4;5;9;)

The design of SMTVHTR-Power plants will be nearly the same as the AVR design in a capacity range from 20 MWth up to 100 MWth with the following improvements and modifications: /Fig.: 3;/

- Only one instead of two steel pressure vessels;
- Helium gas pipework without surrounding pipes for He-barrier-gas;
- He/primary – He/secondary heat exchanger instead of steam generator in the pressure vessel;
- He cooling gas temperature up to 1.100° C/ 10 to 70 bar;
- He-barrier-gas system is not necessary;
- He/sec. / water-steam-generator up to 200 bar; 525/525°C;

All the experiences gained from the complete plant, as well as 23 years of successful operation of the AVR will be the basis for the design of the SMTVHTR. It will be designd to produce heat and electricity for all kinds of secondary plants mainly those consuming very high heat, such as coal gasification, drinking water and hydrogen production and natural gas fracking. (6;8;)

This compact Small Modul Reactor Concept can also be installed in large ships to drive them with nuclear power and on platforms to produce electricity in polar regions and for oil drilling platforms. (6;8;)

The safety of this design was proven during the first worldwide first MCA simulation tests. (2;4;5;) The thermal behavior of the AVR core in those difficult situations is shown in /Fig.:4./ These tests proved the total safety of the AVR design under all circumstances. (2;4;7;)

The improved AVR is by far the best developed and operational completely tested SMR.
Further and more detail design explanations are published in atw special print and atw 3 (2018). (2;4;9;)
Larger THTR up to 4.000 MWth are designd with a prestressed concrete pressure vessel (PCPV) for safety reasons. (2;4;) /Fig.:5/

Literature:

1./ "AVR-History." AVR GmbH, special print.
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3./ "AVR Versuchsatomkraftwerk mit Kugelhaufenreaktor in Jülich". Atw special print 5/1966.
4./ "The Technology of High Temperature Reactors". U.Cleve, K.Kugeler, K.Knizia. ICAPP-Congress Nice 2011.
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8./ Results from Nuclear Cogeneration Industriel Initiative". G. Wrochna; NCBI Poland 2016.
9./ "Breeding of fissile Uranium using Thorium with Pebble Fuel Elements". U. Cleve EIR-Conference; May 2013.
10./ "Zukunftsdialog der Bundeskanzlerin: Thorium als Energie-quelle."

Figures:

Fig.: 1 (same in 2/ Fig.:1)
Fig.: 2 (same in 2/ Fig.: 13)
Fig.: 3 (same in 2/ Fig.: 3)

Fig.: 4 (same in 2/ Fig.: 20)
Fig.: 5 (same in 2/ Fig.: 9)

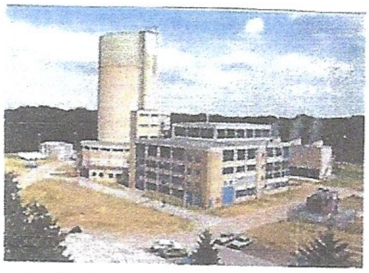


Fig. 1.
The AVR 46 MWth/15 MWel Experimental HTR Power plant.

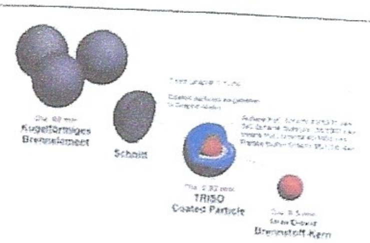


Fig. 13.
Composition of a TRISO-pebble.

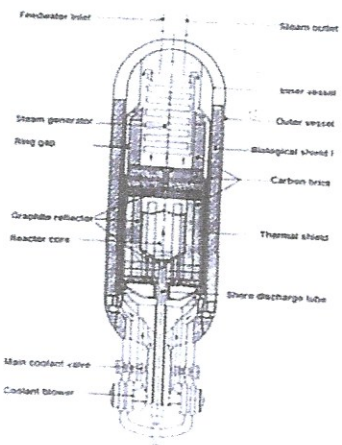


Fig. 3.
Section through the AVR reactor.

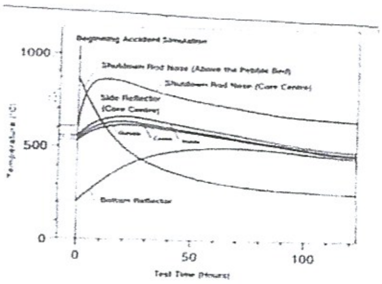


Fig. 20.
Results of loss of coolant LOCA/MCA accident of AVR.

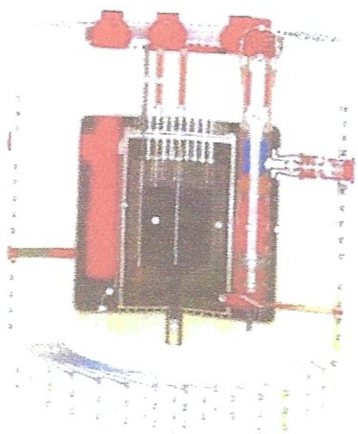


Fig. 9.
Pre-stressed concrete pressure vessel and THRT-300 core.

1966

Im November wird in Frankreich das erste Gezeitenkraftwerk eingeweiht.

1967

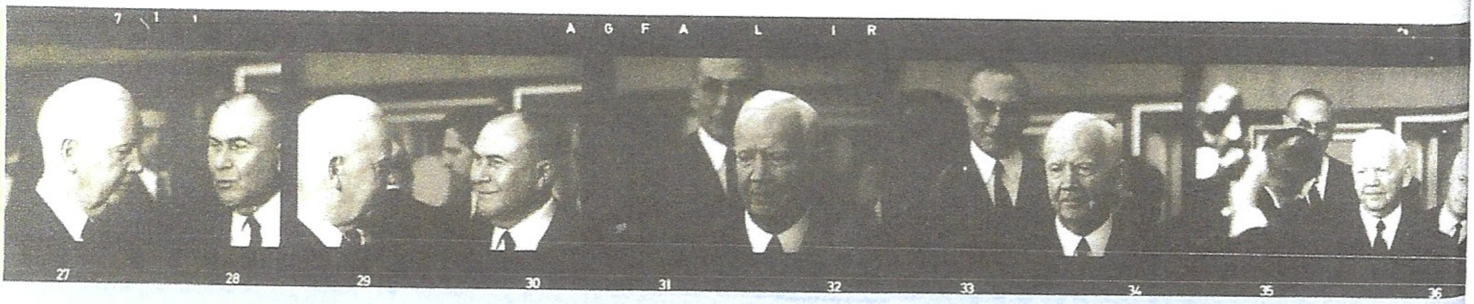
In der BRD beginnt das Farbfernseh-Zeitalter.

Der AVR-Reaktor als Besichtigungsmagnet für Politiker und Staatschefs in den Jahren 1967-69: v.l.n.r.: der Schah von Persien, Minister Dr. Stoltenberg und Bundespräsident Dr. Dr. Heinemann

Als Kritikalität oder kritischer Zustand wird der Normalzustand eines Reaktors bezeichnet, bei dem eine sich selbst erhaltende Kettenreaktion abläuft.

In der heutigen Zeit sind wir daran gewöhnt, dass Computer uns Ergebnisse selbst zu den komplexesten Berechnungen in Sekundenbruchteilen liefern. Es gab in den 1960er Jahren noch keine CAD-Programme, die neben der 3D-Erstellung und -Visualisierung des Konstruktionsteils auch noch Finite-Elemente-Berechnungen durchführen und die zugehörige Konstruktionszeichnung inklusive der Bemaßung quasi als Nebenprodukt auswerfen konnten. Zur Planungs- und Bauzeit des AVR-Reaktors musste noch von Hand und per Rechenschieber gerechnet werden. Die Richtigkeit der Ergebnisse unterlag jeweils der Verantwortung des Einzelnen, sei es Wissenschaftler, Konstrukteur oder technischer Zeichner.

Die Leistung aller Beteiligten an diesem Projekt kann deshalb nicht hoch genug eingeschätzt und gewürdigt werden.



Besuch des Bundespräsidenten Heinrich Lübke am 22. Oktober 1968