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Consultant's Report on UNIDO Mission to Zaïre

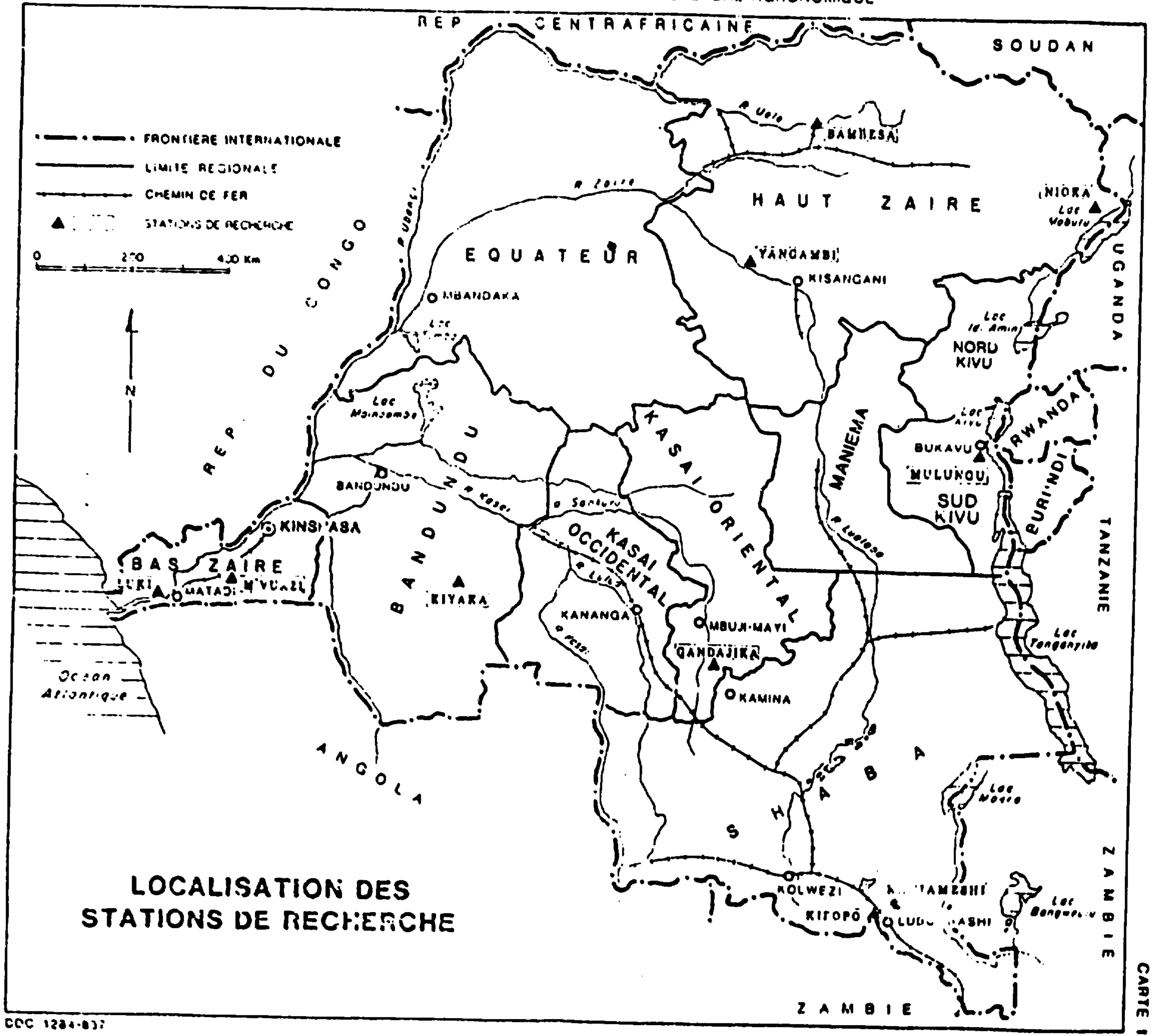
(Development of Policies and Programs in Biotechnology)

Mission to KINSHASA (10 - 16 February 1990)

Report established by Prof. D. LE RUDULIER

During my mission to Kinshasa, I was received by M. J.A. HEBGA, Directeur-Conseiller ONUDI and M. J. MEELKER, who had organized discussions with national authorities, scientists and also organized visits of laboratories. Their help was greatly appreciated.

REPUBLIQUE DU ZAIRE —— PROJET DE RECHERCHE AGRONOMIQUE



LOCALISATION DES
STATIONS DE RECHERCHE

INTRODUCTION

Zaïre is a country of 2.345.000 km^2 (30 millions of habitants) divided into 9 regions (Bas Zaïre, Bandundu, Equateur, Haut Zaïre, Kivu, Kasai oriental, Kasai occidental, Shaba, Maniema ; cf map) and 27 subregions. It has been independant since 1960. Three Universities are located in Kinshasa, Kisangani and Lubumbashi.

The main agricultural productions are peanuts, bananas, several kinds of wood, cacao, coffee, tea, sugar cane, cassava, corn, rice, coton, tobacco, rubber, oil palm, quinquina...

It is obvious to point out that the country still strongly suffer of a lack of infrastructures (roads, railways and other kind of communications, telephones) **and has to face critical heath problems.**

I.- NEEDS OF THE COUNTRY

During my stay in Kinshasa, I have meet two "Citoyens Commissaires d'Etat" : Ministers (Agronomy, Education and Scientific Research). They both agree that the country needs to develop basic infrastructures.

Up to now there is no biotechnology programs within the country and **it is totally unrealiste to imagine to introduce high technology such as genetic engineering**. The technology of recombinant DNA is not use and there is no way to introduce it now.

The priorities are to achieve self-sufficiency in food production by paying more and more attention to the crucial problem of **food preservation** and to **build up the industrial sector**. Technological capabilities are quite low even in Kinshasa and, except few traditional research stations, almost inexistant in other regions.

II.- CURRENT INSTITUTIONS, WORK IN PROGRESS AND HUMAN RESSOURCES

Several institutions have been visited in Kinshasa :

- INERA : Institut National pour l'Etude et la Recherche Agronomique (National Institute for Agronomy)
- INRB : Institut National des Recherches Biomédicales (National Biomedical Research Institute)
- CREN-K : Centre Régional d'Etudes Nucléaires de Kinshasa (Nuclear Center of Kinshasa).

In addition some informations concerning a Research Station, 2000 km outside Kinshasa (CRAAL, Centre de Recherches Agro Alimentaire de Lubumbashi), have been obtained.

1.- INERA

The headquaters of this Institute are located in Kinshasa. I was received by the President, Prof. (Dr.) ONYEMBE PENE M'BUTU LOLEMA, and two of his collaborators (BINSIKA BI MAYALA and MOSSALA MALCAMBO).

This Institute is coordinating the activities of several agronomical stations through out the Country. They all used classical selection to produce better varieties of different crops like rice, oil palm, soybean, beans...

Some of these local stations are developing transformation process to produce soybean milk and proteins (CRSAT, Center for Technological and Applied Scientific Researchs for example). The production of soybean has greatly increased recently and is giving encouragement. In collaboration with FAO, through the "Programme National des Engrais" (National Fertilizer Program), inoculums are produced but the production should be developed.

In vitro cultures are not in use in Zaïre and the infrastructures are misssing (except in private Institutions such as PLZ, Plantations Lever in Zaïre, dealing with oil palm in Binga). From the point of view of the President of INERA, developing *in vitro* cultures is not a priority for Zaïre. However, some *in vitro* plants are in use in the country but produced by the International Institute for Tropical Agriculture (IITA) in Ibadan (Nigeria). The establishment of stable links with this Center should be encouraged.

The technology of *in vitro* plants is also developed in collaboration with the Ruanda and the Burundi inside the CEPGL (Economic Community of Great lakes Countries : Zaïre, Burundi, Ruanda) at Gitega (Burundi). L'IRAZ (Institute for Research in Agronomy and Zootechnology) is in charge of different productions such as bananas, cassava, sweet potato... I was told that this Institute is well equipped with growth chambers, green houses and nurseries.

These two collaborations with IITA (Nigeria) and IRAZ (Burundi) seem well adapted to the needs of the country for the *in vitro* plant production, according to the national authorities. It's not a necessity for Zaïre to develop its own center. It is obvious that I agree on this conclusion, the priorities for developing the country are elsewhere. However, scientists should be trained to use this technology in both centers.

2.- INRB

This biomedical center, created six years ago and inaugurated by the French President F. Mitterand, has been financed by the French government and the Institut Pasteur of Paris. This Institute, directed by a French doctor, is autofinanced by the price of medical tests done here. It's a sorte of "private institution" also in charge of epidemiological studies.

The visit of the INRB was conducted by Dr KANKIEMZA MUANA 'MBO, Microbiologist and co-director.

This institute, located downtown Kinshasa, is established in very nice and clean buildings. One part of the facilities is currently rent by an american group working on AIDS.

About 17 scientists (among them 5 french persons) and 30 technicians (10 of them have been trained in the Institut Pasteur) are working in 9 laboratories :

- microbiology
- biochemistry
- physics
- toxicology
- entomology
- hematology
- virology
- immunology
- pathology.

Each group has large specific rooms, dust-free, and is well equipped with modern machines. It's obvious that the equipment is correctly used and well protected. All basic equipment is available there : several sterile hoods, many refrigerated centrifuges, ultracentrifuges (Beckman), spectrophotometers (Beckman and other), Coulter counters, multi analyzers for blood parameters, flamme photometer, very performant photonic microscopes, low temperature freezers, ice machine, electrophoretic equipment, Millipore distilled water system, incubators, etc...

In addition to the laboratories, the Institute has a nice library and an impressive animal husbandry for mice, rates, rabbits, monkeys and chimpanzee (14). This large husbandry is absolutely clean. According to the Director there is no other comparable Institute in the whole country and even in central Africa.

It is clear that this Institute is greatly dependent upon foreign support, mainly from France. All the chemicals, analysis kits, vaccins... are obtained from the Institut Pasteur, Pasteur Productions or Merieux.

In the future, it might be possible to develop more fundamental and applied researchs in this Institute. Production of antibiotics, analysis kits and may be vaccins is a possibility.

Obviously, this Institute is an exception in Zaïre.

During a private conversation, Dr. KANKIENZA has mentioned a specific project he would like to develop on a completely different aspect (not biomedical). This project is concerned with the transformation of agricultural products of high starch content (cassava, bananas, sweet potatoes...) in order to produce carbohydrates of low molecular weight. This could certainly be done in collaboration with INERA, for example or other Institutions. However, in his project (cf annexe I), Dr. KANKIENZA has mentioned the possibility to develop genetic engineering and molecular cloning in Zaïre, as "it has been done in Cuba, Venezuela..." he says. I totally disagree on this **unrealistic point of view.**

3.- CREN-K

a. Short history of the Center

As the independence of the country loomed large, the Belgian government decides to create a permanent Institution to deal with nuclear energy in the Belgian Congo. In June, 10, 1960, King Baudouin of Belgium took an "arrêté" creating the "Commissariat des Sciences Nucléaires" with the following aims :

- promoting and sustaining research in nuclear science in order to apply its results to the development of the Congo.
- assisting in the building and running of nuclear power plants and of installations for the production of radioisotopes.
- insuring the centralization of informations and documentations related to the work done or projected in the Congo in nuclear field.

During the first five years of the post-independence period, in spite of a poor overall national situation, nuclear science research started to flourish. In 1965, President KASA-VUBU decided to make the "Commissariat des Sciences Nucléaires" operational and to launch an upgrading program of the nuclear reactor from a Triga Mark I to a more powerful Triga Mark II machine. In 1967, the annual gathering of the heads of state of the

"Organisation of African Unity, OAU", which took place in Kinshasa, decided to transform the Kinshasa nuclear center into a Regional Nuclear Center, the so-called CREN-K, whose aims was to provide nuclear research facilities as well as radioisotopes to all the members of the OAU. The first stone of the new building to house the reactor was down in 1969 during the first ever African nuclear research Conference organized in Kinshasa. The new reactor and laboratory facilities was completed and inaugurated by President MOBUTU SESE SEKO, on March 30, 1972. Two years later, on November 20, 1974, the reactor was pulsed to more than 1 600 MWth becoming in the process the most powerful reactor in the African continent, which it is still to day. This reactor is located inside the campus of the University of Kinshasa. The basic characteristics of the CREN-K Triga Mark II reactor are described in Annex II.

b - Main activities of the Center

Nuclear research in Zaïre has diversified ever the year encompassing all the traditional fields of research, from nuclear engineering to nuclear chemistry through agriculture, nuclear medecine and radiobiology.

* **Nuclear chemistry** is dealing with :

- activation analysis of minor elements or trace elements of soils, control of trace metallic elements presents in "concentrate cupper" exported, control of pollution around Kinshasa ...

- production of radioisotopes and radioactive molecules using the reactor Triga Mark II.

- preparation of reactants for radioimmunological measurements (biomedical aspects).

- use of radioactive tracers for gold industry.

* **Nuclear medicine** performed in Zaïre can be renged in two categories : treatment activities and diagnosis activities :

- The treatment activities have been consisting essentially of using ^{131}I radioiodine to treat some cases of hyperthyroidism and of thyroid cancer. Sometimes radium therapy has been used in gynecology to treat the cancer of the cervix of the uterus.

- The diagnosis activities have involved numerous tests used in clinical routine to confirm a medical diagnosis or to monitor a patient's state after appropriate modalities of treatment. They are :

- brain, thyroid and liver scintigraphy

- functional or *in vitro* tests with radioimmunoassay techniques carried out on biological fluids. They yield quantitative informations regarding the functional state of the endocrine system, for example.

* **Agricultural researchs** are mainly concerned with :

- soil chemical analysis : isotopic dilution method is used to appreciate labile stock of potassium, calcium and phosphore in tropical soils.

- soil physic : hydrodynamic ...

- improvement of quality and quantity of cultivated plants : maize, rice, sorghum, peanuts, beans, soybeans and cassava. To reach this goal, the Department of Genetic and Plant breeding uses the following methods :

(1) radioinduced mutants from nuclear radiation,

(2) basic improvement methods leading to the establishment of inbeed lines, synthetic and hybrids varieties with high yield potential,

(3) management and improvement of phytogenetic ressources.

I was told (without any details) that some positive results have been obtained with peanut, soybean, rice and maize.

- biological nitrogen fixation analysis with legume systems (*Rhizobium japonicum* - soybean) and rice associated N_2-fixing bacteria.

- nutritional analysis of legume seeds which constitute an important source of food proteins and could be introduced in food habits. The main plants concerned are legumes (*Psophocarpus scandens* , *Sphenostylis stenocarpa* , *Phaseolus lunatus*) with high level content in proteins and carbon hydrates. They could be substituted to sweet potato and help selve the problem of protein deficiency in african developing countries.

c. Project for the development of a biotechnological unit in the Center.

Among the scientists I met, Prof. KABONZA and MBAYA NTUMBULA have developed a project concerning a biotechnological unit which is proposed within the CREN-K. The objectives of this unit are to focuse on and help solve **malnutrition and health problems** in Zaïre.

* Agricultural projects

Two main aspects are proposed :

(1) Nitrogen fixation by Legumes. The utilization of fertilizers is more and more expensive, and the country cannot afford them. The increasing of surfaces planted with legumes might help to solve part of this problem. However, the local production of inoculum is a necessity and should be encouraged.

The program is :

- isolation, purification and characterization of *Rhizobium* strains
- production of different types of inoculum
- improvement of plant growth in green houses and fields
- studies on the effects of mycorrhiza (phosphore utlization)

Genetic studies on *Rhizobium* and plant hoots are also proposed but from what I have seen in the laboratory, it seems unrealistic.

(2) Nitrogen fixing bacteria associated with rice and sugar cane. The objectives are to enhance the yields by using free-living diazotrophs.

The main steps of the scientific program are :

- isolation, purification and identification of the bacteria,
- measurement of nitrogen fixation activity of rice and sugar cane grown with associated bacteria,
- selection of mutants (plants and bacteria) insensitive to copper, aluminium or heavy metals.

It is well known that N_2-fixation activity of such associations is always very low and might not contribute to significantly enhance nitrogen content of the plants. In the case of rice, it may be better to try to introduce well adapted strains of *Azolla*, a very efficient N_2-fixing fern.

* Medical projects

Two aspects are also proposed :

(1) Detection of tropical diseases using radioactive DNA probes and/or enzymatic probes.

The rapid characterization of pathogens is a crucial necessity and both technologies are important. ^{32}P-probes and probes associated with alcaline phosphate, acid phosphate or peroxydase are good candidates.

In a first step, the main objectives are the detection of pathogenic strains of *E. coli*, *Salmonella*, *Shigella*, *Trypanosoma*, *Plasmodium falciparum* and *Entamoeba hystolytica*. Production of diagnosis kits for hospitals is a necessity and might be developed.

(2) Studies of medicinal plants with antibiotic properties

The traditional medicine is always frequently used. It is proposed to prepare an inventory of plants used in the case of bacterial disease, to test "*in vitro*" extracts of these plants, to characterize the active molecules and test the toxicity. Production of the molecules might also be planned through the *in vitro* culture of callus but I haven't seen an adequate structure.

A similar project has been developed by the CESNOV (Centre d'Etudes des Substances Naturelles d'Origine Végétales) created in 1981 (Faculty of Pharmacy, University of Kinshasa Prof. MPUSA KAPUNDU and KALENDA DIBUNGI).

Several professors and doctors are involved in this biotechnological project. Among them LUYINDULA Ndiku, KABINDA P.P., MBAYA Ntumbula, TSHITENGE wa Kanana, KALALA Lunganza, KABONZA, PENGE O'NKO, TONA, KADIMA T., MULUMBA B., TITE ... They are all from the CREN-K, Faculty of Medicine or Faculty of Pharmacy. Many of these scientists have been trained outside Zaïre, mainly Belgium and France. However, from what I have seen in the laboratories (very old equipment, very often out of order..) one can be very anxious about the success of the proposed projects.

4. CRAAL in Lubumbashi (not visited)

This center is now mainly involved in controls of the quality of different productions such as juices or jams from local fruits (goyave, mangue, papaye ...), flours from legumes or cereals (corn, beans, peanuts, soybeans ...) and aromatic herbs (onions, garlic, ginger ...).

One of the main problem about fruit production is the **preservation of the productions** which are mainly local, at a small scale. Marketing is also a real problem because of quality problems, difficulties of transportations and absence of cold rooms.

This center is facing crucial problems of budget and crucial difficulties to hire permanent researchers, especially by in Microbiology.

III.- POLICIES OF THE COUNTRY IN THE FIELD OF BIOTECHNOLOGY. APPROPRIATE PROGRAMMES

It is obvious that the country has to face infrastructural problems before being able to establish efficient biotechnology centers.

According to the Commissaire d'Etat for the University and Scientific Research and also to the Commissariat d'Etat for Agriculture, **genetic engineering is not a priority for the country**, and one can easily agree. However, there is a political task to develop researchs in three areas :

(1) **Preservation of the current productions** since a large pourcentage is not beneficial to the population.

(2) **Propagation of plants of high protein content and plants resistant to pathogens**. Such a program can be developed through tissue culture, in collaboration with other african countries. The *in vitro* laboratory already in Gitega (Burundi) should play an important role in this project.

(3) **Transformation of agricultural products** : production of canned local fruits (papayes, mangues, pineapples, strawberries ...) and legumes (tomatoes, mushroms...), production of jams (goyaves, bananas...), preparation of grilled soybean biscuits are among the priorities in this field.

(4) **Specific biotechnological developments.** The main possible developments are : nitrogen fixation (symbiotic or/and associative), medicinal plants, antibioties and auto-vaccines, nuclear medicine, diagnosis kits. To be worthwhile these developments should involved the best scientists in the country and strong collaborations with industrialized countries are needed.

IV.- REGIONAL AND INTERNATIONAL COOPERATION

Zaïre has already developed scientific connections with other Research Centers in Africa, mainly with IITA (International Institut for Tropical Agriculture) in Ibadan (Nigeria) and also with IRAZ (Institut for Research in Agronomy and Zootechny) in Gitega (Burundi). In both Institutes, short term and/or long-term training in the form of workshops and course could be organized on different aspects of tissue culture.

Cooperative training program should also be developed with other african countries and other Institutions in Europe or elsewhere. Zaïre has a long tradition of scientific exchanges with Belgium and France. A large proportion of scientists have been trained at the University of Louvain (Belgium) or at the Centre à l'Energie Atomique in Saclay or Grenoble (France). These exchanges should be encouraged by long-term fellowship.

Another important possibility is to participate in **training activities of ICGEB in agribiology** with emphasis on crop improvement, **and human health** with emphasis on antibiotics and vaccine production.

V.- CONCLUSIONS

As already pointed out, **Zaïre has to face and solve crucial infrastructural problems before being able to develop research of international standard.** At the present time, it would be an utopia to transfer the genetic engineering technology to Zaïre without a strong and permanent cooperation with the industrialized world. Even if this condition is satisfied, I will not recommend the development of this technology for the moment.

To day, there is a diaspora of Zaïrian scientists trained in the developed world and still in contact with laboratories abroad. These contacts should be on an extensive scale. This pool of scientists should be as active as possible in train and remotivate other scientists in the country. However, these scientists should not attempt to compete directly with research institutes in the developed world. On the other hand, they should not content themselves with repetition of what has already been achieved elsewhere. Rather, they should make extensions of established work into areas of specifically Zaïrian significance. In order to be efficient, projects critically dependent on very new types of instrumentation, which is temperamental and only intermittently functional is developed countries, should be avoided. In the same idea, analytical methods which need large importations of biochemicals should not be used (DNA recombinant technology, for example).

The immediate objectives should be to **develop a critical mass of scientific expertise in biotechnology**, and to develop multidisciplinary approaches with scientific interactions among established traditional research units. Several Zaïrian scientists, formally trained abroad in varied places, and now working in Institute such as CREN-K, represent potential candidates to coordinate a biotechnological strategy.

ANNEXE I

Dr. KANKIENZA MUANA'MBO
B.P. 1197 - KINSHASA 1
Tel : 24299 - 24740

Kinshasa, le 5 Novembre 1988.

ZAI [GEN.

A Monsieur le Réprésentant Resident
de l'ONUDI au Zaïre
KINSHASA/GOMBE.-

cc. Mr. Souto
22.11.

Monsieur le Représentant,

Désireux de promouvoir une unité de production utilisant le processus d'application des biotechnologies à la transformation et au traitement des aliments courants au Zaïre, j'ai l'honneur de recourir à votre organisme pour solliciter votre concours ainsi que les éléments techniques dont vous pourriez disposer pour la mise au point de ce projet.

Le projet vise à utiliser les techniques microbiologiques pour transformer les produits agricoles riches en amidon en substances ayant une teneur plus élevée en protéines, destinées à l'alimentation humaine et des animaux d'élevage.

Il vise spécialement la mise en oeuvre :

- des techniques de fermentation en milieu solide pour l'enrichissement en protéines des substraits amylacés (manioc - bananes - patates douces) aux fins d'obtenir des aliments ferments enrichis en protéines : AFEP.
  en transformant par exemple la farine de manioc qui contient habituelleme 2 à 3% des protéines et 80 à 90% d'amidon en un produit renfermant 18 à 2 des protéines et 30 à 35% des sucres assimilables.
- des techniques de fermentation lactiques des produits agricoles amylacés et cellulosiques à des fins :
  - conservation (ensilage)
  - d'amélioration de la degestibilité des bagasses de canne à sucre pour les ruminants
  - de production à des faibles coûts d'enzymes amylolytiques et cellulosiques
  - detoxification des dechets des industries agrico-alimentaires (élimination des tanins polyphenols et de la cafeine des porche des grains de café.

Convainu de l'impact réel sur l'amélioration de l'état de nutrition des populations et sur le developpement économique du pays de la réalisation de ce projet d'une part et d'autre part de la disponibilité : - sur le plan national des matières premières et des compétences en microbiologie - et su le plan international des technologies, du savoir-faire et des équipements dans les domaines des fermentations continues, d'immobilisation des enzyme et des cellules, de génie genetiques et de clonage de gènes nous pensons qu comme dans d'autres pays (Mexiques - Argentine - Chili - Cuba - Venesuela - Costa Rica - Guatemala - Martinique) ce projet pourrait être réalisable au Zaïre.

C'est en vue d'obtenir des conseils, des données scientifiques et techniques.

1/ sur les cultures industrielles (continue) des souches des micro-organismes le plus performants (les Aspergillus : Niger - Flanes et ORYZAE, les hactobacillus, leuconostoes - Pedio dans les bacteries METHYLOPHILUS METHYLOTROPHUS - les METHYLOMONAS CLARA. Les champignons filamentaux : FUSARIUM Graminearum - les candida

- Penicellium - utelis, parafenica - TORULOPSIS - RHIZOPUS - TRICHODERMA CANDIDA et des SPIRULINES : Spirulina MAXINA,platensis,

11/sur les équipements (fermentateur en milieu solide -cultures industrielles substrats - réactifs etc...)

111/ et sur les procedés que nous nous adressons à votre Institution.

La protection des résultats de recherches et le secret industriel rendant inaccessibles les informations disponibles dans de nombreuses entreprises industrielles exploitant ces procédés à grande échelle, ne nous laisse d'autre choix que de recourir à vous pour réunir ces éléments indispensables à la formulation de notre projet.

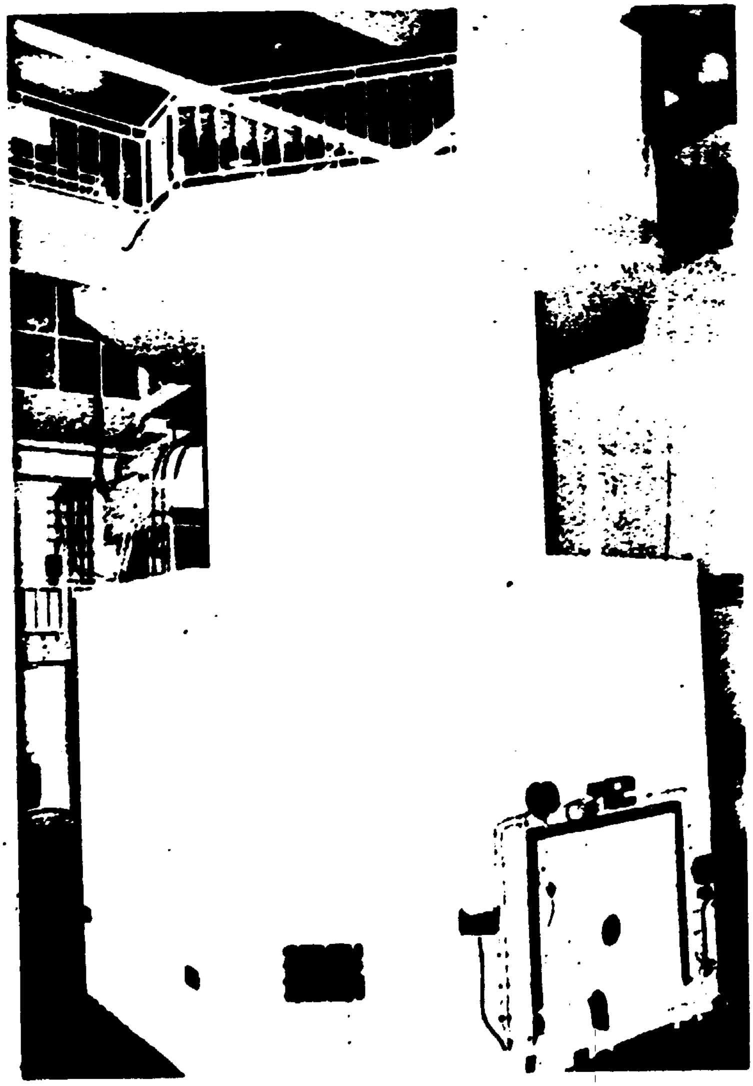
Les Nations Unies ayant financé ou cofinancé de nombreux projets semblables notamment au CUBA, nous pensons que par votre canal, nous pourrions accédé à toute les données utiles.

En vous remerciant de l'intérêt que vous accorderez à notre demande, je vous prie d'agréer, Monsieur le Représentant, l'expressio de ma haute considération.

Dr. KANKIENZA MUANA'MBO

ANNEXE II.

II^{ème} partie :
LE PRINCIPAL ACQUIS TECHNIQUE :
LE REACTEUR TRIGA Mark II



From : Recherches Nucléaires et Développement du Zaïre : 25 ans d'activités. Presses du Commissariat général à l'Energie Atomique. 1986

SPECIFIC OPERATING PROBLEMS OF THE C.R.E.N.-K. TRIGA MK II REACTOR

Prof. MALU wa KALENGA *

ABSTRACT

The paper reviews the basic caracteristics of the C.R.E.N.-K. Triga Mark II reactor. It dwells extensively on the operating problems encontered by the reactor managers during 26 years of operation that is since the criticality of the first C.R.E.N.-K Triga Mark I in 1959.

The most serious problems concern fuel element bowing, power fluctuations and lazy Susan problem.

Overall the managing record has been outstanding due in part to the intrinsic quality of the Triga Mark II reactor and in part to the ability and dedication of the staff.

RESUME

L'article présente les caractéristiques de base du réacteur Triga Mark II du C.R.E.N.-K. Il étudie ensuite de façon extensive les problèmes rencontrés dans l'utilisation des réacteurs de recherche au Zaïre pendant 26 ans c'est-à-dire depuis la criticité du premier réacteur Triga Mark I du C.R.E.N.-K. en 1959.

Les problèmes les plus sérieux concernent le courbure d'élément combustible, la fluctuation de la puissance, et le problème du lazy Susan.

Globalement, les résultats de 26 ans d'expérience, qui se révèlent excellents, sont dus en partie à l'excellente qualité du réacteur Triga Mark II et en partie à la compétence et au dévouement des techniciens du réacteur.

I. Description of the C.R.E.N.-K. Triga Mark II Reactor.

The CREN-K Triga Mk II reactor is a 1 Mw steady state, 1600 Mw nominal pulse peak Power and light water pool reactor, which went critical on march 30 1972, in a site inside the Campus of the "Université de Kinshasa".

* Commissaire Général à l'Energie Atomique de la République du Zaïre.

1.1. General description of the reactor

1.1.1. Reactor pool.

The reactor pool structure consist of a 5 mm thick cylindrical aluminium thank 7,20 m deep. Its inside diameter is 1,98 m. The tank is embedded in an octogonal-shaped heavy concrete mass, 2,40 m thick. The concrete has a density equal to 3,00 due to the use of baryte. The pool is filled with 23 m^3 of demineralized water.

1.1.2. The reflector.

The reflector surrounding the reactor core consist of a ring shaped block of graphite 0,559 m high and 0,305 m thick, encased in a leak tight welded aluminium can. The reflector has an inside diameter of approximately 0,457 m. Its weight in about 770 Kg.

1.1.3. The grid plates.

A top and a bottom grid plates provide accurate spacing and lateral positioning of the core components. They are made of anodized aluminium to prevent wear and corrosion.
The top grid plate is 0,495 m in diameter 19 mm thick. It rests on the top side of the reflector container and is secured there by 4 screws of anodized aluminium. The grid contains 90 fuel locations in the form of holes (38,23 mm in diameter) bands usually called rings (ring B to F). The center hole "ring A") in the top grid plate is 38.4 mm in diameter and serves as a guide for the central thimble.
Cooling water passes trough the plate by way of the area between the triangular spacer blocks on the top of the fuel elements and the round holes in the grid.

The botton grid plate, in addition to providing accurate spacing between fuel-moderator elements, also carries the entire weight of the core. It is 0,407 m in diameter and 19 mm thick. The grid plats has a support welded to the underside of the reflector container. The bottom grid plate contains 87 holes, 7,15 mm in diameter, in alignment with the holes in the top grid plate and are machined to receive the adaptor ends of the fuel elements. It also contains 3 holes about 38,23 mm in diameter that allow passage of the fuel follower control rods. The central thimble hole in the bottom grid plate is 39,7 mm in diameter. 36 holes, 15,9 mm in diameter, organized in 3 circular bands concentric with the central hole, plus two additional bands of holes located between B and C ring and between C and D-rings, provide water passage area through the lower grid plate.

I.1.4. Fuel-moderator elements and fuel follower control rods.

The active part of the CREN-K Triga MK II reactor core is made up of a lattice of 66 type 104 Triga individual fuel elements, 1 type 204 Triga Instrumented fuel element and 3 type 304 Triga Fueled follower control rods (FFCR). These "fuel elements" are located in 70 corresponding fuel holes in the bottom grid plates. Each type 104 Triga Individual fuel element is a stainless steel cladded rod, 3,76 mm in outside diameter having a 38,1 cm active section. Each active section contains 8 % weight of 20 % enriched uranium, homogeneously mixed with 92 % weight of Zirconium hydride ($Zr\ H_{1.6}$) serving as neutron moderator. It is located between two inactive sections made of graphite. 10,67 cm in lengh. The graphite serves as a vertical reflector in the fuel element. An adapter fits the fuel element in each grid plate. The overall length of the fuel element is 72,05 cm. A type 204 Triga Instrument fuel element is similar to a type 104 Triga Individual fuel element but contains in addition three chro-alumel thermocouples in the fuel-moderator which provide fuel temperature information to the control console. Each one of the three Fueled Follower Control rods is a sealed stainless steel tube 102,87 cm long, 34,29 cm in outside diameter containing 31,1 cm of boron carbide as neutron absorbant in its upper section, 38,1 cm of 8 % weight of Zirconium hybride mixture in the lower section and 10,67 cm of graphite reflector on each end.

I.1.5. Graphite dummy elements.

Graphite dummy element occupy the position not filled by fuel-moderator elements and other core components. These elements are entirely filled of graphite. They are aluminium cladded but are of the same dimensions as the stainless steel fuel elements. 11 graphite elements are localed in the F-ring of the reactor core.

I.1.6. Control rod assembly.

The control rod assembly consists of three fueled follower control rods and one "water follower" borated graphite pulse rod and their respective drive-assemblies.

An anodized aluminium rod joins each one of the three Fueled Follower Control rods to an amarture that is part of an electro-mechanical rod-drive assembly. The connexion to the armature is made by way of an electric contact with a 24 V magnets in the drive assembly. The control rod can go up and down as initiated from the control console, or can shut down quickly the reactor by falling down in the core when the current on the magnet is interrupted.

The fueled follower control rods occupy core positions C10 for the safety rod, D1 for the regulating rod and D10 for the Shim rod.
The purely absorbing pulse rod, on the other hand, is located in core position C4 and has a electro-pneumatic drive-assembly for large prompt insertion of reactivity in pulse mode of operation.
One digital voltmeter and series of illuminated push buttom and other lamps at the console indicate the instantaneous vertical position and overell status, of each control rod. The four control rods have the following respective worth:

Safety	:	$ 4,70
Pulse	:	≥$ 3,00
Shim	:	$ 3,25
Regulating	:	$ 3,17

I.1.7. Neutron source.

The neutron source in a 600 mCi Radium-Berylium source. This activity corresponds to a neutron emission of $0,992 \times 10^{7}$ neutrons per second. The neutron source is located in one F-ring position of the core.

I.1.8. Irradiation facilities.

The reactor offers a number of basic and advanced irradiation facilities for a large number of experiments :

1) The Rotary specimen Rack (Lazy Suzam) is a 40-irradiation positions, ring-shaped divice, located in a circular well in the refle tor assembly. It has a specimen-removal tube, a drive-and-indicator assembly and a tube-and-shaft assembly that connect it to the drive-and-indicator assembly.
Typical Polyetnylene or aluminium containers are used in this facility. The usable space in each container is about 33 cm^3. The Lazy Suzan has a total capacity of 80 such containers and an average thermal flux of 5×10^{12} $n/cm^2/sec$ at 1 MW of reactor power.
A specimen-lifting assembly serves as a tool for insertion and removal of containers.

2) matic transfer systems allows the production of very short-lived ra otopes. One of these transfer systems is a Gen ral Atomic Rabbit. Its irradiation position is in the core locat on F-22 where a thermal flux of about $2 \times 10^{13} n/cm^2/sec$ at 1 MW is obtainable. Samples can be irradiated up to

5 min. in the automatic mode. The Manuel mode of operation is used for longer durations of irradiation.

The irradiation terminal of the other transfer system exposes samples to a thermal flux of about 2×10^{10} n/cm^2/sec. just against the outside of the reflector. This transfer system has also both a manuel and an automatic mode of operation.

3) One thermal colum and four beam-tubes for various experiments whith neutrons.
4) The central thimble and any other pool area at reator core level offer irradiation possibilities mainly when a watertight container is provided.

I.1.9. Water systems.

The demineralized water of the Primary system of the reactor circulates in a forced manner under the action of a 40 m^3/hour pumps for reactor power up to 250 Kw. Above this power level a 90 m^3/hour pump is used.

In addition to acting as a neutron moderator and providing biological protection to personnel working at the top of the reactor, the water cools the reactor core. The heat is transfered to a secondary water system through a 72 plate heat-exchanger.

The secondary water system has one 70 m^3/hour and one 140 m^3/hour pumps for the above mentioned low and high ranges of reactor power levels, respectively. Four cooling towers outside the reactor building provide heat-exchange with the atmosphere. To prevent cases of water shortage the secondary system is fed with town water system through a 11 m^3 reserve tank.

Water demineralization is obtained in a mixed-bed type E-40 Theodor Christ ion-exchanger after prior passage through a carbon filter unit. A small 1 m^3/hour stainless steel pump is located in the demineralization by-pass line. Water temperature at different point, its activity and conductivity are visualized at the control console in the form either of readingsor lamp signals.

I.1.10. Control console and reactor Instrumentation.

The control console contains a control panel with four sets of push buttoms and various indicators for handling the four control rods. Five control channels allow the operator to follow closely and at all range reactor power evolution. Ther are :

1) The "Starting Channel" that uses a BF 3 neutron detector and a log ratemeter. It is used to monitor the reactor power from shutdown (source level) to

approximately 10 watts. In terms of impulsion on the log-ratemeter one goes from about 10^2 to 10^6 impulsions.

2) The "Starting and Power Channel" that uses a Reuter stockes chamber in conjunction with a type PA 5 peamplifier and a log & Linear Power Channel both of General Atomic design. This channel permits the monitoring of the reactor power from source level (about 10^{-10} KW) to full Power. This channel has per cent power meter and a periodmeter. The latter indicates reactor period from ± infinity to 3 seconds.

3) The "Pico Channel" is a linear channel that consists of a General Atomic Multi-range picoammeter NMP-4 reading current from a compensated ion chamber with display on the blue pen of a type Electronik 194 dual-pen Honey-well recorder. The 15 ranges of the picoammeter permit the reading of the reactor power in term of current from 1.10^{-10} A to 1.10^{-3} A with 3×10^{-10}, 3×10^{-9}, etc. as intermediate ranges.

4) The fourth channel is made up of an uncompensated ion chamber and a General Radiological type 4007A shutdown amplifier equipment. It reads the reactor power from about 100 watts to full power in four current decades : from 10^{-8}A to 10^{-4}A.

5) The "Pulse channel" uses a Gulf Electronics Systems Pulse chassis and a type WL Westinghouse uncompensated ion chamber.
In the pulse mode of reactor operation the pulse channel gives :

a) Instant peak "nv" on a "nv-meter" on the blue-pen of the dual-pen Honey-well recorder and optionally on a type 906 T Honeywell visicorder.

b) Integrated power "nvt" on a "nvt-meter" and optionally on the visicorder.

c) Instant peak fuel temperature on two meters and on the red-pen of the dual-pen recorder.

In steady-state mode the pulse channel gives the corresponding reactor power current on a movable picoammeter because the magnitude of the current is too smal for the scale on the nv-meter (about 6×10^{-7}A at 1 MW).
Fuel temperature signal from the instrumented fuel element in core position B-1 is also provided through the pulse channel, so that instant peak fuel temperature in pulse operation can be read on two different meters as well as on the red-pen of the dual-pen recorder.

In steady-state mode fuel temperature reading is given on the two meters only, but through the same pulse channel.
The pulse channel finally allows pulse rod shutdown delay setting from 1 to 15 seconds plus an infinity setting position.

To insure safe working conditions for the personnel and safe startup and operation of the reactor, almost every installed health physics equipment and important auxillary machine in the reactor hall has some kind of monitor in the console.
For safety reasons the electronics wiring of the reactor console caries a good number of built-in logics.
On can list for example :

- different interlocks of the four control rods on each others;
- the scram logic consisting of fourteen different automatic reactor shutdown (scram) possibilities, each of which corresponds to one specific predetermined event or incident. If any one of such events or incidents occurs the control rod magnet current line is opened so that the reactor is shut down without any intervention of the operator. On the other hand, 6 manual scram buttons disseminated in different levels of the reactor bay allow shutdown of the reactor from any one in the hall in case of emergency. Every scram event is signaled by a labelled red lamps on the console;
- the alarm yellow lamp logic that call the attention of the reactor staff on particular situation that need to be investigated and corrected but that does not need to shut down the reactor. One of these "yellow" alarm is the "minimum source level" alarm that locks the four control rods in one given position, and hence, prevent any reactor startup.

Both scram and alarm signals are based on a " fail-safe" system so that any absence or mal-function or "off" state of an instrument for exemple is signaled as if this equipment detected too much activity.

- In addition to other performances, the pulse mode logic allows pulsing only when residual power of reactor is less than 1 KW on the "Starting and Power Channel" and the "Pico Channel" is on one of its ranges not higher than 1×10^{-6}A.

I.2. Reactor hall.

The reactor hall is a windowless all concrete building. It is 19,80 m long, 17,80 m large, 14,60 m high and has four working levels.

- The 3 m deep underground is mainly occupied by water system pipings and pumps, the heat-echanger, the ion-exchanger, etc.

- The basement (or zero level-floor) is an area where different experiments can be carried out using the beam-tubes and the thermal colum. The control units and receiver assemblies of the two irradiation and pneumatic transfer systems and most of health physics heavy equipments are situated at this level.

- The Intermediate level (3,75 m) provides a counting-room, a multipurpose office and an open area.

- Finally the upper level (7,50 m) contains the control-room and the reactor supervisor office. Two bridges join this working level to the top of the reactor pool.

The ambiant pressure in the reactor hall is always maintained slightly less than the atmospheric pressure, so that possible air contamination or dust will not go from inside the building toward the outside. The only way out for air from the reactor hall is in a forced manner through 99 % absolute filters and in an unique chimey which is constantly under monitor for Argon A-41 concentration. Any excess in concentration initiates an "evacuation" alarm.
Three 7 HP air-conditioning machines are used in the extraction of the air of the hall.

II. Reactor operation report.

II.1. Operating statistics.

The Triga Mark II reactor has completed 2640 hours of power operation time and 472.000 KW hours of integrated steady-state power from its initial startup in March 24 1972 to December 31, 1982. That makes a yearly average of reactor operating time of 240 hours.
Triga MK II reactor maximum power level was 50 KW until july 1974. It was then upgrated to 1 MW and the pulse rod was made operative this same year.

In the 1974-1982 period, 98 pulses in the range from $ 1.00 to $ 2.5. were performed. A total of nearly 2.200 containers has been irradiated. This represents approximately 1.500 irradiated specimens.

II.2. Maintenance and operation statistics.

Routine reactor maintenance is carried out by way of a daily operation check-list and of a monthly check-list. "General checklist" type including a thorough examination of the overall installation is performed once a year.

III. Other statistics related to the operation of the C.R.E.N.-K. reactors.

Since the start up of the first 50 KW Triga Mark I reactor in 1959 the staff of the CREN-K has accumulated 26 years of operation and maintenance experience with this type of swiming pool reactor. Experience gained provides the opportunity to present useful operating parameters and data as well as informations on abnormal occurence.

During the post 26 years, we have operated two triga reactors, a 50 KW reactor from 1952 to 1970 and a 1 MW, pulsing type, Triga reactor from 1972 to today. The accumulated energy generation is shown in table I.

Table I.

Energy generation in two Triga reactors at CREN-K facility				
Reactor	Year critical	Steady state/Pulsing limit		Energy generation to 6/85 (MWD)
		Steady state (MW)	Pulse	
Mark I	1959	0,05	-	2,5 decommissioned 1970
Mark II	1972	1	3,00	30.

Some other statistics

A) The observed pool water evaporation rates , has been of the order of 5 cm/week.

B) Resin Bed maintenance : one change every two years; average dose rate 30 mr/hr.

C) Control rod and drive maintenance :

- no change in control rod position;
- change of rod drive Motors : 2 due to electrical problem in the rod drive assembly ;
- the initial General Atomic circuitry, was changed to avoid the rod going up in case a live wire is broken.

D) On the Triga Mark II, one has to cope with vibration of the control rod.

F) Object retriaval from reactor pool and core.

Over 26 years one has rarely the opportunity to pratice the retrieval of dropped object which is always a difficult job except for floating object. To remove dirt and small object of all type lying on the tank bottom, the best way is to use a pump to create water suction. Mechanical claw on end of long pole to reach the object has also been used.

G) Water Chemistry for reactor Pool.

Clean, pure water in the reactor tank promote good operation by reducing the likelihood of corosion of the reactor components and reducing the quantity of radioactive material.

H) Radioactivity release in the atmosphere.

- The release of radioactivity into the environment is a primary concern in the operation of nuclear reactors. Monitoring of the effluents from reactor sites is required to assure that exposure to facility personnel and to the general public does not exceed the recommandation of the International Commission on Radiological Protection (I.C.R.P.) and (or) applicable regulations of various state agencies.

- For the Triga the only measurable radionucleide of reactor origin that is released in the atmosphere during normal operation is Argon-41. It is therefore necessary :

1) to develop a comparatively simple and reproductible technique for independently establishing the Argon-41 concentration in the Triga ventilation discharge system at various reactor power levels;

2) to compare the independently derived Argon-41 concentration to the concentration indicated by the existing Argon-41 stack monitoring system under indentical condition.

The system used in the CREN-K Triga Mark II has shown itself to be excellent. The system monitor not only gaz but also particulate release. Over the 26 years of reactor operation no release of radioactivity in the atmosphere above normal level has been recorded.

IV. Specific problems with the operation of the Triga Mark II reactor.

IV.1. Bowing of fuel element.

Four fuel element length and bowing measuring tests were performed during the period 1974-1982.
During the 1976 test, 2 of the core fuel elements were found to have bowing in excess of the acceptable limits. No cracks was observed on the fuel elements cladding. Both fuel elements where transfered in the hot fuel storage wells.

The postulated mechanisms of swelling and bowing in the damaged fuel element may be discussed as a number of interrelated phenomena :

1) hydrogen migration under thermal gradients from regions of higher temperature to regions of lower temperature in the fuel is a governing factor in causing swelling of the fuel;

2) generation of high local gas pressures in the fuel matrix during very high power pulsing results in swelling and increased pore size. The gaz pressure is produced by hydrogen evolution in the hot spots near the surface of the fuel rod were increased hydrogen concentration exist.
These increased hydrogen concentrations result from relatively long-term steady state operation during which the hydrogen tends to redistribute radially and axially by migrating to the cooler surface region.

From the foregoing discussion, it is possible to ascribe the bowing and swelling phenomena observed in the damaged fuel elements to the following series of events, (2) :

1. hydrogen migrates toward the cooler surface region of the fuel in an unsymetrical configuration governed by thermal gradients and temperatures. The migration occurs over long periods of steady-state operation;

2. during steady-state operation, essentially no hydrogen migrates to the immediate surface region of the fuel or to the central part of the rod which is the hottest part of the fuel element because of the temperature gradient. The high central temperature forces hydrogen away from the center, and very low migration rates at the immediate fuel surface region temperature prevent hydrogen build-up in this region;

3. concentration of hydrogen takes place in the fuel internal to the cool surface area. This may set up the conditions for circumferential cracks near the surface, possibly during later high power pulse operation.

4. the concomitant Increase in hydrogen pressure in the hot spots during high power pulsing results in swelling and an increase in pore size.

One should note that the fuel temperature safety limit is unaffected by the events and process discussed above because it is set by the average H/Zr ratio in the element. The safety limit is based on the resulting hydrogen pressure exerced on the fuel element clad, tending to rupture it.

To investigate further the presence of cracks on the fuel element we could have conducted a neutron and gamma radiography. Indeed (4) :

1) Triga reactor neutron radiography facility can be set up to produce both neutron and gamma radiography of reactor fuel.

2) In the case of UO_2 fuel, conventional thermal neutron radiography produce excellent quality radiographs. These radiographs may be used to detect various defects in the fuel such as enrichment differences, creck, end-capping, inclusion.

3) For Triga fuel elements, conventional thermal neutron radiography will not show however the internal structure. This is due to the high hydrogen content of the fuel. The elements are typically 8.5 w/o uranium in $Zr\text{-}H_{1,6}$, the density of hydrogen in the fuel being about 80 % that of the water. Further while epithermal neutron radiography using Indium foil significantly improves the radiography, defects may go undetected.

4) As an alternative to neutron radiography, high energy gamma radiographs of Triga fuel elements can be taken. The gamma spectrum emitted by reactor core is sufficienty high in energy so that very good radiographs may be

obtained with this technique. These radiographs show excellent detail for the intermal structure of the Triga Fuel.

In our case we felt it was not useful to carry out this elaborated investigation in the case of the two damaged fuels.

IV. 2. Power fluctuation.

After the up-grading of the reactor power to 1 MW, power fluctuations were recorded. After extensive investigations it was discovered that the power fluctuations was due to excessive lateral motion of the control rod induced by the action of the forced flow of the cooling water.

This was due to a 4 mm excess difference between the 34,29 mm diameter of the fueled follower control rods and the 38,23 mm diameter of the hole in the top grid plate. To solve the problem, aluminium ring about 1,5 mm thick were put in the proper holes in the grid plate.

IV.3. Lazy Suzan problem.

The weakest part of an otherwise excellent Triga reactor is the rotary specimen rack (Lazy Suzan).

This item wich is a mobile part in the reactor must withstand relatively high neutron and gamma flux in normal operation.

In order to reduce the radiation damage, particularly induced oxydation, it is advisable to use an electric drive in order to rotate on a continuous bases the lazy suzan during operation

The CREN-K Triga Reactor has not such a system.
So far during the past 26 years we have experiences two failures of the lazy suzan affecting respectively the first Triga Mark I reactor and the second Triga Mark II reactor.

It was impossible in each case to rotate the rotary rack. It replacement from a 7 meters distance represent a huge task. This operation required a partial dismembering of the top of the reactor. It was sucessfuly carried out the last time in 1977.

VI.4. Cocked (tilted) fuel element.

The core is encased within a cyclindrical aluminium container which house the reflector.The reflector provides support for the upper an lower grid plates. The grid plates are aluminium plate structure 1,9 cm thick which are positionned and fastened to the reflector. Fuel elements are loaded into the core from above by lowiring an element through the upper grid plate lattice position until the botton fixture of the element rests on and is seated in its correct countersunk hole in the lower grid plate. When seated properly, the button fixture of an element does not totally penetrate the lower grid plate but rests in the beveled region of a countersunk hole under its own weight. The bevels in the lower grid plate act to restrain lateral and limited vertical motion of the fuel elements. Due to various facto. one can witness, cocked (tilted) fuel element. Potential contributors to cocked Triga fuel elements include:

1) improper seating of an element during its loading into the core lattice;
2) warped or insecurely fastened grid plates
3) hydraulic lifting of an element during steady state or pulse operation;
4) vibrational loads during pulsing, which cause displacement of the bottom fixture of an element up and out of its bevel. All these contributors require concurrent or subsequent vibrational and (or) hydraulic loads to augment lateral displacement.

Item 3. particularly during high power pulsing is considered the most potential mechanism for causing mis-seated elements.

Very few cases of cocked fuel elements were recorded in the CREN-K Triga Mark reactors in the past 26 years.

IV.5. Solenoid pick up problem.

The solenoid operated specimen pickup tool happened to be engaged in the 15,9 mm diameter probing hole in the bottom of one of the Lazy Suzan irradiation tubes. Actuation of the assembly in order to release it was unsuccessful. We succeeded in solving the problem by cutting the electric leads near enough to the pickup tool, losing the latter in the irradiation tube. The operation was carried out by using a special tool manufactured for the circumstance. A red label was put on the corresponding indicator position to forbid future use of the concerned irradiation position.

IV. Conclusion

The staff of the CREN-K has accumulated a good experience in the building and maintenance of the Triga reactor over the 26 years of the existence of the Kinshasa nuclear center.

The staff has encountered some unavoidable problems in the running of a reactor which is still the most powerful research reactor in Africa, at least in the pulsing mode. No accidents however of any sort has been recorded in 26 years of operation either with the Triga Mark I on the Triga Mark II reactor.

This record speaks well for the intrinsic quality of the Triga reactor which is probably the safest machine available in the open market.

The record is also a tribute to the ability and the dedication of the staff.

REFERENCES

(1) Rapport de sécurité du Réacteur Triga Mark II du CREN-K; éditeur : Malu wa Kalenga; Kinshasa, édition C.G.E.A., 1976, 458 pages.

(2) General atomic, Eighth biennial U.S. Triga user's conference papers and abstracts; TOC-14; Idaho Falls, Idaho; 1982, 203 pages.

(3) Malu wa Kalenga, Solenoïd pick-up problem on the CREN-K Triga Mark II, reactor; Revue Zaïroise des Sciences Nucléaires; Vol.II,n°1-2, juin-decembre 1981; pp.111-115.

(4) Clark Darid, Final safegnard report for the Cornell University Triga Reactor; University of Cornell, CURL-2; may 1961; 250 pages.

(5) Malu wa Kalenga; Power stabilisation of the Triga Mark II reactor of CREN-K; in Proceeding of the Conference on Triga reactor, Salt-lake city, U.S.A.; San Diego General Atomic Press; TOC-7; 1976; pages 3-38 à 3-48.