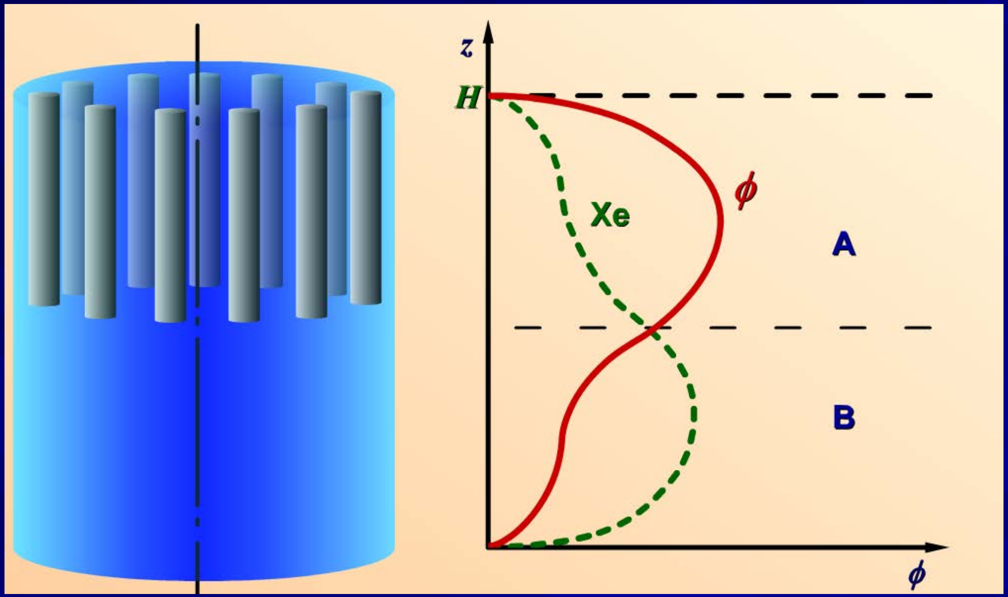
MULTIMEDIA COURSE ON NUCLEAR REACTORS PHYSICS, APLICATION TO A TAILORED ON THE JOB TRAINIG COURSE.



Prof. PhD. Javier Dies
Doctor Engineer
Professor Chair in Nuclear Engineering
Upc- Barcelona-Tech, Spain

Nuclear Engineering Research Group (NERG)
School of Engineering of Barcelona (ETSEIB), Technical University of Catalonia (UPC), http://nerg.upc.edu/
tel. 34-934017144 , email. Javier.dies@upc.edu
Avda. Diagonal 647, 08028, Barcelona, Spain

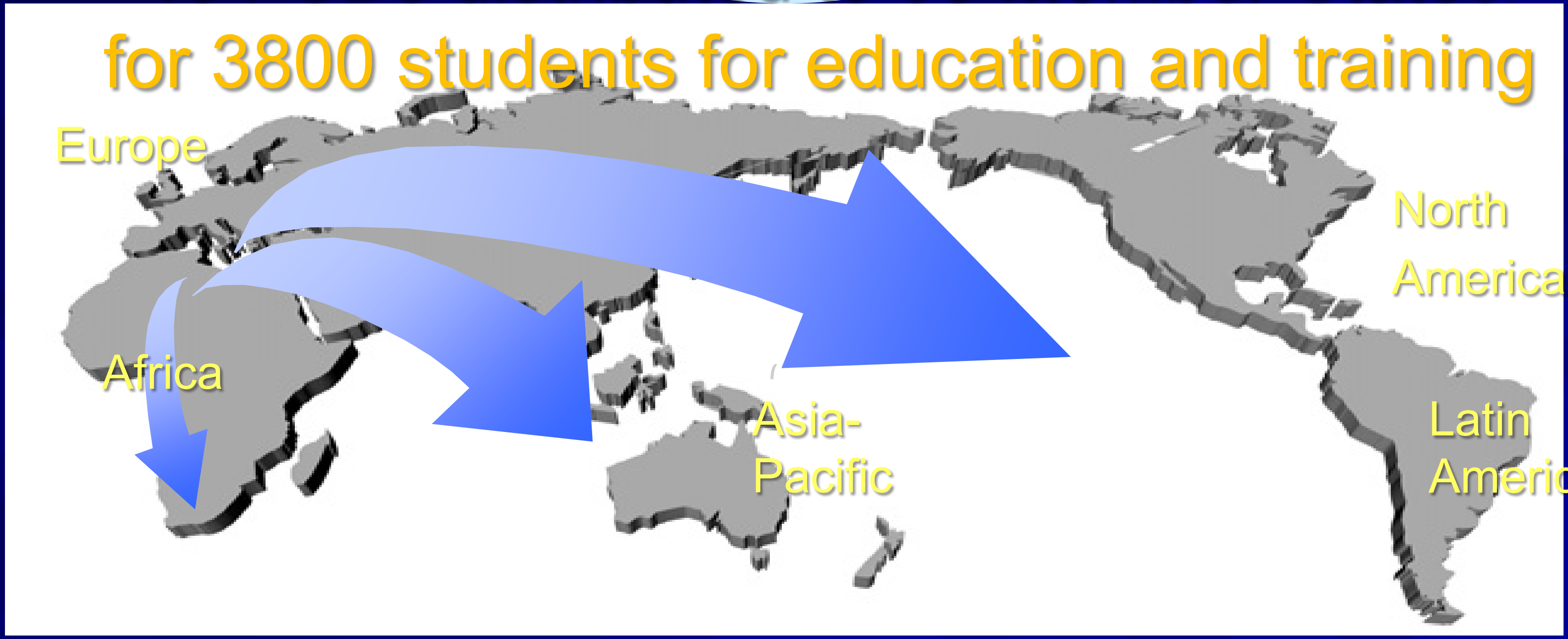
Multimedia on Nuclear Reactor Physics

IAEA International Atomic Energy Agency

- In order to improve education and training quality, a Multimedia on Nuclear Reactor Physics has been developed.
- In some institutions, this course is called Fundamentals of Nuclear Reactor Operation.
- Nowadays, this multimedia has about 800 slides and the text is in Spanish, English, French and Russian .
- Until now about 126 institutions from 53 countries have applied for the multimedia.
- The teacher uses the multimedia during his lectures.
- Students use it at home to study this course.

Multimedia on Nuclear Reactor Physic

454 CDs distributed to 53 Member States for 3800 students for education and training



Armenia, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech, Finland, France, Germany, Hungary, Italy, Kazakhstan, Montenegro, Netherlands, Poland, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, UK, Ukraine

Algeria, Ghana, Kenya, South Africa

Bangladesh, China, India, Indonesia, Iraq, Israel, Japan, Korea, Malaysia, Mongolia, Pakistan, Palestine, the Philippines, Saudi Arabia, Syria, Thailand, UAE, Vietnam , Iran

Argentine, Brazil, Chile, Mexico, Peru, USA

Technical University of Catalonia (UPC), BarcelonaTech
School of Engineering of Barcelona (ETSEIB)
Department of Physics and Nuclear Engineering (DFEN)
Nuclear Engineering Research Group (NERG)

MULTIMEDIA ON NUCLEAR REACTOR PHYSICS

Version 4.3

English *Spanish*

French *Russian*

Javier Dies
Francesc Puig
Claubia Pereira

- Nowadays, this multimedia has about 800 slides and the text is in:

  - English
  - Spanish
  - French
  - Russian.
  - Chinese (very soon will be ready)

- Applications in EDUCATION
- Since 2001 in Nuclear Reactor Physics course at UPC Barcelona,
  - Master Level, Engineering degree, nuclear major.
  - 60 hours – 5 ECTS
  - extended course, from September to December, evaluation in January.

Applications in TRAINING:

A tailored on the job training course of two weeks based on this multimedia is organized in nuclear power plants and nuclear institutions worldwide on request.

- Applications in TRAINING
- Since 2009, Fundamentals of reactor operation at Nuclear Power Plant Asco-Vandellos (Tarragona, Spain)
  - 60 hours training course
  - compacted course, 2 weeks,
  - Skipping chapter 5 and 6.
  - For new employers at NPP with university degree (engineers, physicians, chemistries, informatics)

- Applications in TRAINING
- Fundamentals of Reactor Operation course for Operators of NPP.
    - 60 hours training course
    - Compacted course
    - For new operators
    - For refreshing course of operators
    - Skipping chapter 5 and 6

- Applications in TRAINING: July 2013, Nuclear Reactor Physics, University of Ghana, School of Nuclear and Alied Sciences.
    - compacted course, 2 weeks.

- A new procedure, in order to facilitate the distribution worldwide is now ready from IAEA web, enable the multimedia direct download.
- The new version is ready for:
  - Windows

  And very soon for :
  - Android
  - ISO systems

- http://bit.do/NuclearReactorPhysics

We offer two things:

1. Download free of charge the multimedia on NRP.

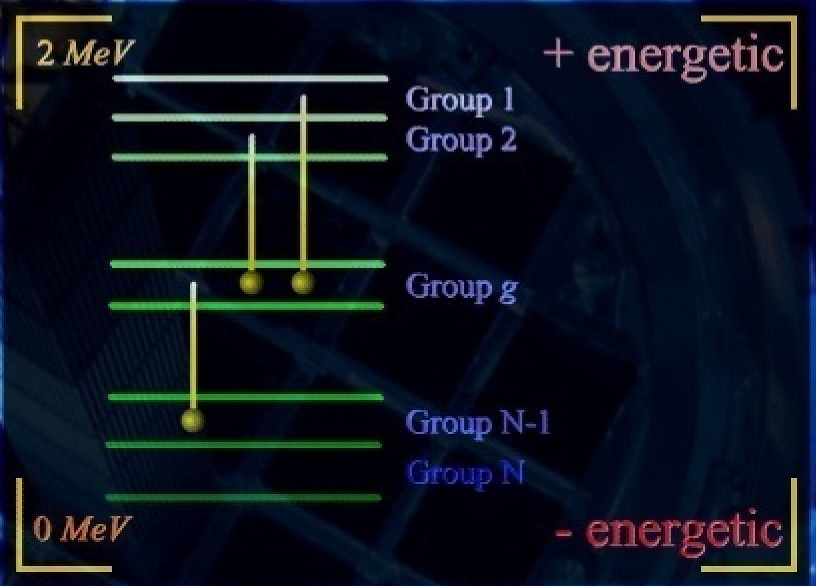
2. Organize a two weeks training course on the job, in your institution.

- This multimedia is complemented with a experimental program developed with a conceptual nuclear power plant simulator SIREP-1300 from Corys –Tess (France).

DIES, J.; TAPIA, C.; PUIG, F.; VILLAR, D.; "Experiences program in nuclear engineering area. SIREP 1300 nuclear power plant conceptual simulator (DFEN-ETSEIB-UPC), (language: English), E-prints UPC, pág. 206, Barcelona, 2012. ttp://hdl.handle.net/2117/17190

NUCLEAR REACTOR PHYSICS

Title



FISSION PROCESS IN A NUCLEAR REACTOR

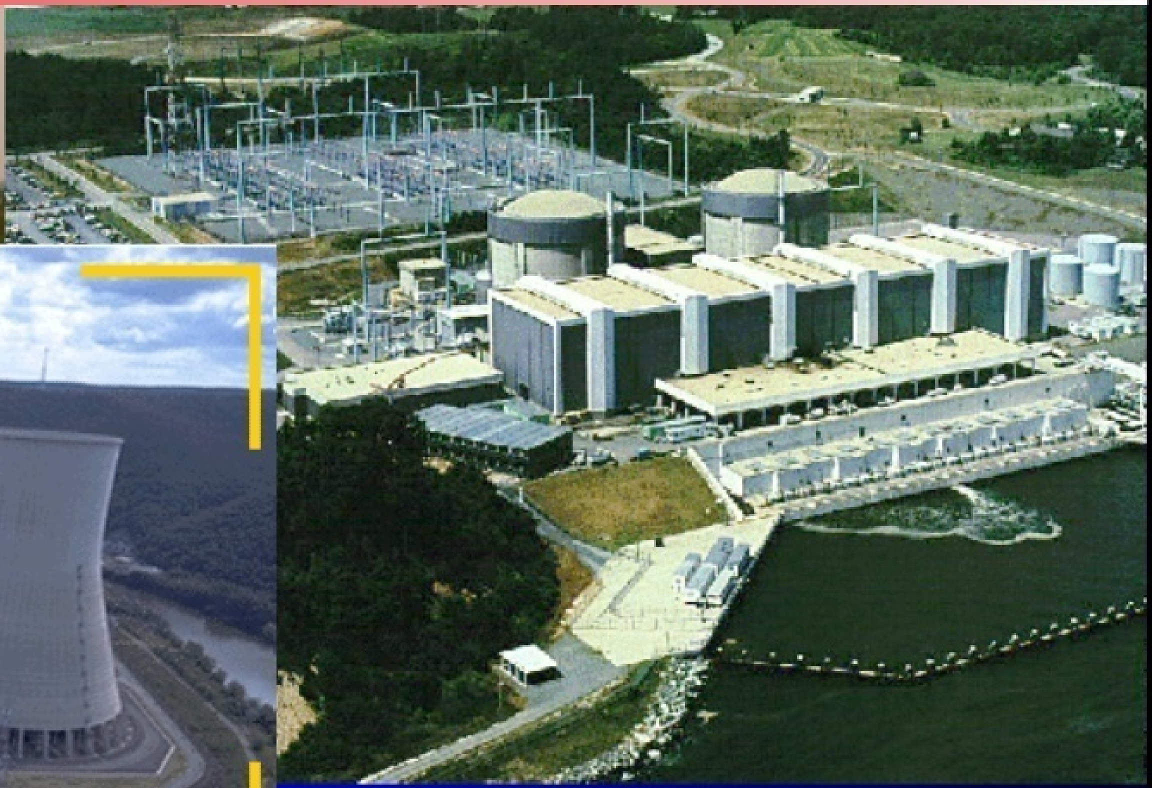


Figure 13 - Nuclear power plants

In a nuclear reactor, there are two important aspects that should be considered in connection with radioactivity from fission products.

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NEUTRON MULTIPLICATION IN A NUCLEAR REACTOR

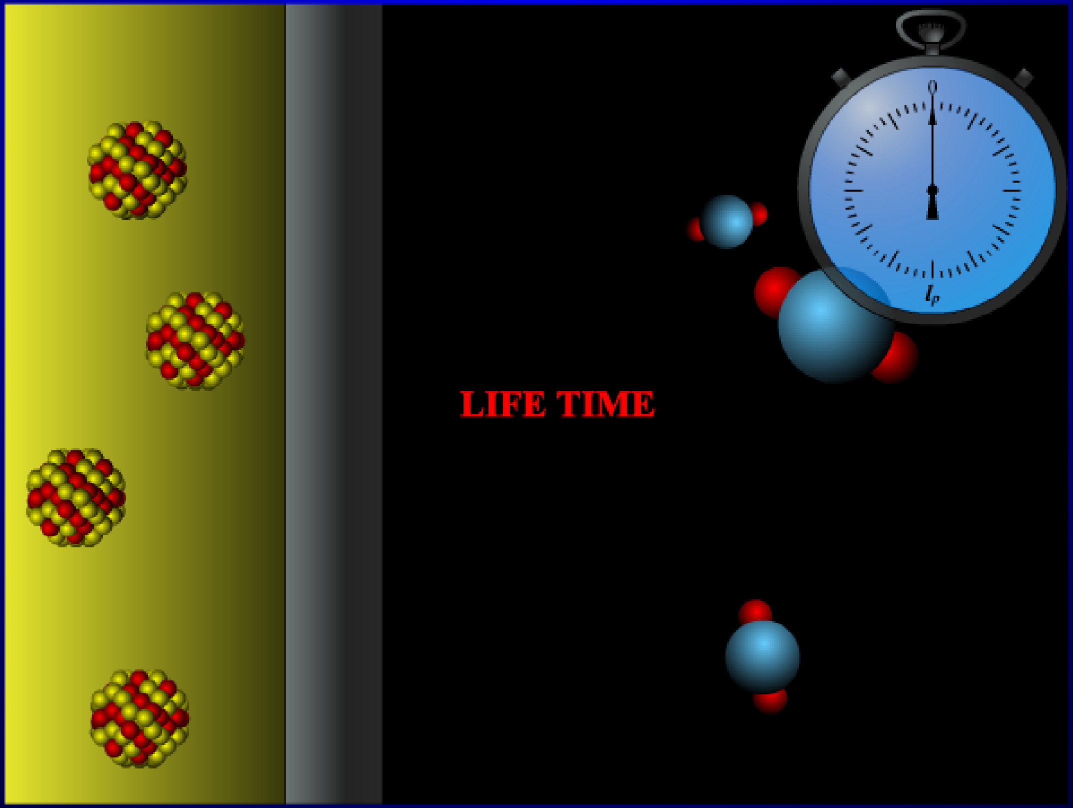
Another definition of the multiplication factor k can be expressed in terms of a balance:

$$k = \frac{\textit{neutron production rate in the reactor}}{\textit{neutron loss rate (absorption + leakage) in the reactor}} \equiv \frac{P(t)}{L(t)} \qquad (2)$$

In this way lifetime of the free neutron (***l***) can be defined, being equal to:

$$l \equiv \frac{N(t)}{L(t)} \qquad (3)$$

where ***N(t)*** is the total population of neutrons in the reactor at time ***t***.



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$$\rho = \frac{\omega \cdot l_p}{1+\omega \cdot l_p} + \frac{\omega}{1+\omega \cdot l_p} \cdot \frac{\beta}{\omega + \lambda} \qquad (29)$$

1. If $\omega = 0$, then $\rho = 0$,
2. If ω varies from zero to $+\infty$, ρ grows positively, taking as limit the value *1*,
3. If ω varies from *0* to $-\lambda$ (with values to the right of $-\lambda$), ρ tends to $-\infty$;
4. If ω tends to $-\lambda$ (with values to the left of $-\lambda$), ρ tends to $+\infty$;
5. If ω tends to $-1/l_p$ (with values to the right of $-1/l_p$), ρ tends to $-\infty$;
6. If ω tends to $-1/l_p$ (with values to the left of $-1/l_p$), ρ tends to $+\infty$
7. If ω tends to $-\infty$, ρ tends to $+1$.

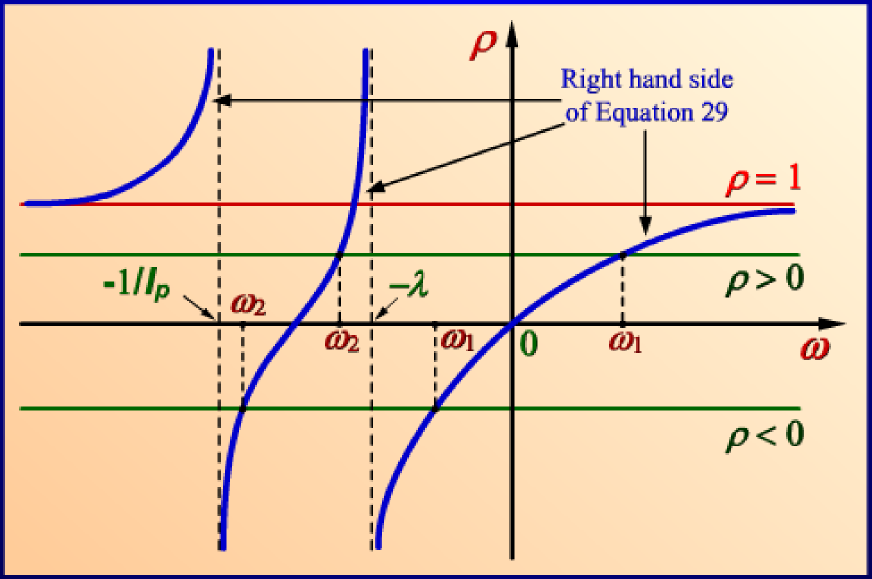
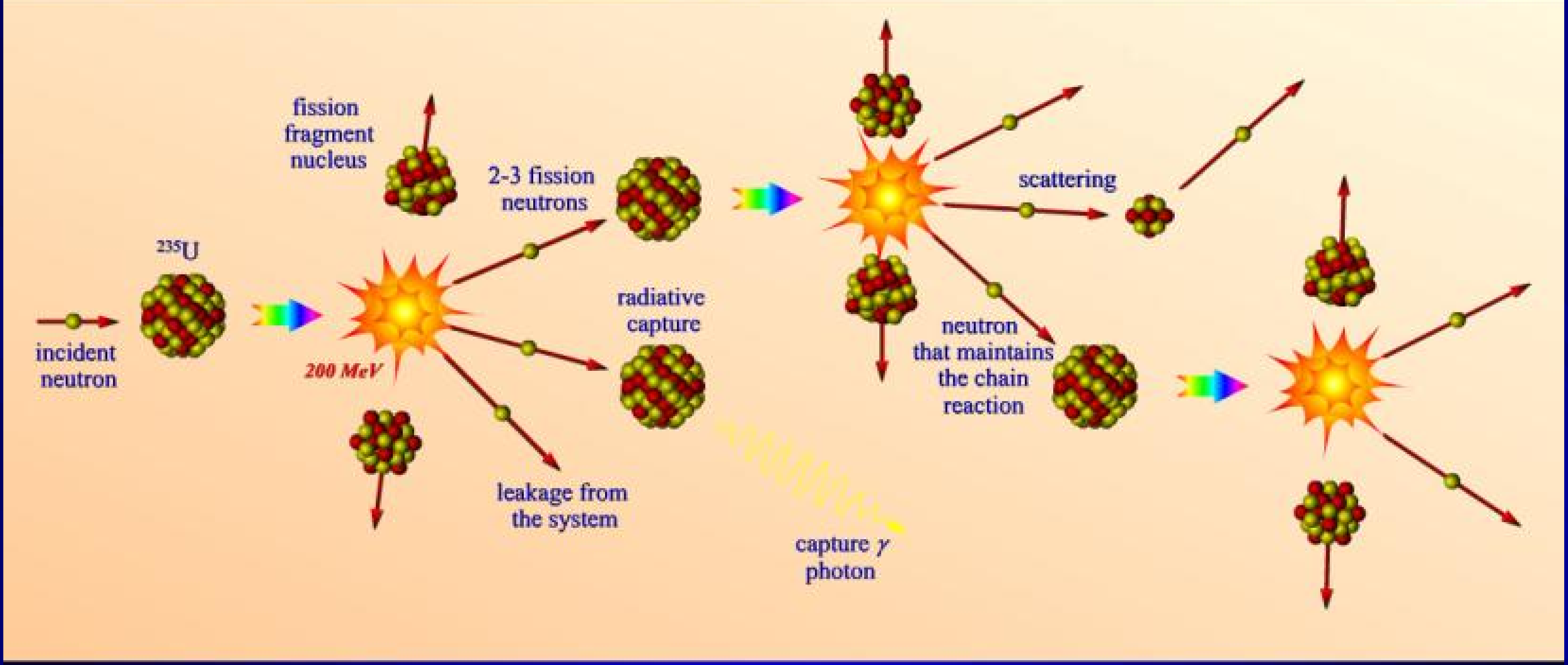


Figure 8 - Variation of ρ as a function of ω (1 group of delayed neutrons)

Samples of Nuclear Reactor Physics Multimedia (language: English):

NEUTRON MULTIPLICATION IN A NUCLEAR REACTOR



In order to adjust ***k*** to the desired value, neutron production rate has to be adjusted with the rate of disappearance.

The neutrons from the reactor may disappear in two ways:

(a) escaping from the reactor through its surface and

(b) being absorbed by nuclear reactions and radiative capture reactions in the material that comprises the reactor.

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CHEMICAL SHIM

Example 1 - A **PWR** type reactor has a total of reactivity excess of ***20%***, while the total reactivity value of control rods is ***12%***. What should be the minimum concentration of boric acid, in *ppm* and in *g/l* in the water (moderator) so that the reactor does not become critical, knowing that its thermal utilization factor (without boric acid) is ***0.900***?

Solution. The amount of negative reactivity to be assigned to chemical shim, or boric acid, will be ***20 – 12 = 8%***. From Eq. (8), the boron concentration should be:

$$\rho_W = 1.92 \cdot C \cdot 10^{-3} \cdot (1 - f_o) \qquad (8)$$

$$C = \frac{\rho \cdot 10^3}{1.92 \cdot (1 - f_o)} = \frac{0.08 \cdot 10^3}{1.92 \cdot (1 - 0.9)} = 417 \; ppm \; de \; boro$$

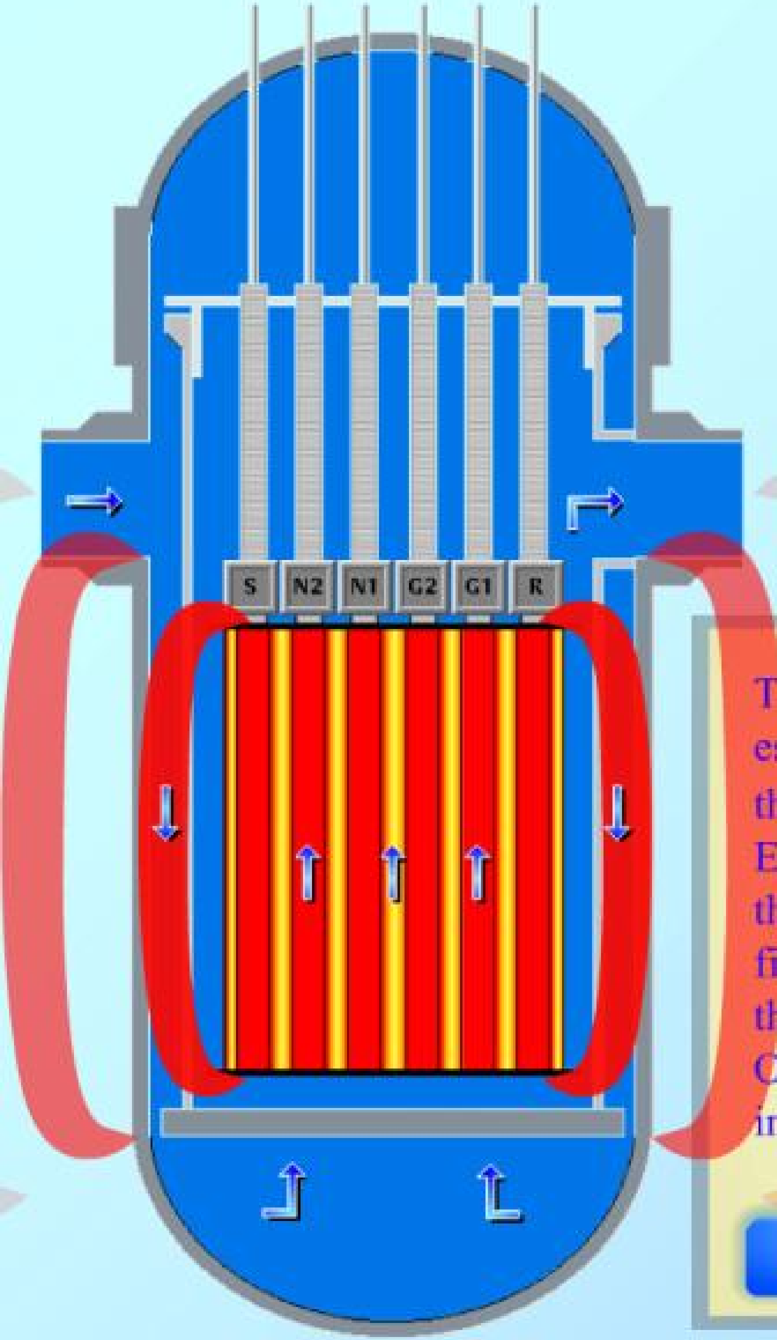
The molecular mass of boric acid (H_3BO_3) is $3 \times 1 + 10.8 + 3 \times 16 = 61.8$.

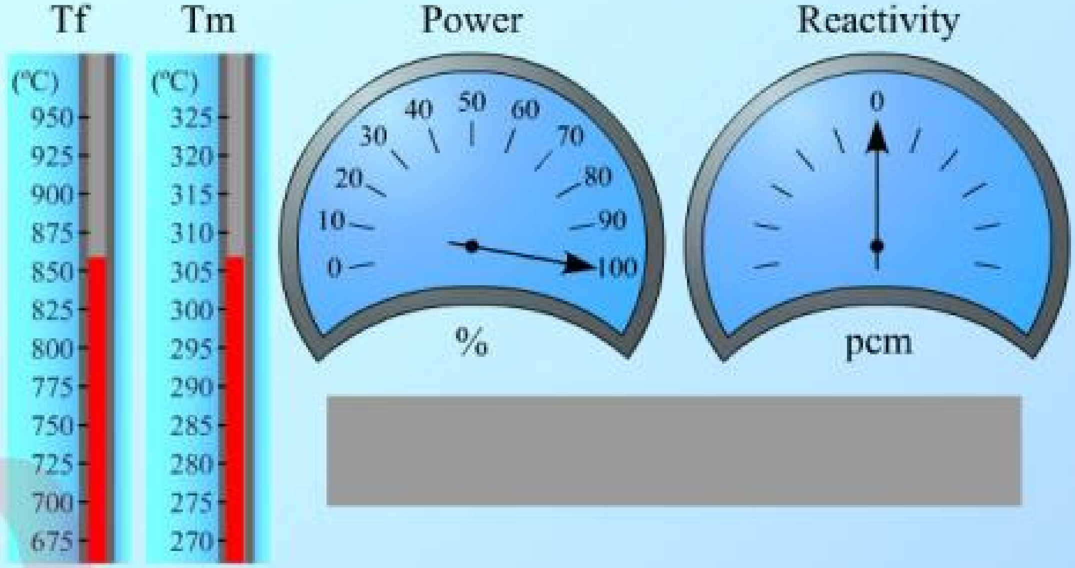
Therefore, the boric acid concentration that is necessary to obtain a boron concentration of ***417 ppm*** is:

$$(61.8 \times 417) / 10.8 = 2386 \; ppm \; of \; boric \; acid.$$

Considering that there will be ***2386 g*** of boric acid in ***10^6 g*** of water, that occupies a volume of about ***1000 l***, the concentration in *g/l* should be ***2386 g / 1000 l = 2.39 g/l***.

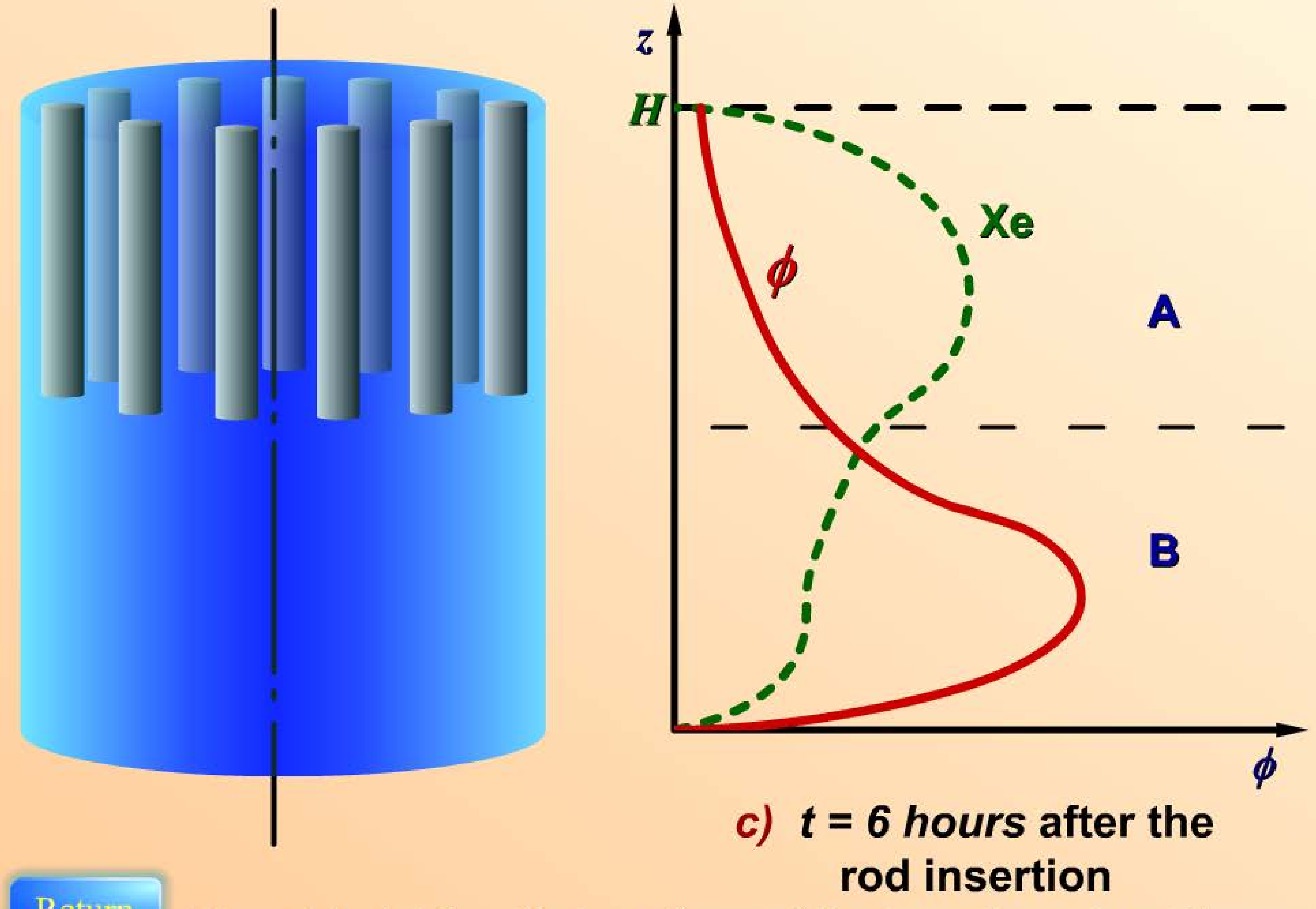
FISSION PROCESS IN A NUCLEAR REACTOR





The first is the fact that the rate of released energy must be estimated. This energy is released in the form of heat due to the emission of γ and β radiation by the fission products.
Even after the shutdown of the reactor, a large amount of heat that is released remains in the fuel due to the presence of fission products. Therefore it becomes necessary to evacuate this heat, not interrupting the flow of coolant in the reactor. Otherwise, the temperature of the fuel elements would increase, and they could suffer damage.

FISSION PRODUCT POISONING



Return

Figure 12 - Axial oscillations of xenon following a change in axial power (III)

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