PROCEEDINGS, 35th CONFERENCE ON REMOTE SYSTEMS TECHNOLOGY, 1987

KEYWORDS: *examination, fuel, hot cells, techniques*

CEA HOT CELL FACILITIES DEVOTED TO IRRADIATED FUEL EXAMINATIONS : STATUS AND NEW DEVELOPMENTS

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ABSTRACT

In connection with French reactors and their fuel examination needs, the CEA hot cell facilities are reviewed. Some examples are briefly described to illustrate new developments in their programs, their techniques and equipment and just how some facilities have been adapted to suit new purposes.

I. CEA LABORATORIES DEVOTED TO IRRADIATED FUEL EXAMINATION IN RELATION TO DIFFERENT REACTOR TYPES

In France, the two main types of reactors that require irradiated fuel examinations are :

- Pressurized Water Reactors (PWR'S) with more than forty power reactors of either 900 or 1300 MWe operated by the EDF.

- Fast Breeder Reactor (FBR'S) with the PHENIX prototype reactor (250 MWe), jointly operated by the CEA and the EDF, and the SUPERPHENIX demonstration reactor (1200 MWe) operated by the European company NERSA (FRANCE - DEBENE - ITALY).

Figures 1 and 2 show, respectively for PWR'S and FBR'S, the circuit of the objects to be examined and the hot cell facilities concerned.

A third program, the Natural Uranium Gas Cooled (UNGG) reactors was developed by the CEA ; four reactors are in operation in France and one in Spain. However, in view of the fact that this type of reactor is no longer built, fuel examinations simply consist of appraising some defective fuel elements, especially those with cladding failures. These examinations are carried out in the "LABORATOIRE D'EXAMENS DE COMBUSTIBLES ACTIFS" (LECA) at the CADARACHE Nuclear Research Center.

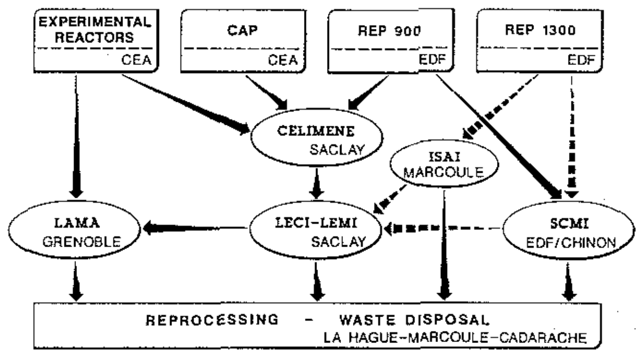


Fig.1. Examination hot cell facilities in the french P.W.R. cycle.

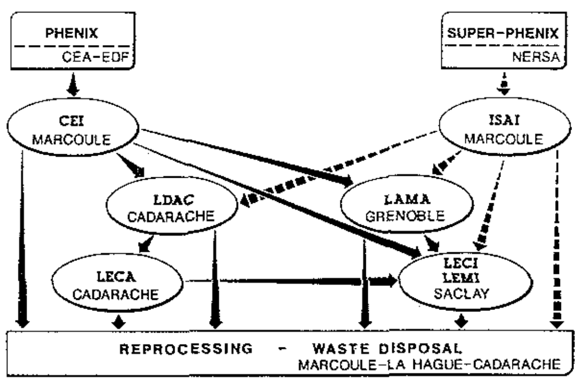


Fig.2. Examination hot cell facilities in the french F.B.R. cycle.

Table 1 presents the list of the CEA irradiated fuel examination hot cell facilities, their role and the origin of the examined objects.

	SITE	ROLE: FUEL – NON DESTRUCTIVE TESTING	ROLE: FUEL – DESTRUCTIVE TESTING	ROLE: MATERIALS	EXAMINED FUEL: REP	EXAMINED FUEL: RNR	EXAMINED FUEL: UNGG
CELIMENE-LECI	SACLAY	+	+		+ + +	+	
LAMA	GRENOBLE	+ +	+		+ +	+	
LDAC	CADARACHE	+				+	
CEI	MARCOULE (PHENIX)	+				+	
ISAI	MARCOULE	+			?	+	
LECA	CADARACHE	+	+ +			+ + +	+
LEMI	SACLAY			+	+	+ +	

Table 1. CEA hot cell facilities deveted to irradiated fuel examination

These facilities are as follows :

- L.E.C.I. : The Irradiated Fuel Examinations Laboratory, located at the SACLAY Nuclear Research Center and connected to the dismantling and non destructive examination cell CELIMENE .

- L.E.M.I. : The Irradiated Material Test Laboratory at the SACLAY Nuclear Research Center.

- L.A.M.A. : The Radioactive Materials Analysis Laboratory at the GRENOBLE Nuclear Research Center.

- L.D.A.C. : The Irradiated Fuel Subassembly Cutup and Examination Laboratory Facility, located at the CADARACHE Nuclear Research Center connected to the RAPSODIE reactor.

- C.E.I. : The Irradiated Fuels Examination Cell inside the PHENIX reactor building at MARCOULE .

- I.S.A.I. : The Irradiated Subassembly Monitoring Facility at MARCOULE .

- L.E.C.A. : The Active Fuel Hot Cell Laboratory Facility at the CADARACHE Nuclear Research Center.

II. CHANGES IN THE EXAMINATION PROGRAMS

In the course of time, the increase of reactor safety studies influenced the irradiation programs and therefore the examination programs. Fuel behaviour analysis in either incidental or accidental conditions led to the examination of more or less heavily damaged fuel elements.

In that respect, the SCARABEE safety program is devoted to the study of hypothetical coolant accidents in FBR subassemblies. The instrumented test section includes a sodium-cooled pin bundle with either 19 or 37 pins, that is highly damaged during the test. Post test examinations performed in LECA require specific preparations prior to the examinations such as the removal of the remaining sodium by heating under vacuum (T= 500°C), the embedding with a low melting temperature alloy (Wood alloy type) and the cutting of large samples (Ø ≃ 10 cm). Accurate metallographic examinations are then performed with the twofold purpose of understanding the phenomena and calibrating the physical code models. Techniques such as quantitative image analysis are used to identify and quantify the distribution of the different structures present within the samples examined (figure 3).

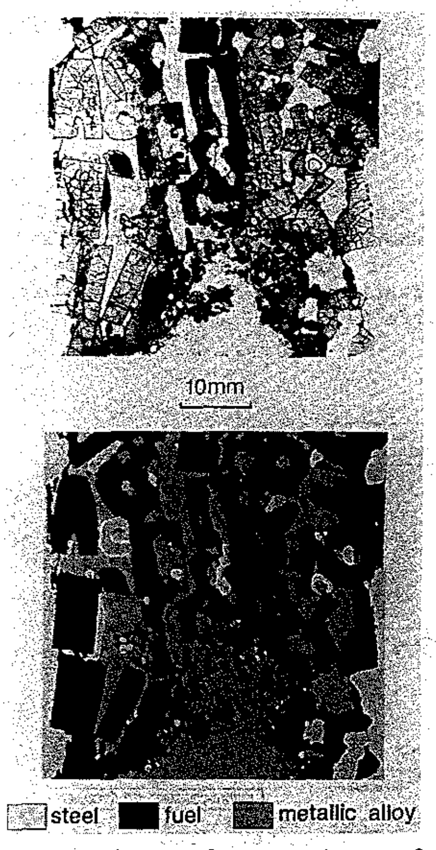


Fig.3. Image analysis of an axial cut of a Scarabee experiment.

In the LECI, similar examinations are being performed on experimental test sections of the PHEBUS program, whose purpose is to study the PWR fuel behaviour in case of a hypothetical accident involving the loss of primary coolant accident.

III. ROLE OF THE HOT CELL FACILITIES IN ADDITION TO FUEL EXAMINATION

In the course of time, the programs and functions of the hot cell facilities evolved along the following main lines :

A. Participation in different fuel cycle tasks downstream from the reactors :

Hot cells facilities are used in the treatment of irradiated elements thus allowing fuel reprocessing and waste rage.

This usually involves mechanical operations (dismantling, cutting...) and also chemical stabilization operations. As a result, an extension of the LECA Laboratory, named STAR (which stands for Reconditionning, Cleaning and Treatment Facility) is now under construction in order to meet these demands and most especially to prepare the reprocessing of defective UNGG fuel elements presently stored in a pool on the CADARACHE site.

As another example, in the LDAC, the recovery of irradiated B_4C from FBR absorber rods has been planned in the prospect of reprocessing or storage, after elimination of the sodium and tritium (figure 4).

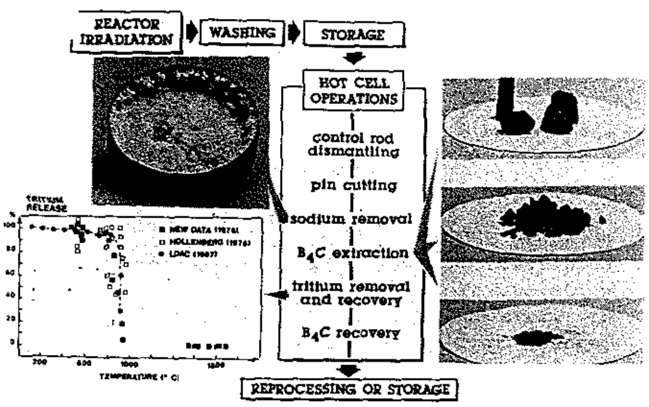
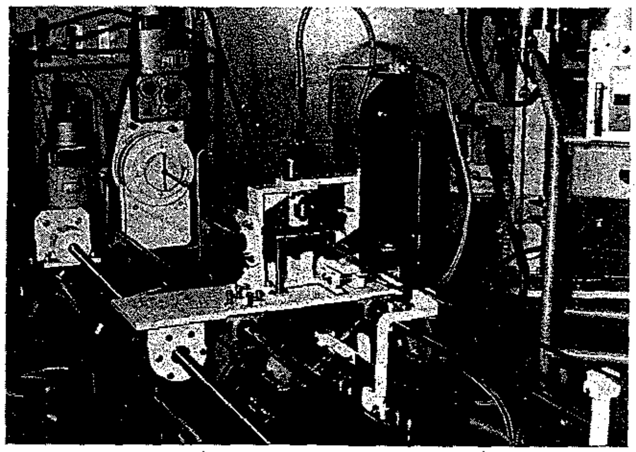


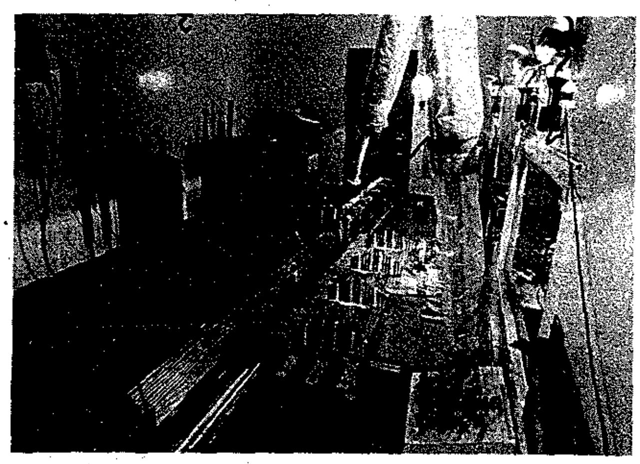
Fig. 4. B_4C recovery from irradiated F.B.R. control rods.

B. Resetting of irradiated pins for specific in-reactor experiments :

In the field of FBR programs, some PHENIX fuel elements are currently re-irradiated either in PHENIX or in the SILOE experimental reactor, after first being reset in a hot cell where possible modifications such as space wire change, fission gas removal, clad weakening... can be performed. As an example, figure 5 illustrates both a semi-automatic bench used in LDAC to change the space wires and also the arrangements made in the CEI in order to reset a PHENIX 217-pin bundle.



MOUNTING OF A NEW SPACER WIRE



ARRANGEMENT FOR A NEW PIN BUNDLE

Fig. 5. Operations for irradiated pins resetting

In the field of PWR programs, the FABRICE process, developed in the LECI, allows us to produce experimental pins of a small dimension either instrumented or not, using standard irradiated fuel pins from power reactors : these pins are destined to be re-irradiated in test reactors such as the OSIRIS or the SILOE reactor. The preparation and the qualification of this process have necessitated the development of specific equipment in the fields of machining, welding, instrumentation and monitoring. Figure 6 represents a multi-function apparatus designed for machining operations before welding.

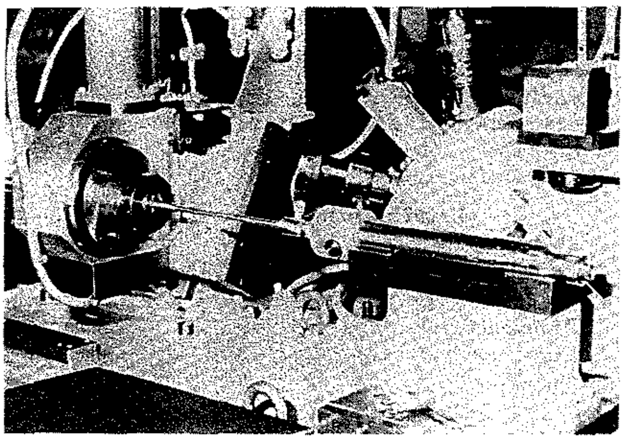


Fig. 6. FABRICE PROCESS
Machining apparatus equipped with Capstan and different tools(bach) and Borescope in operation (front)

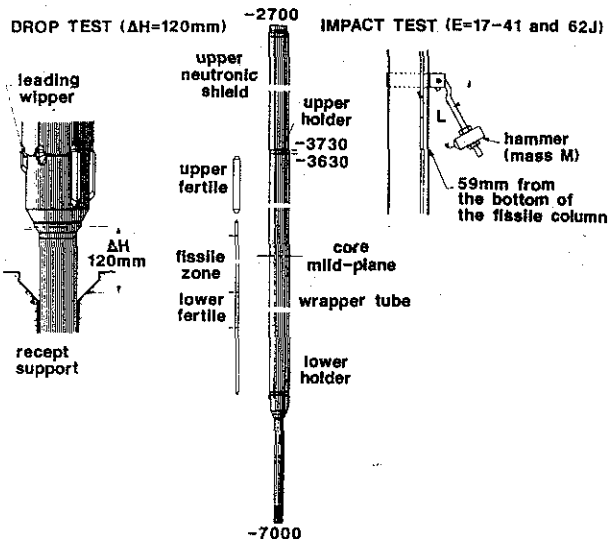


Fig. 7. Mechanical testing on irradiated PHENIX sub-assembly.

- study of the behaviour of defective FBR fuel elements when stored in sodium in conditions representative of the internal storage option now being considered for future FBR reactors :

figure 8 represents a basic diagram of the tests performed in LECA, which consist of heating the pre-irradiated fuel test sections in sodium for about 1000 hours, and observing their subsequent change.

C. Studies and specific tests :

Among these varied types of activities, the following examples can be cited :

- development of news techniques in mechanical testing on tubes by means of electroerosion machined test-pieces resulting in material saving and test simplifying

- mechanical tests on irradiated FBR subassemblies in order to check their behaviour in case of a sudden drop or impact :

figure 7 shows a diagram of the tests carried out at the CEI on a heavily irradiated PHENIX subassembly, equipped with a hexagonal wrapper tube made of ferritic steel.

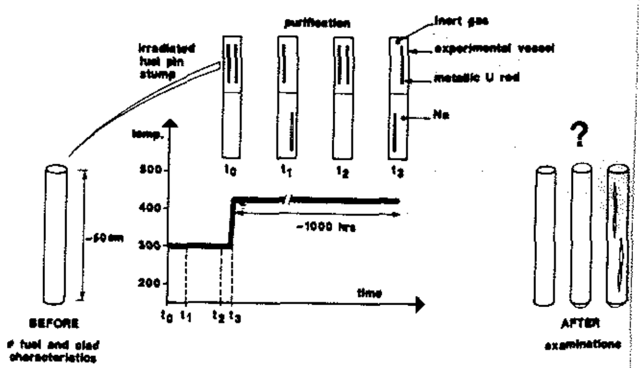


Fig. 8. Irradiated fuel/Na reaction studies "internal storage program".

- the HEVA experimental program, conducted in LAMA, in order to study the fission product release from PWR fuel elements under accidental conditions (highly damaged core) :

These tests are performed on fuel test sections irradiated in EDF power reactors and afterwards re-irradiated in experimental reactors ; they consist of heating the fuel in conditions which simulate the accident studied. The aerosols formed and the fission products released, especially short-live isotopes are then measured and their chemical form determined.

Figure 9 represents the basic diagram of a test and several examples of the results obtained : state of the fuel rod after the test, gamma scanning of the fuel pin, scanning electronic microscopic image of the aerosols...

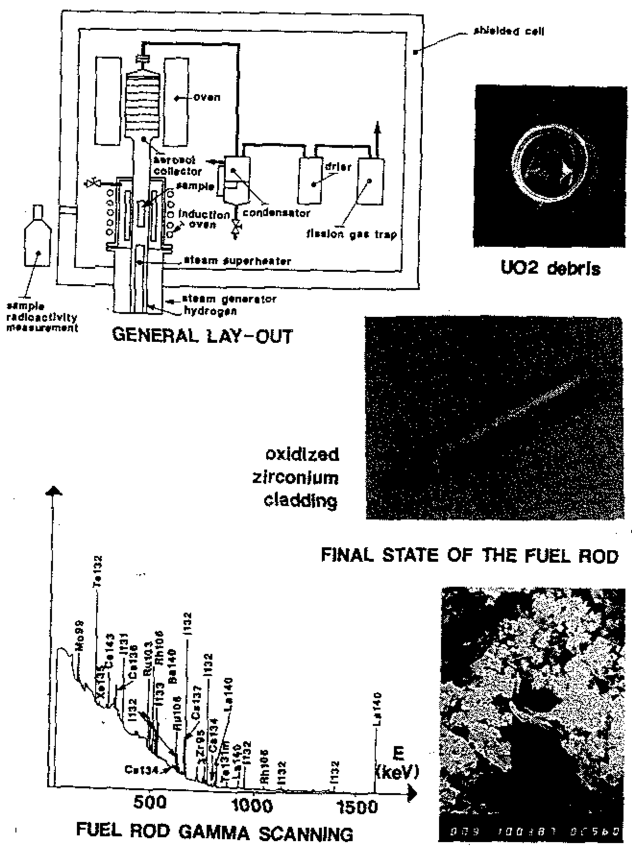


Fig. 9. HEVA experiments

- the EDGAR program, conducted in the LECI on irradiated PWR cladding materials, in order to determine its mechanical behaviour in conditions of an accident involving the loss of primary coolant :

this involves a series of burst tests performed on irradiated clad test sections heated by the Joule effect (for example 100° C/s between 300°C and 1000°C) and undergoing a pressure increase (for example 1 MPa/s up to 10 MPa maximum). The experimental device and associated instrumentation (thermocouples, optical pyrometer, camera...) have been adapted to the demands of remote-controlled work conditions. A similar program, EDGAR INOX, concerning core materials in FBR's is now underway.

IV. ADAPTING HOT CELLS TO THE DEMANDS OF THEIR NEW ROLES

In order to take into account the various changes which have been previously discussed, the actual means and equipment of the hot cells have to be adapted, especially in the following directions :

- Refurbishing and improvement of standard equipment :

within the framework of a plan called "rebirth of the hot cells" (in French, "Jouvence des labos chauds") these facilities have received special funding from the CEA.

- Development of precision methods :

a considerable effort has been undertaken in the field of non destructive inspection of both FBR and PWR fuel elements in the prospect of guiding destructive examinations and limiting their number. This is particularly the case of eddy current controls which provide reliable information concerning the actual state of the clad, which has simply to be confirmed through a metallography of the incriminated zone. An example would be figure 10 which exhibits the fuel cladding chemical interaction (FCCI) on an irradiated pin coming from PHENIX.

Furthermore, supporting the validation of calculation codes, we attempt to provide the most quantitative information possible. Thus, the shielded electron microprobe CAMEBAX, operated at the LECA, has been calibrated to perform quantitative analysis of the fission products present within the FBR irradiated fuel. In the same manner, within the framework of studies pertaining to the reprocessing of irradiated fuel, the LECI has perfected a novel method for preparing insoluble residus (a few microns in size) allowing for their quantitative analysis through EPMA.

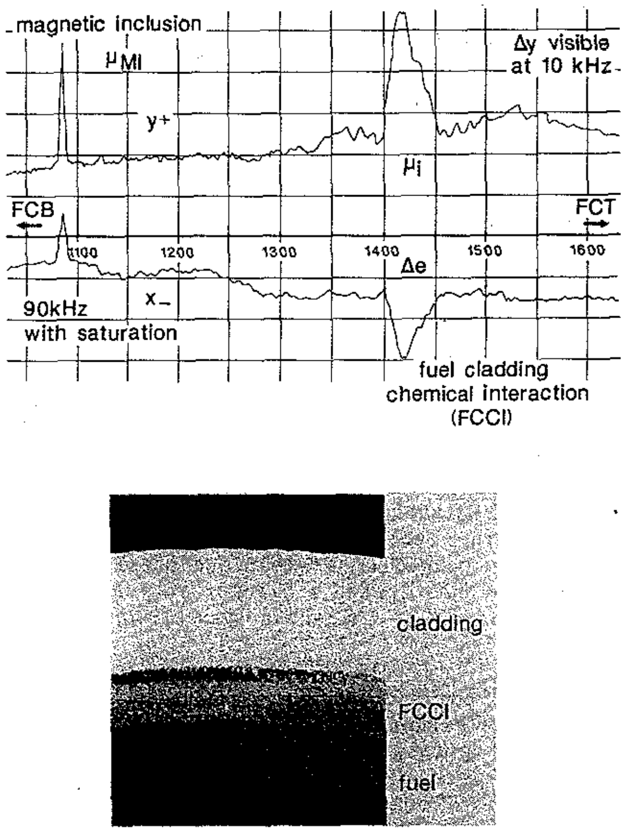


Fig.10. Eddy currents examination some typical results : FCCI

- Development of remote control operation methods and automatisation processes :

the main fields of application concern cell decontamination, the automatisation and computerization of metallographic lines as well as the acquisition and processing of data - of the LEMI mechanical tests in particular - and the perfecting of remote-controlled manipulators.

V. OPTIMISATION OF THE USE OF HOT CELL FACILITIES

Taking into account the different functions and the corresponding adaptations of these facilities led to the constitution of an entire "fleet" of hot cells which must be used in an optimum economic manner. This can lead to the use of certain facilities to fulfill roles for which they were not originally designed.

Thus, after ten years of operation within the framework of the EL3 test reactor, the CELIMENE cell was modified to receive, dismantle and assess PWR subassemblies both standard and experimental, coming from power reactors.

Likewise, given the excellent potential capacities of ISAI facility, built for needs of SUPERPHENIX, it is now also being considered for use in receiving and examining PWR fuel elements. This facility has not yet been put into service.

VI. CONCLUSION

Taking into consideration the enumeration and the examples which have just been discussed, it should be noted that the CEA has at its disposition an entire "fleet" of fuel examination hot cells highly diversified. They should be optimized to the full extent of their productivity, performance, versatility and used at the lowest cost.

In the future, given a certain maturity which has now been attained in the field of nuclear reactors, we can expect the hot cells to be more and more in demand to meet the needs of the entire fuel cycle in addition to their traditional role involving fuel examination.