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USE OF GASCOOLED HIGH TEMPERATURE TRANSPORTABLE REACTORS FOR FOOD PRESERVATION

Remond R. Pahladsingh
62-12 Tolhuis – 6537 TG Nijmegen
The Netherlands

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Remond R. Pahladsingh
62-12 Tolhuis – 6537 TG Nijmegen   The Netherlands
Phone: +31 24 3443931
Fax: +31 24 3443931
e-mail: r.pahladsingh2@chello.nl

Keywords: Inherent Safety, Natural Safety System, Natural Cooling System, Radiation Processing of Food and Medical Products.

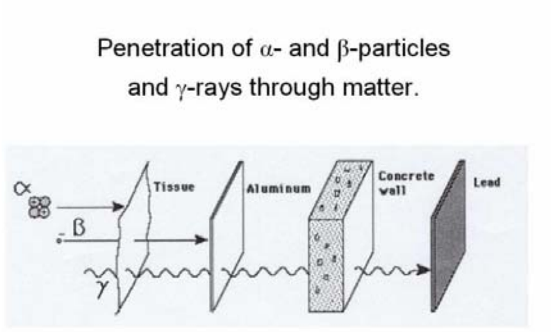
Abstract:
During the fission process in most of the presently operating nuclear reactors nuclear energy is converted into thermal energy and transferred to common steamcycles for powergeneration. As part of the fission process also α-, β- and neutrons particles are released from the nucleus; the release of gamma-rays is also a part of the fission process.

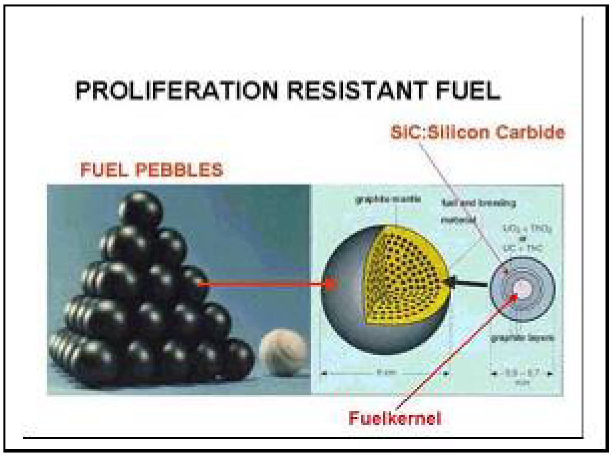
In present nuclear reactors α-, β-, neutrons particles and particularly Gamma-rays are not gainfully used as a result of the reactor design and of the containment. These plants are built as required by present regulations and international standards for safety.

The inherently safe HTR reactor, by its physics and design, does not need a special reinforced containment and it is worth looking into the possibilities of this design feature to use the by-products, such as Gamma-rays, from nuclear fission.

In the HTR Pebble Bed Reactors the α-, and β-particles will remain in the kernels in the pebbles. This means that only the neutron particles and gamma-rays will be available outside the reactor pressure vessel.

In this report a proposal is presented to use the gamma-rays of the transportable, modular HTR reactor for irradiation of food and agricultural produce.





For neutron shielding a reflector is placed inside the reactor while outside the reactor neutron- and thermal-shielding will be accomplished with water.
The high energy gamma-rays will pass through the water-shield and could be harnessed for radiation processing of food and medical products, [figure 2/4].

Introduction

The SGR reactor has been developed using the DOE Generation IV guidelines, appendix A, for transportable, modular, simple and economical power-plants for the future electricity supply. In the concept also the additional requirements to meet deregulation and liberalization have been included and an attempt has been made to maximize the use of the types of energy that are released during the fission process. By doing so, it shows that the high temperature SGR power-plants becomes more of an energy-station instead of an electric power plant and can provide several useful solutions for important basic requirements for our present and future societies.

For papers on co-generation and reactor shielding of the SGR, see ICONE papers of previous conferences [6, 7].

Constraints in Limits to the Growth

In the last century Dr. M.K. Hubbert published his calculation about the peaking of the oil production for the USA and for the World. In figure 1 the graphs of Dr. Hubbert and Dr. Ryman are shown. In the figure the following information is added to these graphs :

1-increase in use of fertilizers from 1940 through 1975 [11], (Club of Rome)

2-decrease in availability of agricultural resources [11], (Club of Rome)

3- increase in global population [11], (Club of Rome).

4- expected growth in oil consumption [1], IEA (Paris).

It is evident that these developments and their fall-out will create tremendous pressure on the availability of Food and Water in this century. It also means that huge efforts have to be made to preserve food and agriculture produce to minimize use of land, water and fertilizers and yet to be able to provide sufficient food for a humane world.

The use of gamma-rays for food preservation by radiation processing has been studied extensively, is well-established and is used in many countries in the world at the moment (Irradiation For Food Safety And Quality, P. Loaharanu and P. Thomas (Eds.) Technomic Publishing Co. Inc., Basel, 2001).

Present practice in food and agricultural produce irradiation.

The common practice is to either use radioisotope resources such as Cobalt 60 and Cesium 137 as a source of gamma rays or machine sources such as electron accelerators as a source of electrons or X-rays. The energy levels permitted for food processing by electrons and x-rays are 10 and 5 MeV, respectively. For these applications special irradiation plants have to be constructed that have inherent disadvantages in relation to processing of agricultural produce. Agricultural commodities are season, region and location specific. Economic viability of radiation processing plants is governed not only by the annual throughput but also by the year round availability of the food and agricultural commodities for processing. The economic viability of stationary plants therefore often becomes questionable. In another scenario, for example, ships going for deep sea fishing may not be able to bring their produce to onshore radiation processing plants well in time. Such vessels would greatly benefit from an on board multipurpose energy station (to be all the time at the right location when looked at from preservation and packaging of fishery products). There is a long standing need for portable radiation processing units, either accelerator or radioisotope based. By combining electric power generation, heat production, drinking water production and food preservation the SGR will be a competitive solution in the search for safe preservation technologies.

Concerns on present application of cobalt-60 (Co60) and cesium137 (Cs137)

There is a growing concern that a substantial increase in the use of Cobalt 60 and Cesium 137 could create problems in safe management, handling and disposal of used "man- made" radioactive materials [14, 15]

Growing need for Gamma-rays for Food preservation and sterilization.

When studying the conclusions in Limits to the Growth [11] it is evident that to be able to secure food and agriculture produce for the global population in this century, intensive food-preservation technology will be required. As a possible solution the HTR reactor technology with the multi-pass fuel concept is proposed as shown in figure 2 in the HTR-modulreaktor that is being used as the reference design for all new pebble bed HTR reactors.

From the point of view of application to food and medical products, one would essentially need radiation energies in the range of 1 to 5 MeV and doses in the range of 30 to 10000 Gy. For sterilization of food, medical and health-care product doses higher than 10 kGy and up to 25-40 kGy may be required .The main focus in getting a fixed energy and hence a uniform dose delivery pattern should be possible in the HTR-reactor with the multipass fuelcycle set-up. One needs to map the gamma ray intensities and doses that would be available at different points in the irradiation chambers spatially and temporally.

Advantage of using inherently safe SGR for gamma radiation application

In the past the nuclear reactor kept growing to huge powerplants that needed extensive high voltage grids to bring the power to the consumer; the present EPR reactor has a power output of 1600 MWe. Because of the not rational exposure of the public to the threat of nuclear energy, often used with rather vague agenda's, nuclear plants had to disappear behind the horizon. The popular hype (is) was: "NIMBY: Not in my backyard"; in connection with radiation this is denouncing reality and life.

The SGR, see figure 3, with its inherently safe features, as shown in the test results in appendix B and [19], can be brought back in the society, as one of the solutions for the future many Mega-cities, see figure 6, to exploit all the benefits that are possible with the fission process of thorium and uranium while at the same time offer the best safety requirements to the ever exposure to radiation of all life.

During electric power generation, the SGR will provide the gamma rays that can be continuously measured and used to control a variable speed conveyor system to expose food, agricultural produce, healthcare and medical products to the right dose for safe and hygienic used in the society. In table 1 advisory technological dose limits for food and agriculture produce is shown.

Conclusions

With the extensive research and data available on preservation [9,12,13,16,17] of food and agriculture produce it is possible to develop systems for the high temperature gascooled reactors, with the multi-pass fuel-cycle, that can effectively provide the right dose intensity and exposure time for each product to be preserved or sterilized. This can be done by measurement of the gamma-intensity in the gamma-chambers and use this information/data for the right exposure time of each product using variable speed belt conveying systems. These conveyor systems could be installed vertical or horizontal as shown in figure: 5

This type of application of the SGR energy-station for irradiation purposes can avoid the building of special food irradiation plants and the energy released during fission is used in a more effective way. Furthermore fuel usage and disposal control is more stricter for nuclear power stations in comparison with cobalt and cesium "man-made" isotopes.

Finally it is worth mentioning that the pebble bed SGR reactor can be fit in a nuclear fuel program the increase fuel efficiency whereby the pebble bed reactor is the first user of the enriched fuel (15-18%); the used pebble with a feul enrichment of about 4% could be used in LWR- and Candu reactor fuelcycles before final storage as spent- or processed fuel [20].

Acknowledgement:

The author wants to thank all his friends and colleagues in the nuclear industry for their suggestions and support to be able to write this report.

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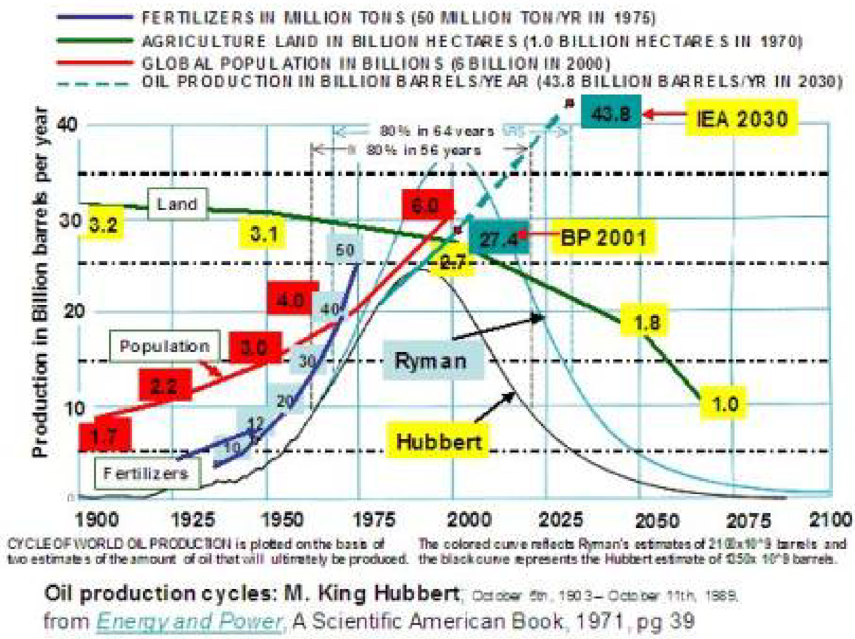
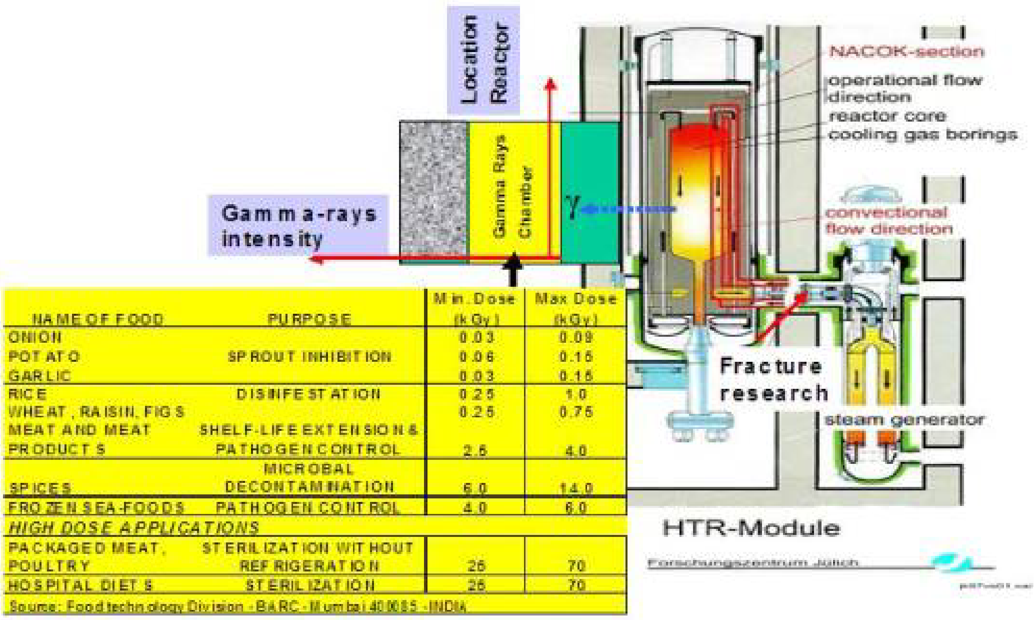


Figure 1: Hubbert's Graphs on peaking of global oil-production



NAME OF FOOD	PURPOSE	Min. Dose (kGy)	Max Dose (kGy)
ONION	SPROUT INHIBITION	0.03	0.09
POTATO		0.06	0.15
GARLIC		0.03	0.15
RICE	DISINFESTATION	0.25	1.0
WHEAT, RAISIN, FIGS		0.25	0.75
MEAT AND MEAT PRODUCTS	SHELF-LIFE EXTENSION & PATHOGEN CONTROL	2.5	4.0
SPICES	MICROBAL DECONTAMINATION	6.0	14.0
FROZEN SEA-FOODS	PATHOGEN CONTROL	4.0	6.0
HIGH DOSE APPLICATIONS			
PACKAGED MEAT, POULTRY	STERILIZATION WITHOUT REFRIGERATION	25	70
HOSPITAL DIETS	STERILIZATION	25	70

Source: Food technology Division - BARC - Mumbai 400085 - INDIA

Figure 2: The HTR-moduulreaktor design with new section for irradiation purposes

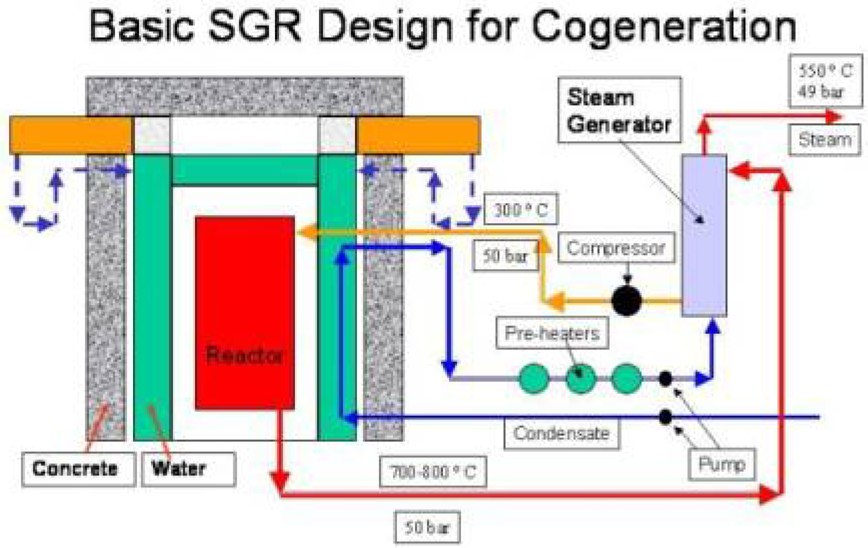


Figure 3: The 10-50 MW electric power SGR Multipurpose Energy-station

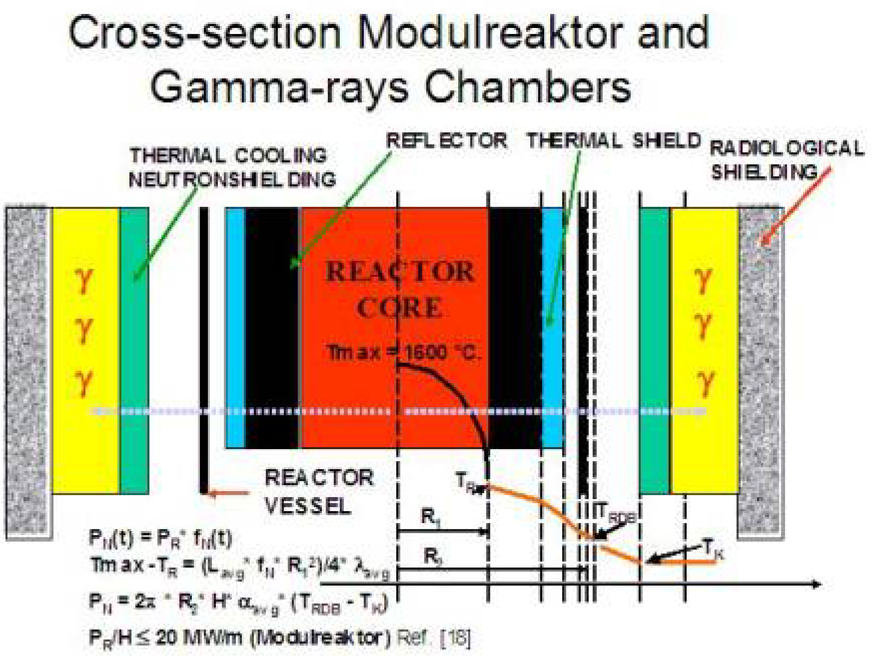


Figure 4: Cross-section temperature-gradient for the HTR-moduulreaktor and the proposed gamma-chambers for gamma-radiation

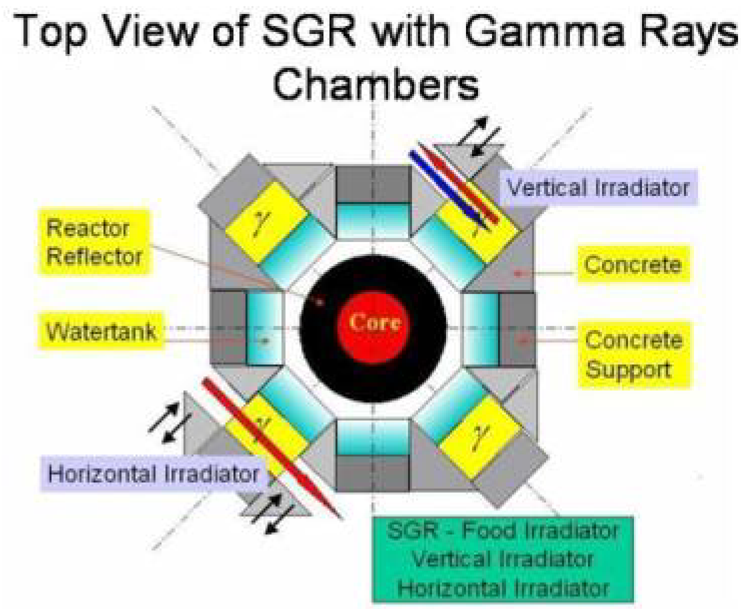


Figure 5: Top-view of the SGR with location for Horizontal - and Vertical Irradiation conveying system

Figure 6: Mega-cities with more than 10 million people by 2050 – Source EPRI

Table 1: Application of Gamma-rays for food-preservation.

Advisory Technological Dose Limits [17]

Class	Food	Purpose of Treatment	Technological dose range (kGy) Min	Max
Class I	Bulbs, stem and root tubers	Inhibit sprouting	0.05	0.2
Class 2	Fresh fruits and vegetables (other than Class 1)	a) Delay ripening b) Insect disinfestation c) Shelf-life extension d) Quarantine application*	0.2 0.2 1.0 0.1	1.0 1.0. 2.5 1.0
Class 3	Cereals and their milled products, pulses and their milled products, nuts, oil seeds, dried fruits and their products	a) Insect disinfestation b) Reduction of microbial load	0.25 1.5	1.0 5.0
Class 4	Fish, aquaculture, seafood and their products (fresh or frozen)	a) Reduction of pathogenic microorganisms** b) Shelf-life extension c) Control of human parasites**	1.0 1.0 0.1	7.0 3.0 2.0
Class 5	Meat and meat products including poultry (fresh and frozen) and eggs	a) Reduction of pathogenic microorganisms** b) Shelf-life extension c) Control of human parasites**	1.0 1.0 0.3	7.0 3.0 2.0
Class 6	Dry vegetables, spices, condiments, dry herbs, tea, coffee, cocoa and plant products	a) Reduction of pathogenic microorganisms** b) Insect disinfestation	6.0 0.3	14.0 1.0
Class 7	Dried food of animal origin	a) Insect disinfestation b) Control of moulds c) Reduction of pathogenic microorganisms	0.3 1.0 2.0	1.0 3.0 7.0
Class 8	Ethnic foods and miscellaneous foods, including but not limited to: health foods, ethnic preparations, hospital foods, food ingredients, military rations, space foods and special spice mixes, RTC/RTE foods	a) Reduction of microorganisms b) Sterilization c) Quarantine control		*** *** ***

* Minimum dose may be specified for particular pests

** Minimum dose may be specified keeping in mind the objective of the treatment to ensure hygienic quality of food.

*** Maximum doses to be specified for particular purpose and foodstuff

Appendix A : DOE Guidelines for a Generation IV transportable nuclear reactor.

U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

PI: Fred R. Mynatt **Proposal No.: 2000-047**

Institution: The University of Tennessee

Collaborators: Massachusetts Institute of Technology, Oak Ridge National Laboratory, Westinghouse Electric Company, Tennessee Valley Authority, Institute of Physics & Power Engineering (Russia), Newport News Shipbuilding

Title: Design and Layout Concepts for Compact, Factory-Produced, Transportable, Generation IV Reactor Systems

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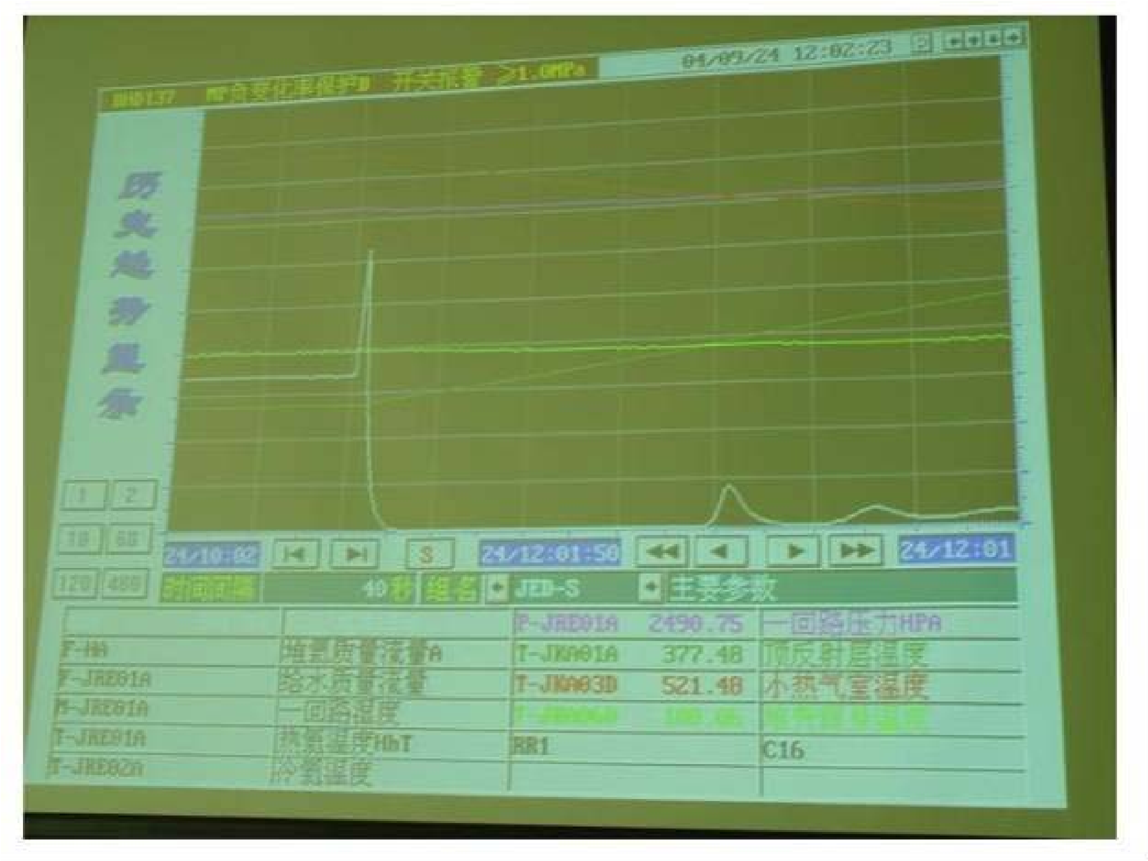
Development and deployment of a new generation of nuclear electric power plants is urgently needed both within the United States and worldwide. The need for new electric power plants is very evident both to replace old power plants and to expand the power supply. While global warming is widely debated, there is a growing consensus that it is a potential worldwide problem and that generation of greenhouse gases should be avoided in new and replacement electric power plants. It is also clear that new nuclear power plants will not be readily accepted by the public until sufficient changes are evident to resolve economic, safety, waste and proliferation concerns. The public generally accepts nuclear power plants already deployed, but this same public will demand resolution of long-standing problems prior to deployment of new nuclear power plants.

Generation IV nuclear power plant concepts developed in the U.S. Department of Energy (DOE) Nuclear Energy Research Initiative offer the potential for resolving the problems that prevent the deployment of new nuclear power plants. Concepts for compact, modular , power plants have been developed with inherent design features to mitigate proliferation and safety concerns (1,2,3,4,5,6). The biggest concern for these compact plant concepts is economics. Can they be produced at an acceptable cost, and will they facilitate innovative financing and ownership arrangements to make deployment economically feasible?

The purpose of this research project is to develop compact Generation IV nuclear power plant design and layout concepts that maximize the benefits of factory-based fabrication and optimal packaging, transportation and siting. The potentially small footprint of Generation IV systems offers the opportunity for maximum factory fabrication and optimal packaging for transportation and siting. Barge mounting is an option to be considered and will offer flexibility for siting including floating installation, on-shore fixed siting, and transportation to nearby inland sites. Railroad and truck transportation of system modules will also be considered in this work.

Appendix B : The inherent safety test for HTR nuclear reactor



Test performed at the Tsinghua University, Beijing – China on September 24, 2004 at 10:30 a.m [ref. 19].

Test conditions:

1: Increase the reactivity with $5*10^{-3}$ Δk/k.

2: Shutdown helium cooling pump.