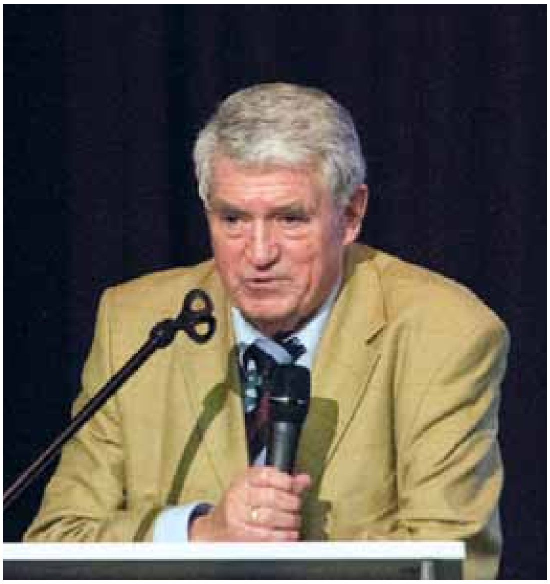
Urban Cleve

Breeding of Fissile Uranium 233 Using Thorium 232 with Pebble Fuel Elements

Dr. Eng. Cleve was head of the engineering department of Brown Boveri/Krupp Reaktorbau GmbH, where he was responsible for the engineering, design, building, testing, and operation of the AVR high-temperature reactor. Later he worked in management for companies that built large power plants. He retired in 1992, and is now the last living member of the BBC/Krupp team. We use here a selection of his slides; the video is at http://newparadigm.schillerinstitute.com



EIRNS/Daniel-Enrico Grasenack-Tente

Dr. Cleve told the conference: "We are in the position to build safe THTR nuclear power plants of all sizes that the market demands."

On Sept. 29, 2010, I gave a talk at an *EIR* event in Frankfurt, with the theme "Technology and Future Possible Applications of Nuclear High Temperature Reactors." It concludes with the statement: "The use of thorium-232 allows the 'breeding' of fissile uranium-233 as a new fuel. Therefore the reserves of U-235, in combination with thorium-232, will suffice indefinitely."

Thorium can be found in small amounts in the Earth's crust. It accumulates, among other places, as a non-usable waste product of the quarrying of rare earths. Pure thorium is a silver crystal, but it is often oxidized and becomes grayish-black. It is considered a radioactive element. Its melting point is 1,842°C. Irradiating thorium Th_{232} with neutrons—thermal neutrons are better suited than fast neutrons—breeds Th_{233}, which decays through protactinium Pa_{233} into uranium-233. Thus it can be used as fertile material in thermal reactors such as the THTR [Thorium High-Temperature Reactor] and the AVR [Experimental Reactor Consortium], as well as the Chinese HTR-10.

The German development of this technology was already tested in the AVR-145MW_{th} reactor in the years prior to the 1989 politically mandated shutdown of this reactor. The AVR was at that time the world's only reactor that was available for this purpose.

Now, more than 20 years later, this technology is accorded great significance worldwide, particularly in China but also in Japan, the U.S.A., Russia, Canada, the Netherlands, Great Britain, France, India, South Africa, and Norway. Please allow me to read a few translated excerpts from a report by Ambrose Evans-Pritchard posted on the Lars Schall website from Jan. 12, 2013:[1]

- "The Chinese are running away with thorium energy, sharpening a global race for the prize of clean, cheap, and safe nuclear power. In Europe, meanwhile, when it comes to thorium, we're threatened with the lights going out."
- [Quoting Prof. Robert Cywinksi from Huddersfield University, who anchors the U.K.'s thorium research network, ThorEA:] "People are beginning to realize that uranium isn't sustainable. We're going to have to breed new nuclear fuel."
- "The aim is to break free of the archaic pressurized-

1. A. Evans-Pritchard: "Chinesen bahnen Weg fur Thorium-Nutzung," Lars Schall, January 2013. The article had appeared in the *Daily Telegraph* on Jan. 6, and all quotes are taken from that English text, except for the reference to Europe, which did not appear there—translator's note.

water reactors fueled by uranium—originally designed for US submarines in the 1950s—opting instead for a new generation of thorium reactors that produce far less toxic waste and cannot blow their top like Fukushima."

• [Referring to Jiang Mianheng, son of former Chinese President Jiang Zemin, who is heading a project on thorium reactors:] "He says that China has enough thorium to power its electricity needs for '20,000 years.'"

• "The beauty of thorium is that you cannot have a Fukushima disaster."

• "Thorium has its flaws.... It is 'fertile' but not fissile, and has to be converted into uranium 233."

• "It can even burn up existing stockpiles of plutonium and hazardous waste."

These are just a few quotes from the 2013 article by Evans-Pritchard.

These were the basic ideas of Prof. Dr. Rudolf Schulten about the development of the THTR-300 back in 1966. He was 50 years ahead of the rest of the world in his thoughts about power engineering, and these thoughts were and still are a milestone in the development of nuclear power. His forward-looking ideas can really only be compared with those of Wernher von Braun about space travel.

So the time has come to put his legacy into action.

The German THTR 300 MWe thorium high-temperature reactor was designed and built starting in 1966, and put into operation in 1986 at the Schmehausen VEW power plant. It was shut down in 1989 by order of the government of the state of North Rhine-Westphalia. Germany thus had more than a 20-year head start in developing this technology, which the world now views as outstanding.

China is building upon it. An experimental HTR-10 MW_{th} is in operation, and a 2 × 250 MW_{th} HTR double-block reactor (for a total of 500MW_{th}, both to be fitted with pebble fuel elements and with a steam turbine of 210 MWe) is under construction and will go into operation in about 2015.

I described in my earlier lecture the pebble fuel elements with "coated particles" [**Figure 1**], which were developed through extensive international collaboration. A spherical fuel element with a diameter of 60 mm has a 5-mm-thick graphite shell. Inside it there are ca. 15,000-35,000 Triso-coated particles [**Figure 2**], each with three silicon carbide shells that are gas-tight up to 1,600°C, having a diameter of 0.9 mm, pressed into the interior of the graphite sphere. The individual particles contain the fuel of various compositions. Each particle thus has its own three-fold containment against the escape of fission products.

This is the reason for the extremely low radioactive load of the entire volume of the primary gas helium in the THTR-300, with 1 × 107 Bq at 47,000 m^3 of helium gas volume = 4.7 × 1011 Bq = 13 Ci. Within a 2,000 m radius of the THTR-300, a total

FIGURE 1

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FIGURE 2

TRISO Fuel Elements

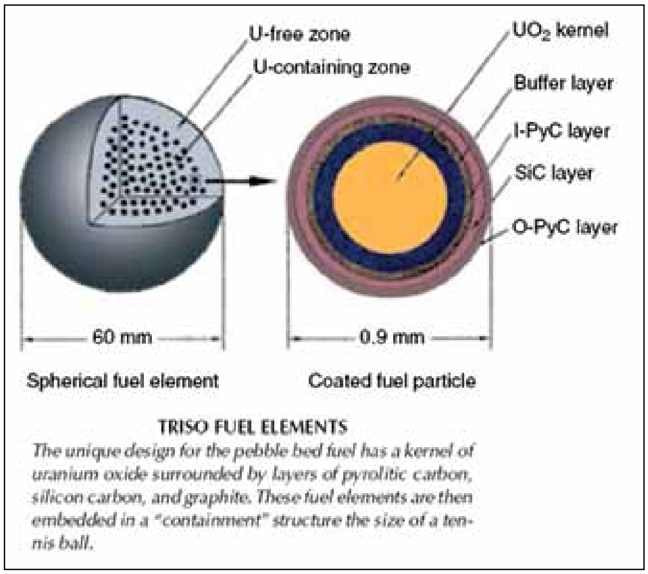

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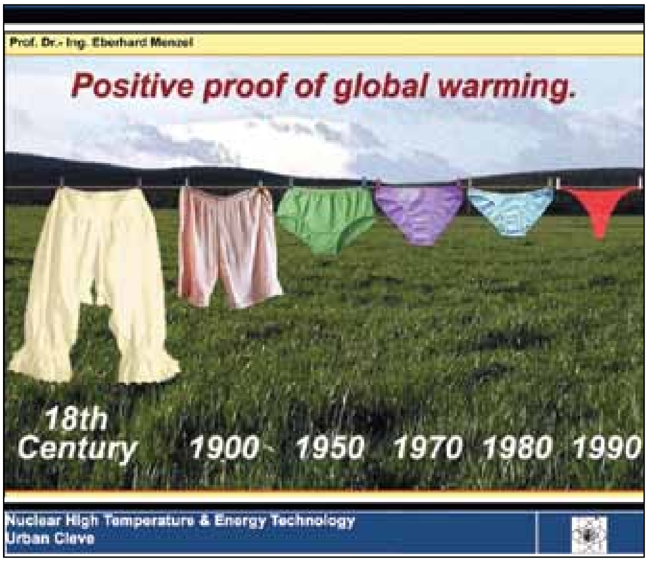
FIGURE 3



emission of the primary gas would have led to soil contamination of approximately 37,302 Bq/m^2, if all the fallout occurred in this close range. This result can be compared to the global fallout from the Chernobyl disaster, which measured 50,000 Bq/m^2 in far-off Schmehausen alone.

This high safety standard is further enhanced by the barriers of the pre-stressed concrete vessel and the containment, whereby new constructions are able to collect the entire helium content of the primary circuit. This means that the "zero-emission concept" has been achieved.

The inherent safety, based on the principles of nuclear physics, was tested and proven in two Maximum Credible Accident tests of the AVR in 1967 and 1976, and an identical test of the Chinese HTR-10. These extreme tests could never have been conducted in a different reactor design; it would have been catastrophic. The reactor accidents at Chernobyl and Fukushima would not have occurred if an HTR had been operating there. Meltdowns are not possible in the HTR/THTR nuclear power plants.

Among the fuel compositions tested in the AVR and used in the THTR-300 with U_{235}-Th_{232} and the U_{233} bred from that, were (U, Th) C_2, (U, Th) O_2, UO_2, ThO_2. Also tested in South Africa were combinations with U_{235}-U_{238}, Th_{232}, Pu-238, 239, 240, 241, 242; all test results are available. All the tests showed that a common combustion of these substances is possible. By means of the burnup measurement of each individual fuel assembly, the burnup of plutonium can also be determined. This makes it possible to meet the requirements of the Non-Proliferation Treaty (NPT).

The pebble fuel element is therefore the most universal, safest, and operationally simplest fuel used by any known nuclear power plants. Fuel cooling installations are not necessary. The spent fuel elements do not require refrigeration, neither in the nuclear power plant itself nor even in storage containers. In the absence of cooling, explosions in the spent fuel holding basins, such as in Fukushima, are excluded.

This also eliminates all the political problems of the search for a permanent waste repository.

With both the negative and positive experiences we have had from the operation of the AVR and THTR-300, we can say that this is, to a large extent, a proven technology.

We are thus in the position to build safe THTR nuclear power plants of all sizes that the market demands.

Translated from German by Susan Welsh

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