RERTR 2011 — 33rd INTERNATIONAL MEETING ON
REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS

October 23-27, 2011
Marriot Santiago Hotel
Santiago, Chile

ININ TRIGA Mark III Reactor Plan Conversion to Use LEU Fuel Instead of HEU/LEU Standard Fuel

J. Flores Callejas,
jorge.floresc@inin.gob.mx
Nuclear Technology Manager
ININ, Carretera Mex-Tol S/N, La Marquesa C.P. 52725 Ocoyoacac, Mexico

ABSTRACT

In accordance to Global Threat Reduction program, Mexico is in progress to be inside of Reduced Enrichment for Research and Test Reactors; TRIGA Mark III reactor operated by National Nuclear Research Institute (ININ) until today uses a combination of HEU (8.5/70) and standard LEU (8.5/20) fuel.
A Procurement and Supply Agreement has been developed by Mexico, the IAEA and the United States of America, the plan is to convert the reactor to use only LEU fuel (30/20) from 2012 to the future.
The complete process must be managed with different government organizations, which establish agreements with international counterparts or must provide the authorizations inside Mexico; all tide schedules must take in count the plans and programs to fabricate, transport and deliver the new LEU fuel and also take care of spent HEU fuel, to return it to country of original supply.

1. Introduction.

National Nuclear Research Institute's TRIGA Mark III nuclear reactor, reached criticity for the first time on November 8th, 1968. (Fig. 1)

Initial core had 79 standard fuel elements (LEU 8.5/20), 4 control rods (three of them with standard fuel follower), 6 graphite rods in F ring and 35 in G ring (Fig. 2).

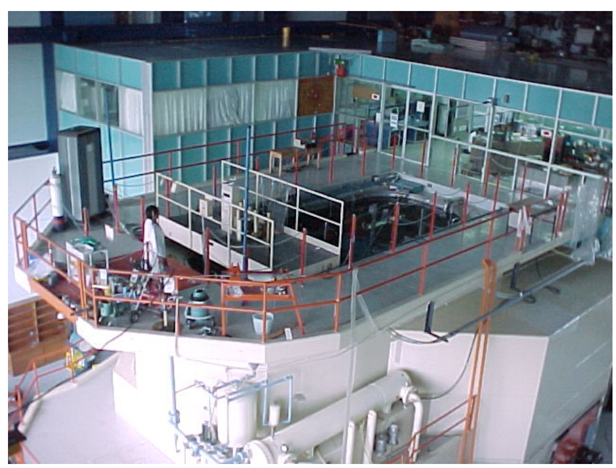


Fig. 1 ININ TRIGA Mark III Reactor

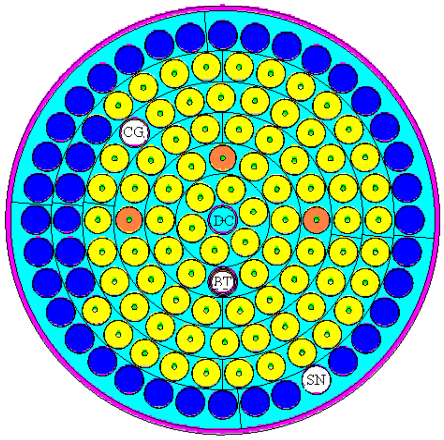


FIG. 2. Initial core with 6 graphite elements in F ring.

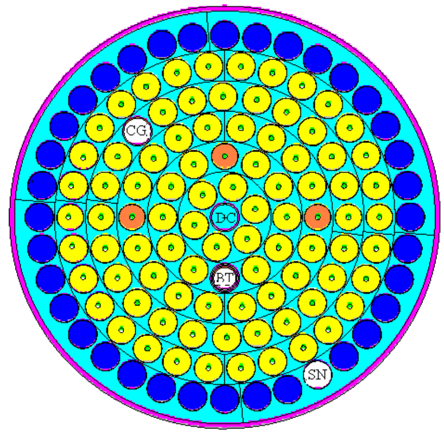
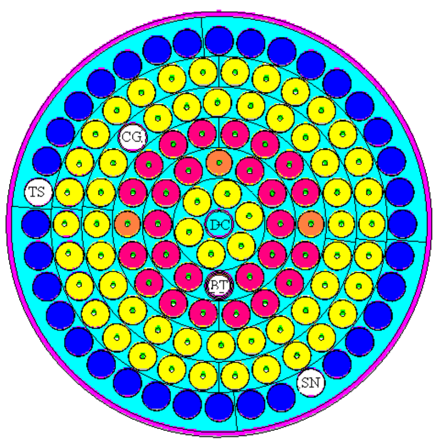


FIG. 3. Nuclear core with 85 fuels and 4 control rods,

In 1975 a rearrange of core fuels was made and 6 graphite rods of F ring were extracted and replaced by standard fuels. The core remained with inner rings (B, C, D, E and F) with standard fuels (Fig. 3).

In 1988 the change of standard fuels of C and D rings by fuels type FLIP (HEU 8.5/70) was made, control rods continued with standard followers.



In order to have the same type of fuels in C and D rings, in June 1989, control rods with standard followers were replaced by control rods with FLIP followers (Fig. 4).

Reactor's nominal power is 1 MWT, operating in a stable mode and it is able to be pulsed to a maximum of 2000 MWT, for approximately 10 ms.

Fig. 4 Current core arrangement.

2. Current reactor main characteristics.

a.- Reactor core.

Reactor's core consists of a cylindrical arrangement with 85 elements of fuel-moderator placed in five concentric rings, 4 control rods and 34 graphite elements placed in a sixth ring that act as a reflector.

b.- Fuel Elements (Fig. 5)

Fuel elements are cylindrical rods with SS-304 cladding, 0.508 mm thickness, with plugs of the same material, welded to the ends. Its total length is approximately 72 cm and 3.63 cm diameter. The fuel is a homogeneous mixture of uranium and zirconium hydride, each element is composed by three cylindrical segments, with a total length of 38.1 cm.

They also have two cylindrical graphite portions at the top and bottom of the element, which act as axial reflectors

In the middle of the fuel material, there is a hole of .457 cm diameter, where a zirconium rod is placed.

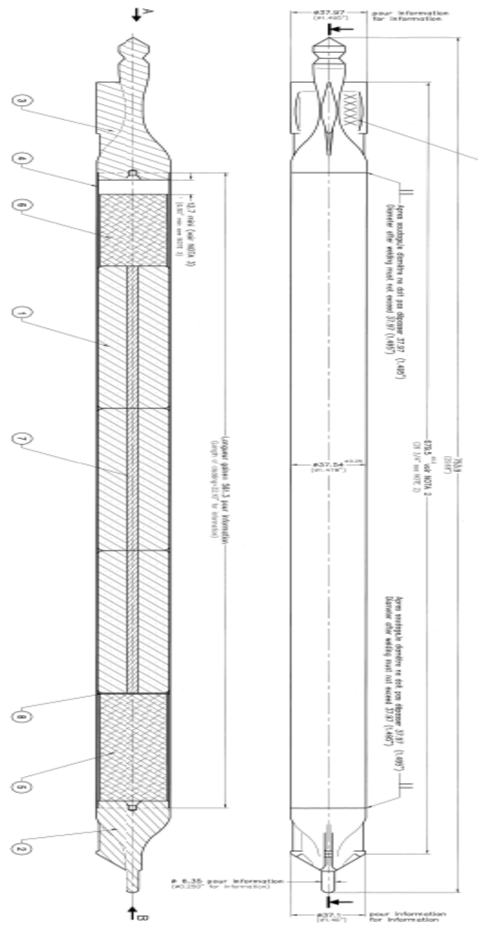


Fig. 5 Fuel Element

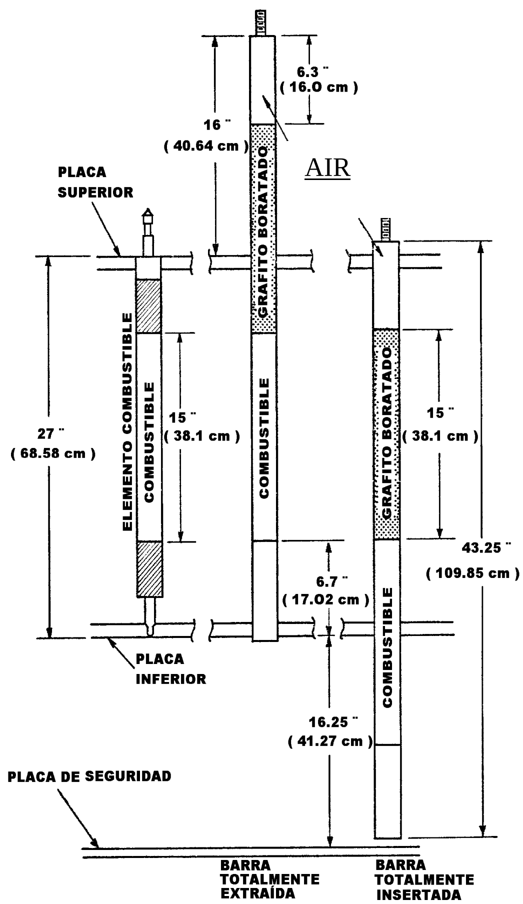


Fig. 6 Control rods with follower.

c.- Reactor Control

The most of reactor's control & instrumentation are located in a control room console, adjacent to its platform. Reactor power is controlled by the movement of three control rods (shim, safety and regulating – follower type) operated by pinion and rack mechanisms and a transient rod operated in a pneumatic way.

d.- Safety Aspects

Mixture uranium - zirconium hydride of the fuel elements, has an intrinsic safety characteristic, its immediate temperature reactivity rate is big and negative. This means neutron production rate decreases instantly when fuel temperature increases and this fuel decrease is very sensitive to fuel temperature increases.

e.- Reactor pool (Fig. 7)

Reactor´s core is submerged in an aluminum pool, which is supported by a reinforced concrete structure (it supports earthquakes even to 0.2 G). Dimensions of the pool are: 7.60 m long, 3.00 m wide and 7.60 m depth, with an estimated volume of 150 m^3. Aluminium thickness varies since 6.3 mm on the top to 19 mm in the wall bottom and in the bottom of the pool.

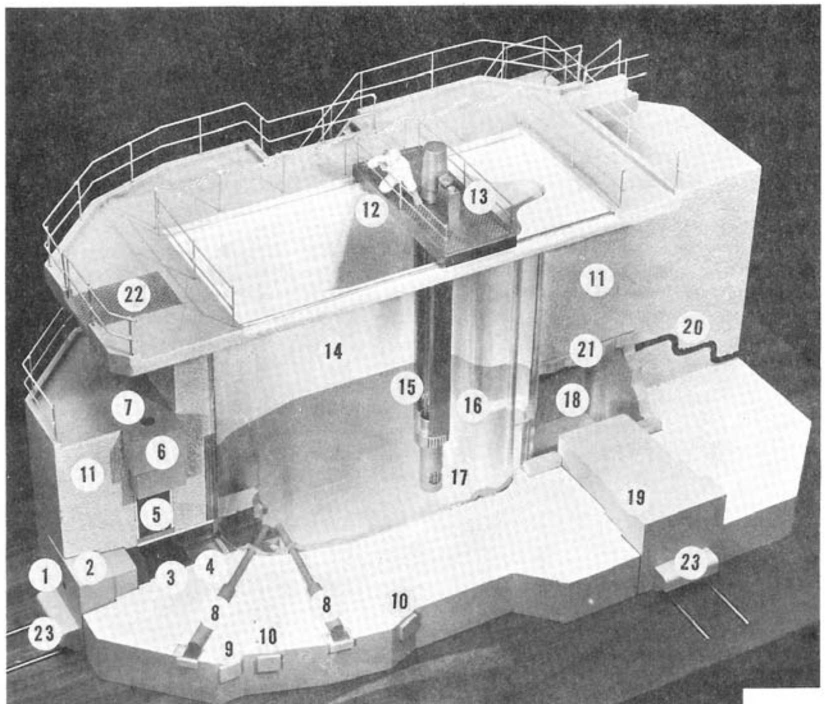


Fig. 7 Pool, platform and shielding.

f.- Shielding (Fig. 7 and 8)
Vertical shielding is covered by six water meters on the top of the core. Radial shielding is covered by concrete shielding which supports aluminium structure.

Exposures average rates with reactor operating at 1MWT measured experimentally, are: 25 mR/h at 50 cm from water surface; lower to 0.1 mR/h at the ends of tangential and radial ports beams; lower to 0.1 mR/h at the end of exposure room (with shielding in radial direction of 3.30 m).

g.- Thermohydraulic Design
TRIGA reactor is designed to operate by natural water pool cooling convection. Cooling system main functions are to dissipate heat generated in the reactor and provide axial shielding against radiation from core. Heat dissipation is obtained by of a heat exchanger and a cooling tower located outside of the building.

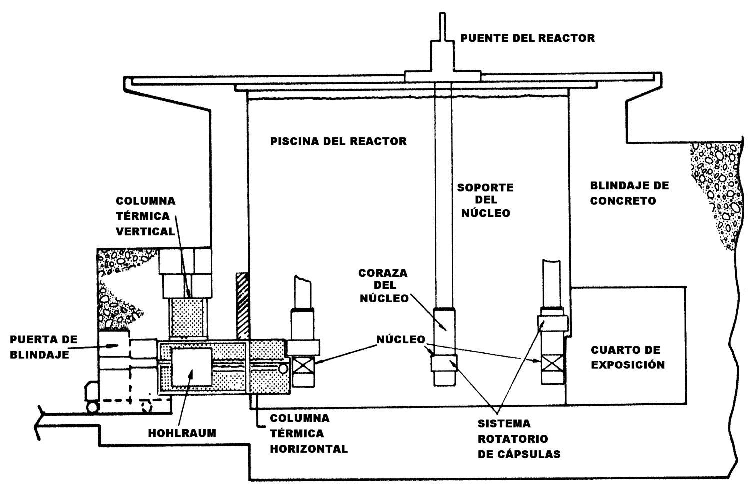


Fig. 8 Core pool arrangement.

i.- Experiment Facilities.

Outside Reactor Core:
Exposure room, beams tubes (radial and tangential) and thermal column.

Reactor Core Periphery:
Capsules pneumatic irradiation system [Rabbit Tube] (in Spanish - SINCA), Capsules rotary irradiation system [Lazy Susan] (in Spanish - SIRCA), Capsules fix irradiation system (in Spanish – SIFCA).

***Inside Reactor Core*. (Central thimble).**

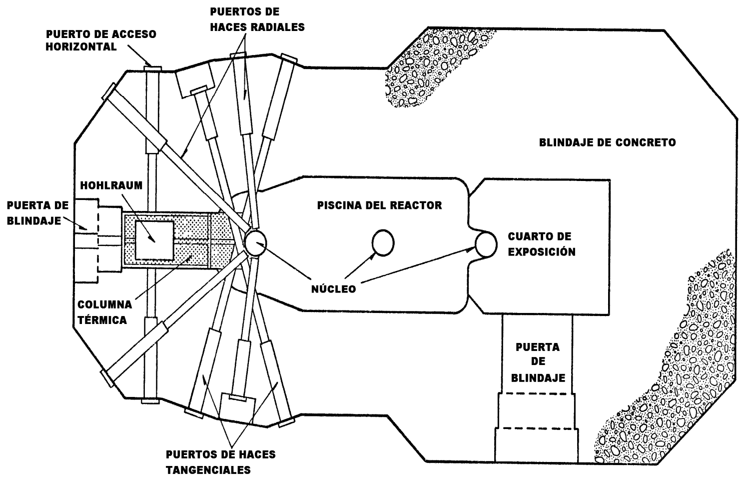


Fig. 9 Experiment Facilities

3.- Instrumentation and control systems. (Fig. 10)

I&C system's function is to monitor constantly operating parameters, as: a) operating power, b) fuels temperature, c) refrigerant flow and temperature in the primary system, and d) radiation intensity in several facility areas. The purpose is to ensure reactor and operating staff safety by keeping parameters within established operating ranges.

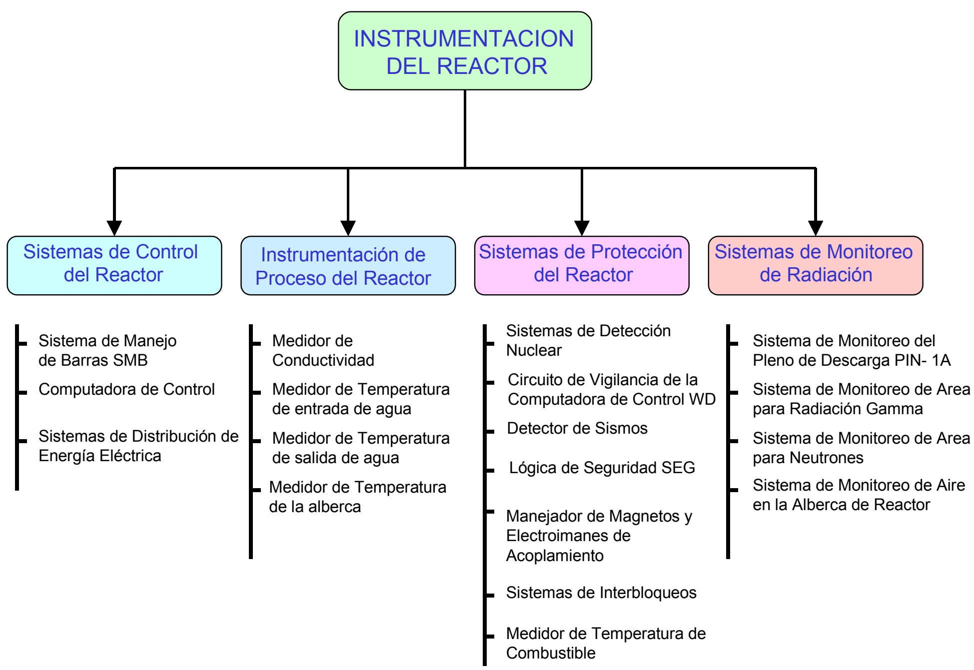


Fig. 10 Reactor Instrumentation Systems

4.- Core conversion to fuel LEU (30/20)

Even previous contacts between Mexico and USA, the detonation of this activity was the statement issued in the Nuclear Security Summit in 2010 (Trilateral announcement between Mexican, USA and Canada executive branch representatives), which stated:

“The three countries acknowledged that this project [conversion of TRIGA] also provides an important step towards the replacement of the research reactor with a new low-enriched uranium fuelled reactor in support of Mexico’s nuclear energy development.”

Since this announcement, several technical and political meetings have been carried out between Mexico, USA and IAEA different organizations, among the main ones, we can mention the following:

- **By Mexico**: Foreign Affairs Secretary, Energy Secretary, Internal Revenue Secretary, Transport & Communication Secretary, National Commission for Nuclear Safety and National Nuclear Research Institute, .
- **By USA**: State Department, Department of Energy, National Nuclear Security Administration, Idaho National Laboratories and fuel provider (GA).
- **IAEA** was asked for being the intermediary during the fuels exchange that will be made (supply of LEU 30/20) from USA to Mexico and supply of HEU (8.5/70), fresh as well as irradiated from Mexico to USA. It was stated the Project and Supply Agreement – GOV/2011/36 Add. 1- Approved on June 7th, 2011.

With the negotiations in progress, calculations to set the best configuration and to optimize reactor’s future operation were started.

Different studied configurations are showed on figures 11, 12, 13 and 14, where figure 14 is core representation that was proposed to operate with new fuel. This core was selected because it complies with criteria specified by Operation Technical Specifications, among which the most important are: k_{eff} aprox. 1.06 and a shutdown margin >0.2 % $\delta k/k$, in negative reactivity. Additionally in this core was postulated a variety of new irradiation positions with many possibilities for research and projects. The core showed on figure 11, having a very high k_{eff}, its manage would be very difficult. It was initiated an iterations sequence, removing fuels elements to reach configuration showed on figure 12.

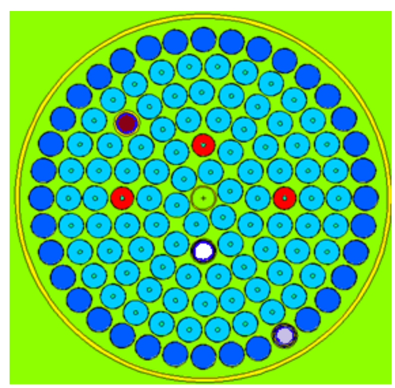


Fig. 11.- Core with 85 LEU’s and 4 control rods
k_{eff} = 1.07959 with a σ of 0.00043.

Configuration of figure 12, even it complied with fundamental criteria, with the elimination of 15 elements in F ring and having a great quantity of holes in this spaces, it would be supposed a considerable drop in neutron flux. Several options were analyzed, and the most significant are shown in figures 13 and 14.

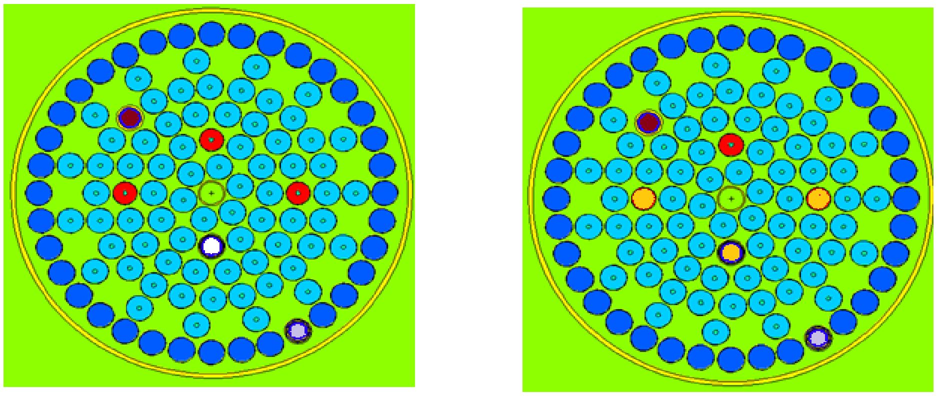


Fig. 12.- CORE WITHOUT 15 FUELS IN F RING.
EXCESS - k_{eff} = 1.05852 with a σ of 0.00042.
SHUTDOWN MARGIN- k_{eff} = 0.99501 with a σ of 0.00044.

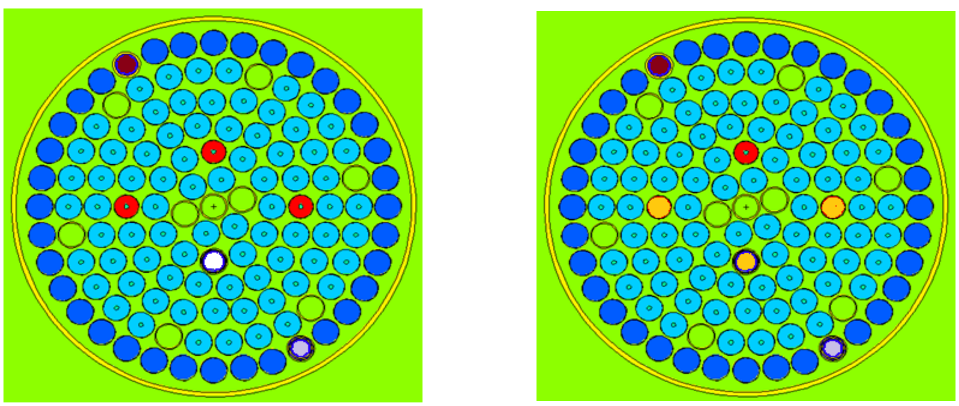


Fig. 13.- CORE WITH 8 ADITIONAL RADIATION POSITIONS
(2 in B and 6 in F)
EXCESS - k_{eff} = 1.06602 with a σ of 0.00044
SHUTDOWN- k_{eff} = 1.00634 with a σ of 0.00041

As previous configuration did not comply with specified criteria, the final selected configuration, having the right fuels elements number and provide additional radiation installations in the core inner part is shown in the following figure.

.

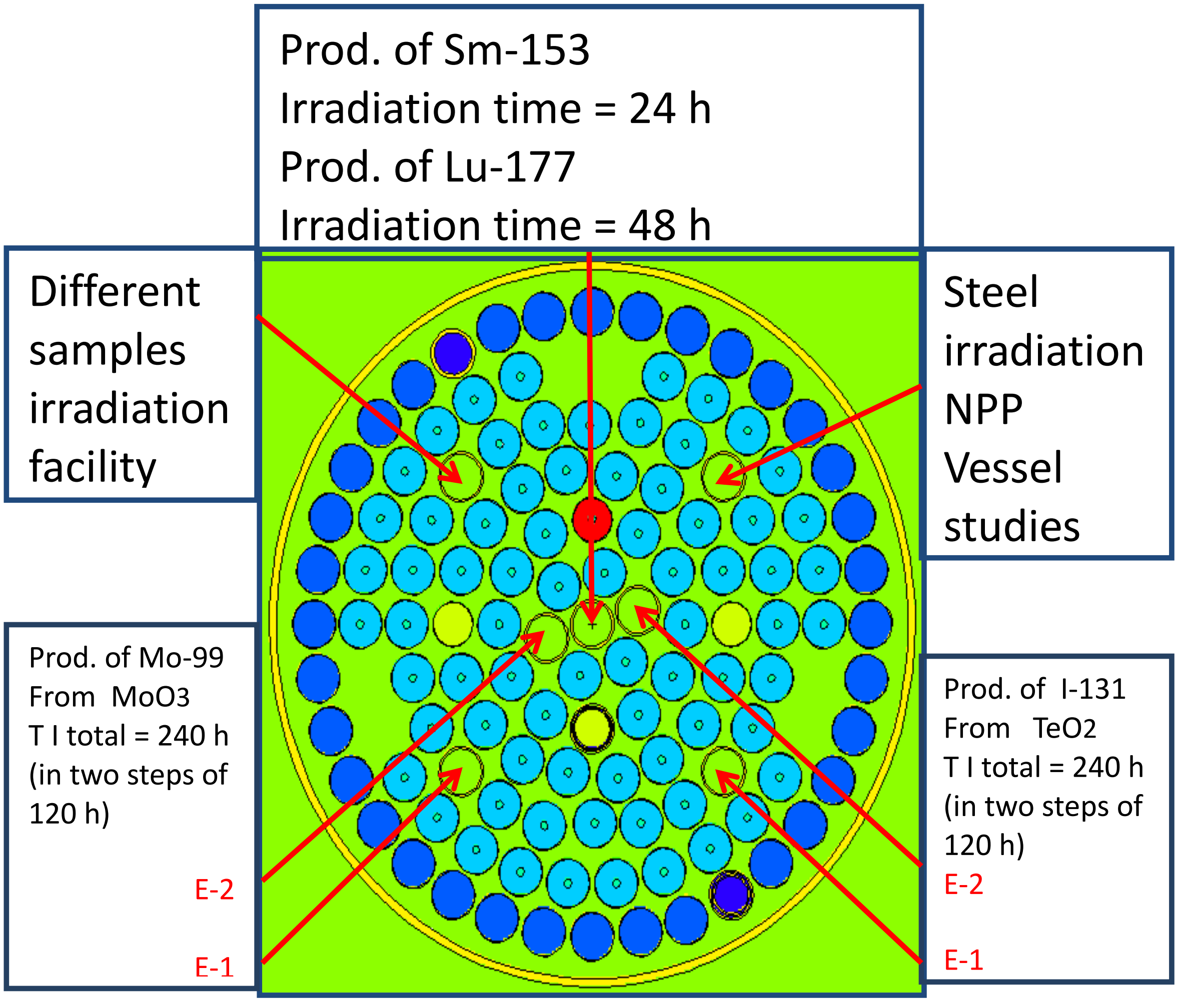


Fig. 14.- CORE WITH 6 RADIATION ADITIONAL POSITIONS
(2 in B and 4 in E) and 6 EMPTY POSITIONS IN F.
EXCESS - k_{eff} = 1.05727 with a σ of 0.00040
SHUTDOWN MARGIN - k_{eff} = 0.99606 with a σ of 0.00045
β-eff = 0.00779

4.- Physical parameters of new core.

Production of delayed neutron and neutron life time.

Value of delayed neutron effective fraction (β_{eff}) for reactor, with LEU (30/20) fuel, is 0.00779 and life time of neutron is 38 μs.

Reactivity ratio / fuel temperature. With a value is -8.0E-5 δk/kºC.

Reactivity ratio / power. It is approximately –1.6 % δk/k.

Reactivity ratio / xenon poisoning.- To be able to operate to a power of 1 MW, is necessary to overcome negative reactivity presented due to xenon poisoning in a balance with a value of -1.7 % $\delta k/k$.

The maxium reactivity excess calculated that is expected to have in the core, will be 5.42 % $\delta k/k$. Value of negative reactivity of control rods is:

ROD TYPE	VALUE	CLADDING MATERIAL
Transient	2.40% $\delta k/k$	Aluminium
Safety	2.18 % $\delta k/k$	Stainless steel
Shim	2.20% $\delta k/k$	Stainless steel
Regulating	3.16% $\delta k/k$	Stainless steel
TOTAL	9.94 % $\delta k/k$	

Fuel characteristics.

Fuel LEU (30/20)	**WEIGHT (%)**
Uranium	30 %
Zirconium	68.0 %
Hydrogen	1.146 %
Erbium	0.9%
Enrichment	20 %
U-235 per element	165 g
Number of elements	74
Atoms rate of H/Zr	1.6
Dimensions	Length : 72 cm Diameter : 3.76 cm
Cladding	Stainless steel with 0.05 cm thickness

Safety systems shutdown values.

PARAMETER	**CUT VALUE**
Power (registered in the channel of % of power)	110 % de 1 MW.
Power (registered in linear channel)	110 % de la escala activa
Period of reactor	Less than 3 s
Earthquake intensity (seismograph at the south of biological shielding).	0.05 G
High voltage fail in ionization compensated chambers.	Less than 600 V.

5.- Conclusions.

With ININ's TRIGA reactor core conversion, it will be started an ambitious facility modernization plan, in which its main support installations will be improved in order to optimize reactor potential and to promote its intensive use by different research and academic groups from Mexico and the region.

We expect first stage will be core restructuration and get it finished at first quarter of 2012. After, among the projects to carry out, it is the modernization of the control console, neutron detection and reactor protection systems, later the plan is to upgrade the area radiological monitoring system, core cooling system and reactor ventilation system, finally the plan is to upgrade laboratories used to support reactor operation.