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COMMISSION OF THE EUROPEAN COMMUNITIES

A RIVET SEAL FOR SAFEGUARDING THE MTR FUEL ELEMENTS

by

S. CRUTZEN, P. JEHENSON, E. BORLOO and W. BUERGERS

1974

Joint Nuclear Research Centre
Ispra Establishement - Italy
Materials Division

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Commission of the European Communities D.G. XIII - C.I.D.
29, rue Aldringen
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This report describes the chosen solution and put some emphasis on the devices and fuel element preparation necessary for the application of seals.

In addition at the conclusions, the minutes of the meeting held at Ispra on this specific subject are entirely reported.

This method was declared ready for practical application by the Safeguards Directorate.

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ABSTRACT

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This report describes the chosen solution and put some emphasis on the devices and fuel element preparation necessary for the application of seals.

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Acknowledgments

The authors express their thanks to Mrs. Bresesti and MM. Bresesti, Dal Cero, Mahler, Rossetti of J.R.C. Ispra and to Mr. Schinkel of R.C.N. Petten for their active participation in this entire study.

1. INTRODUCTION

1.1. Purpose

In the frame of the non profileration treaty, Ispra was given the problem of giving a unique and tamperproof identity to nuclear fuel elements. The first practical case to solve was that of the MTR fuel element plate. A solution was patented in 1969 both for MTR plates and for other types of fuel elements (rods, assemblies). The development work began, however, with the MTR fuel element (1) (2).
A collection of advice and criticisms was received during a meeting of MTR fuel element manufacturers at Ispra in 1969 at which the firms NUKEM, Hanau, Germany; CERCA, Romans, France; and MMN, Mol, Belgium were represented.

1.2. MTR fuel element

The fuel bundle is composed of plates held between two edge plates (Fig. 1).

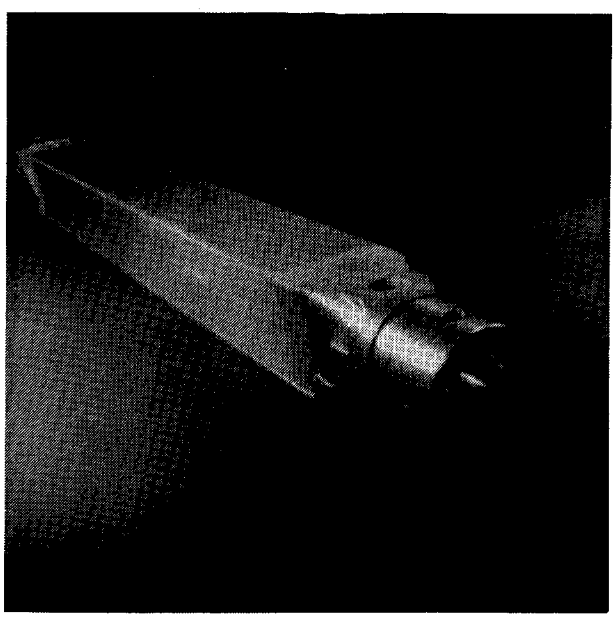


Fig. 1

Two nozzles are welded or screwed to the ends of the fuel element. The plates are fabricated using the picture frame technique: rolling of three superimposed plates, the central one being a frame within which the fuel alloy is placed (Fig. 2)

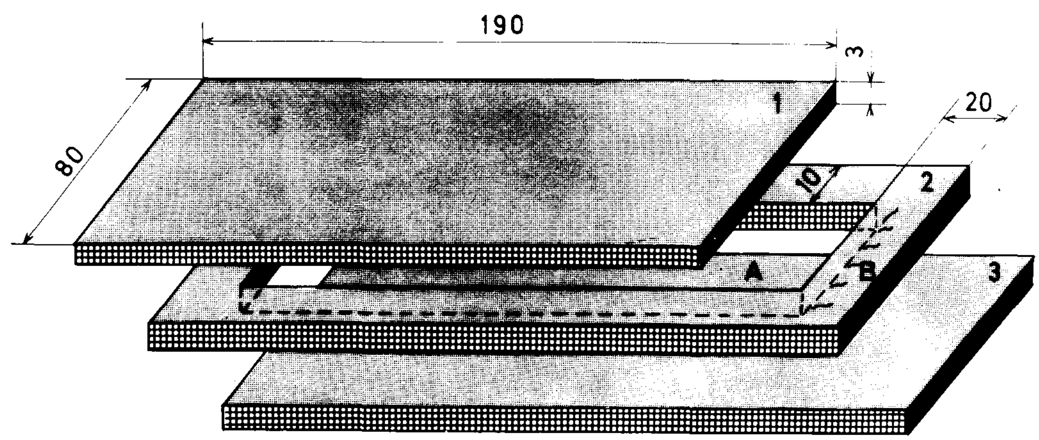


Fig. 2: Initial sandwich for the fabrication of MTR plates

1 and 3 : External plates in Al.

2 : Al central frame.

A : Central window in which the enriched fuel core is placed.

B : Place selected for the introduction of the inclusions used for the identification.

2. IDENTIFICATION OF THE MTR FUEL ELEMENT

Applying the general principle of ultrasonic detection for the identification of natural or artificial internal marks (2) (3) (8), two solutions were tested.

2.1. Identification of the fuel element

2.1.1. During the fabrication process, before rolling, some tungsten inclusions are printed in the upper part of the frame (item B, Fig. 2). The rolling causes these inclusions take random positions in the upper non-active part of the plate.
The fabrication cycle of the plate remains unchanged.

The parameters giving a random and irreproduceable character to this type of marking are:

a) inclusions with random shape,

b) random position of the inclusion when pressed in the frame,

c) random orientation and positioning due to rolling and also to the finishing of the plates (cutting of the ends).

The tungsten inclusions have dimensions of about 1 mm length and 0,3 mm diameter.

2.1.2. The identity is recorded by ultrasonic scanning of the upper edge of the plate (Fig. 3).

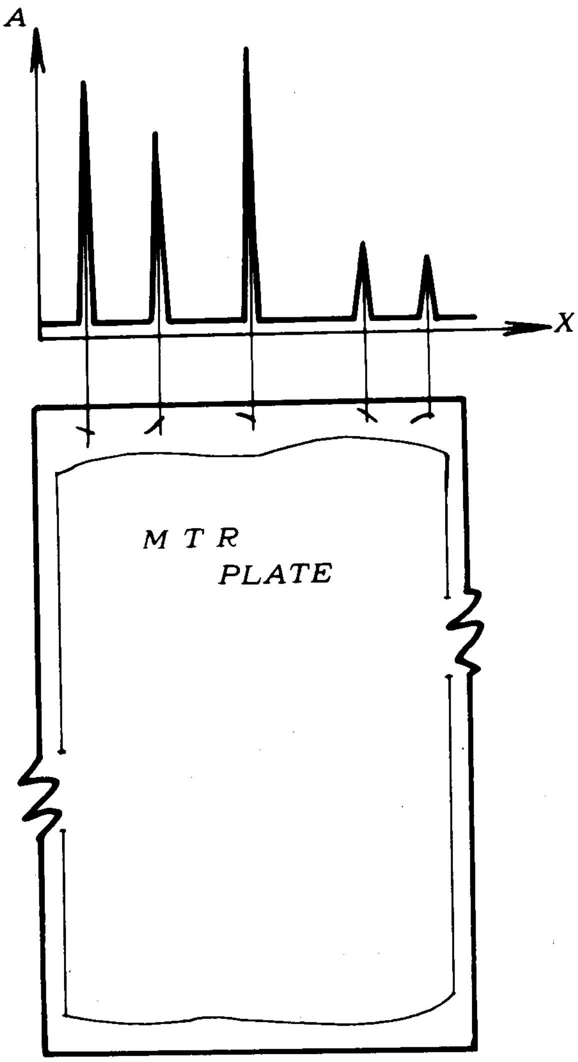


Fig. 3

This examination is made by the immersion technique.
The identities are clear, and easy to record on separate plates.
If one has to check the identity of the plates once they are in the fuel bundle, mechanical scanning is so complicated that another method has been chosen. (Cf. § 2.2)

2.1.3. This identification of MTR fuel plates, tested in the laboratory, has given very good results and it can remain a highly valuable control method for individual fuel plates.

2.2. Identification of the fuel bundle using a seal

2.2.1. Principle

The fissile materials flowing from the fabrication plant to the reprocessing plant are contained in fuel elements. This containment can be considered at the level of the single plate as it is made for the identification of the plates but also at the level of the assembly: the fuel bundle. In order to guarantee the integrity of the "confined" fissile materials, the container must be tamper-resistant and have a unique identity. Instead of using natural or artificial marks printed in the container (edge plates or fuel plates of the MTR element), marked seals are applied.

2.2.2. Rivet seal

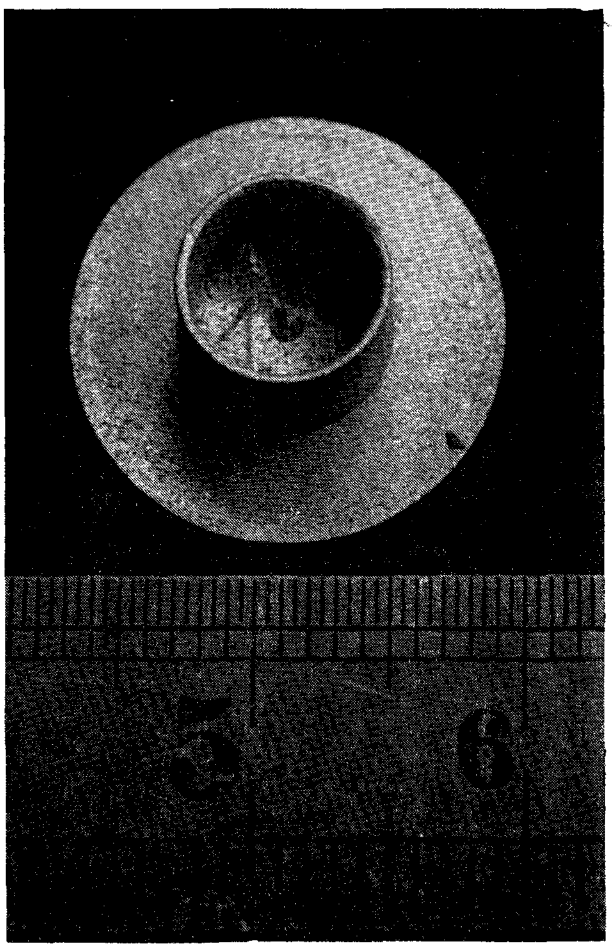


Fig. 4

As shown on Figure 4, the seal is composed of a disc (item 1, Fig. 4) in which the inclusions are inserted (Cf. § 3) following the same identification principle as that described for the identification of the plates.
A cylindrical foot (item 2, Fig. 4) completes the seal and gives the rivet shape.

While positioning the seal in a prepared seat in the fuel element, the foot is deformed and, being made of a special material (Cf. § 3), cannot be taken off without being broken. Rewelding or gluing the foot is quite impossible, in view of both the small dimensions and the weak point (item 3, Fig. 4). A seal cannot be used twice (Cf. § 2.3).

The place chosen for sealing is where the nozzle overlaps the edge plates. (Fig. 5)

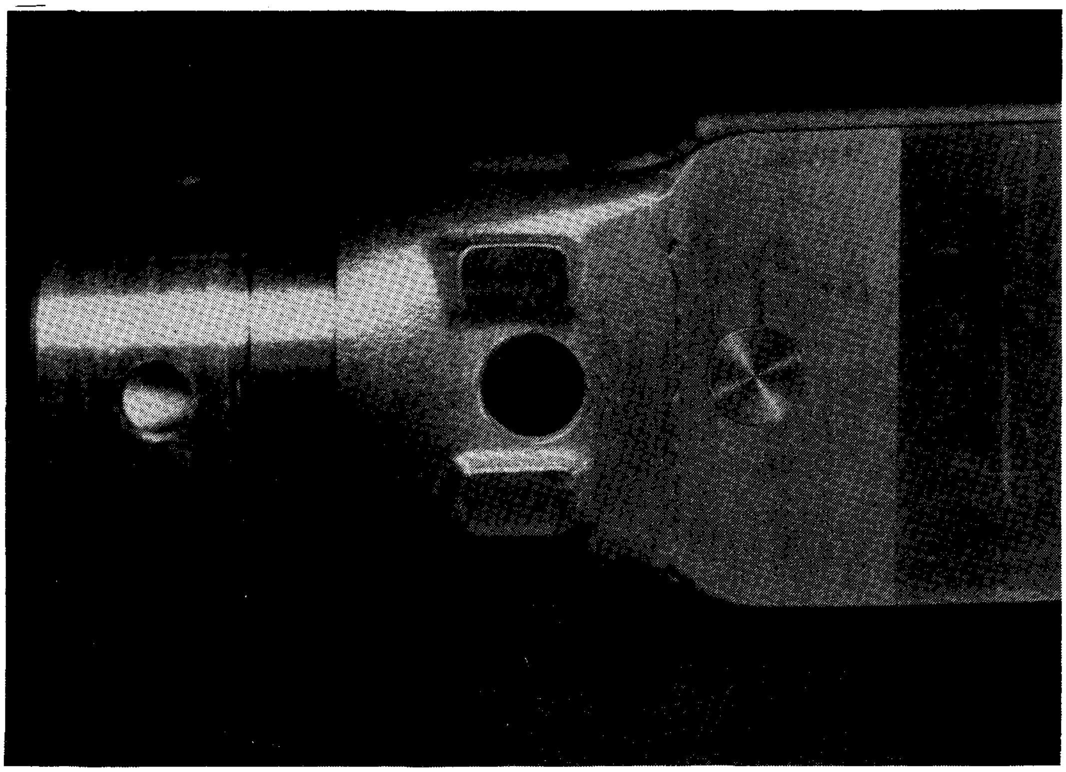


Fig. 5

When dismantling the MTR fuel element, one cannot avoid cutting the nozzle and destroying the edge plates; this is impossible without damaging or removing the seal.

This sealing principle offers the advantage of not modifying the characteristics and the qualities of the containers and of the fuel plates. It eliminates the control of single plates and avoids any difficulties caused by the inclusions being placed rather close to the meat in the MTR plate. During separate visits made to France (CERCA), Italy (SALUGGIA), Belgium (MMN) and Germany (NUKEM), this solution was considered by the MTR fuel element manufacturers as a reliable one for the fuel.

2.3. Identification of the seal (4)

The principle remains the ultrasonic detection of inclusions, but instead of having a plate as in § 2.1.1., we have a disc containing inclusions.

Using industrial ultrasonic apparatus, the signals obtained by scanning the seals are very satisfactory. The general method used is based on reflection due to the great difference of acoustical impedance existing between the matrix and the inclusions. The transducers are standard commercial focused models, which are able to select accurately the zone to be explored.

The mechanical part of the installation serves to position the transducer with great reproducibility (5) and to make the seal rotate regularly around its mechanical axis. (Fig. 6)

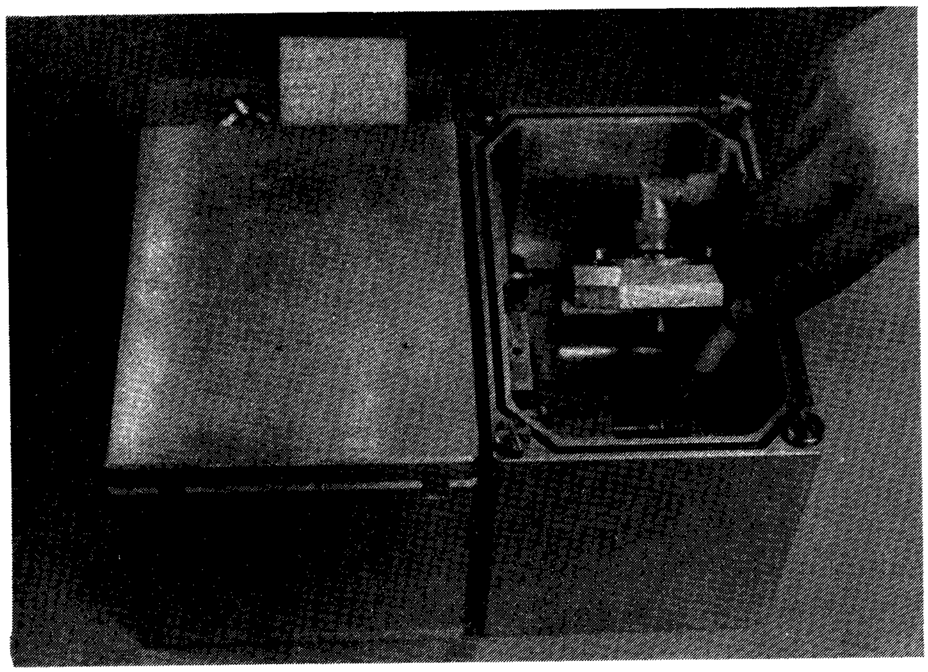


Fig. 6

The installation is calibrated either on an artificial standard defect or on an inclusion in the seal.
The identity is obtained by all the echos coming back from the seal.
Due to the small diameter of the seal, ultrasonic waves give more than one echo for one inclusion and the examination of a small part of the seal would be sufficient for identification purposes. (4) (5).
The structure of the seal has a great influence on the identity.
No structural changes occur during irradiation in the reactor because of the low running temperature.

The identity can be codified without losing its unique character: to each maximum amplitude response is assigned a confidence interval due to the imperfect reproducibility; knowing the maximum and minimum values of implitude response, the number of discrete values which one inclusion can give is calculated. To each of these values one character is assigned. The chosen characters (alphabet Q) and the number of detected inclusions (format I) define a codification language.
This language contains L words:

$$L = Q^I$$

which correspond to L different possible identities.
The registration of the electrical output signals is made in analog form (by pen or photographic recorder) (Fig. 7). The readouts obtained are easy to interpret and may be used integrally or partially as an identity card. These analog data can be coded in digital form for automatic storage and checking.

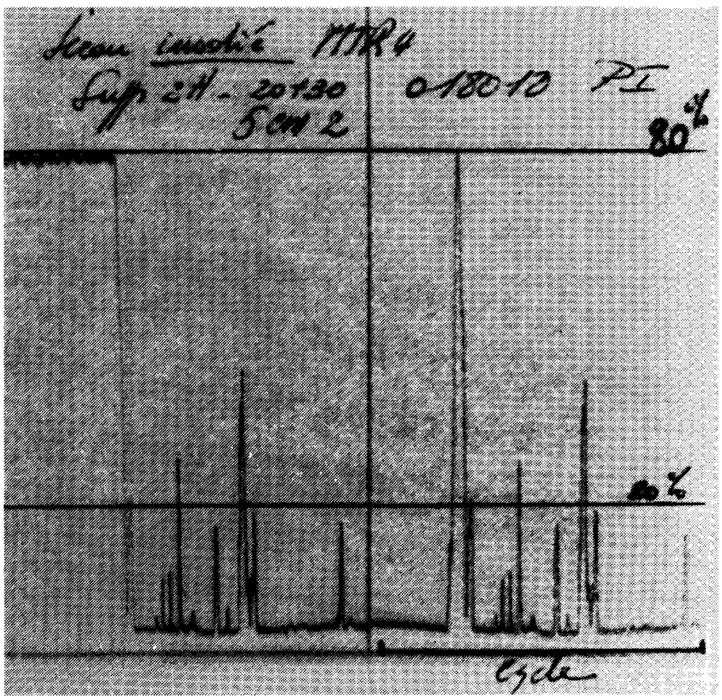


Fig. 7

Fig. 8 illustrates the control chain showing different alternatives. By using the complete chain one can, at any time and without difficulty:

- bring the library up to date,
- print the results,
- have the general situation of the fissile materials under control.

Moreover, with the data centrally stored in a computer, all other information obtained by other control methods can be added in.

A portable apparatus which is under development (6) will give the possibility of immediate verification on the spot.

The whole experiment performed for the identification of MTR fuel elements described in this report deals only with identification by sealing: the seal impedes the dismantling of the bundles and gives the identity to the fuel.

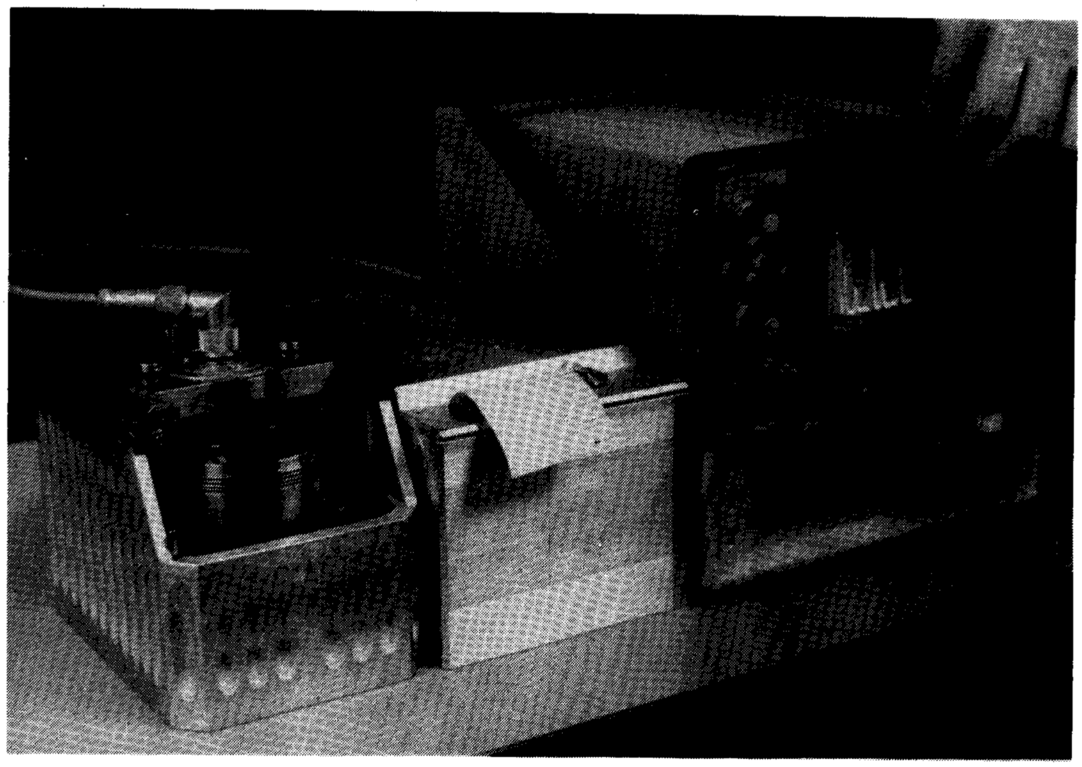
However, the possibility of identifying single plates should not be forgotten.

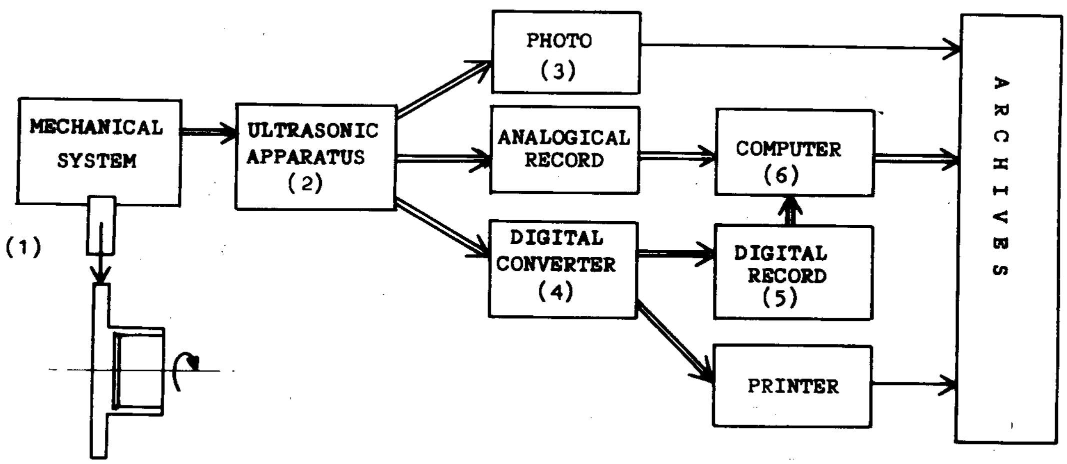
2.4. Different control schemes

2.4.1. Interest of the diverter

The interest of a potential diverter for a given fuel element depends on (7):

- the quality and the quantity of the strategic material contained in a fuel element,
- the accessibility of the fuel element,
- the ease of extraction of the strategic material from the fuel element (which generally requires appropriate chemical facilities).





(1)+(2)+(3) = REDUCED CHAIN
(1)+(2)+(4)+(5) = COMPLETE CHAIN

Fig. 8

Fig. 9 shows graphically for these parameters the interest of the diverter as a function of the position of the fuel in the cycle:

As a result of this schematic analysis, it appears that a minimum of 4 control points are necessary:

1. Sealing of the fabrication plant after physical measurements,
2. Control of the fuel before entering the reactor (new seal),
3. Control of the irradiated fuel in the pool (new seal),
4. Control at the reprocessing plant.

The control point 3 (or 4) could be ignored due to the diminished interest after irradiation.

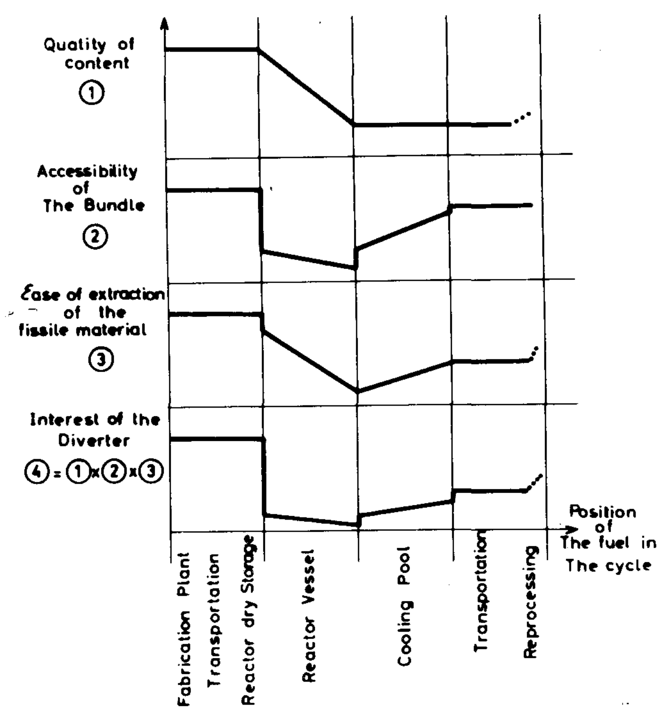


Fig. 9

2.4.2. The seal permits the identity measurement to be done on the spot with portable instruments or at a central control point. It permits a centralization of controls, which increases the reliability of the system. The different sequences could then be as follows for the identification of seals as a function of their position in the fuel cycle:

a) Complete control without portable apparatus (Fig. 10)

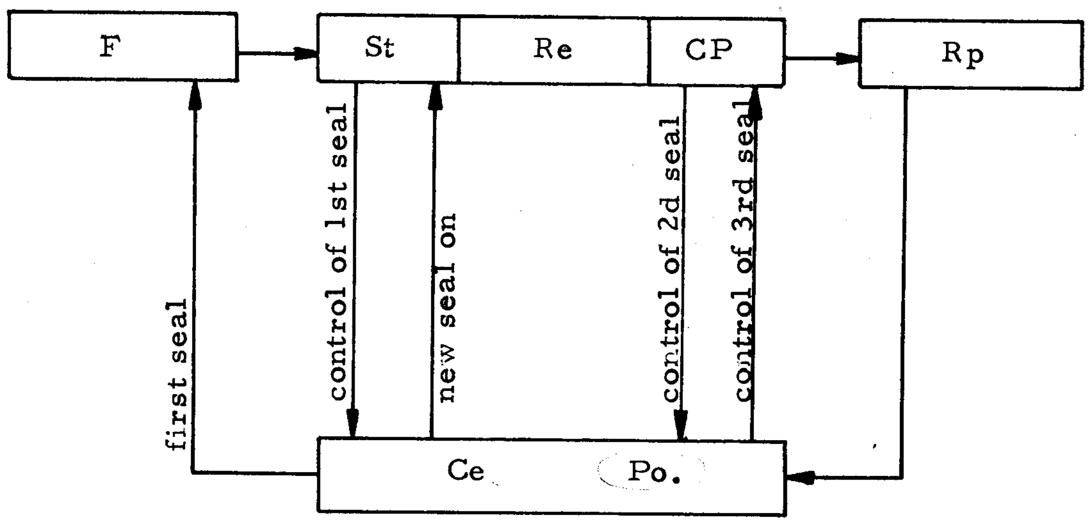


Fig. 10

Legend:

F = Fabrication
St = Storage
Re = Reactor
CP= Cooling Pool
Rp = Reprocessing
Ce Po. = Central Point
PA = Portable Apparatus

Three seals are thus necessary.

b) Simplified without portable apparatus (Fig. 11a and 11b)

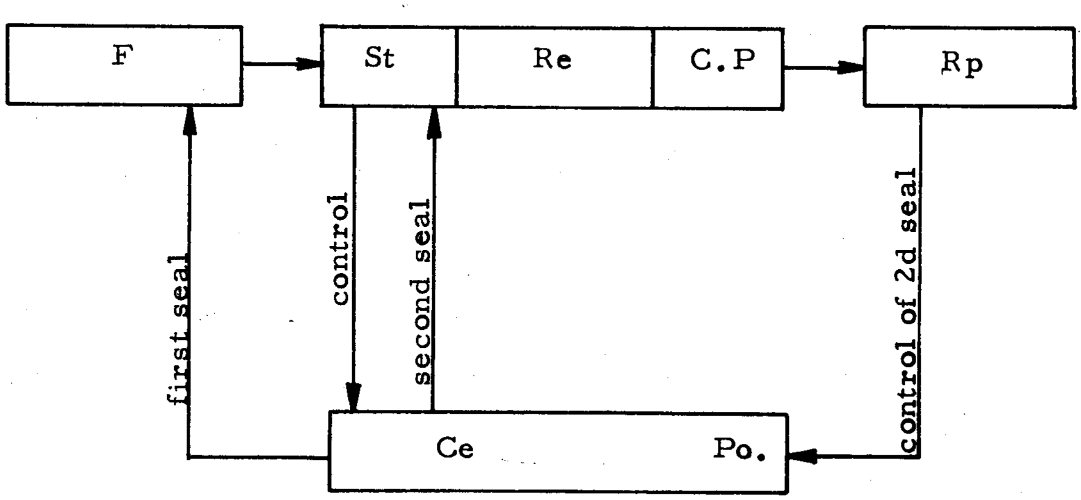


Fig. 11a

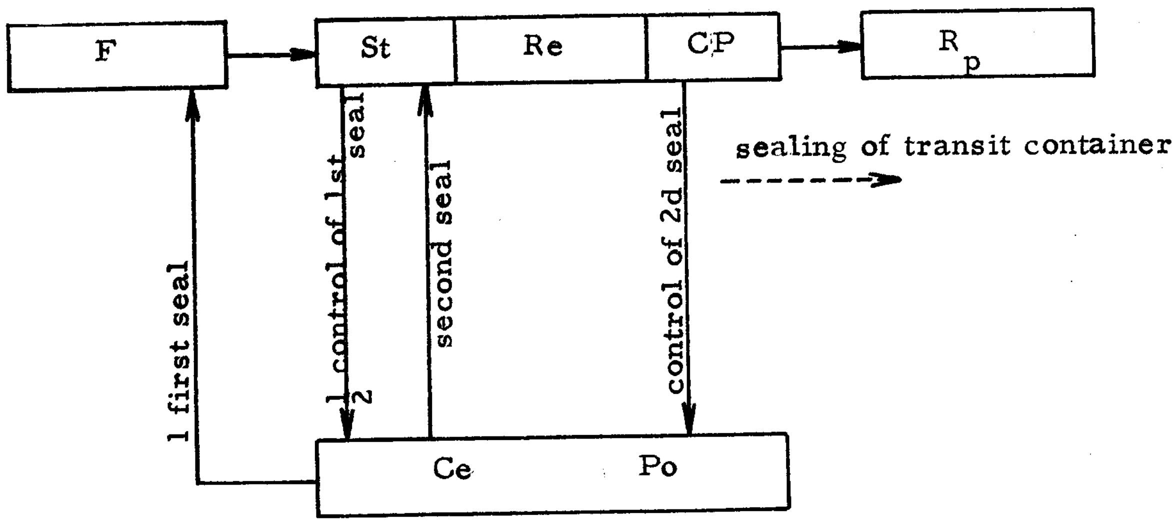


Fig. 11b

c) complete control with portable apparatus (Fig. 12)

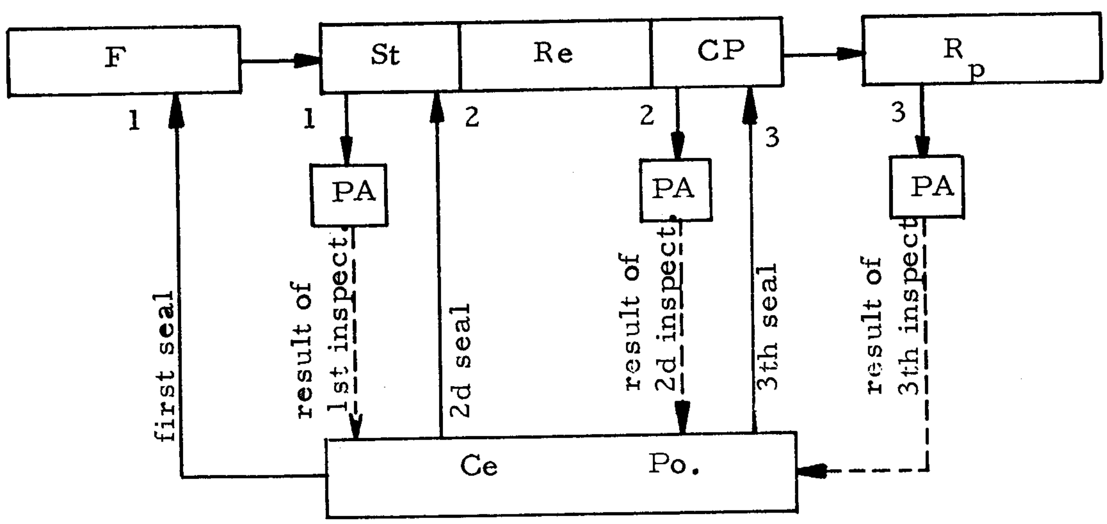


Fig. 12

The central point of control identifies only new seals and keeps the initial records. No transportation of irradiated seals is necessary, no delay occurs in the verification of the identity.

d) Simplified scheme with portable apparatus. (Fig. 13a)

The most logical scheme is:

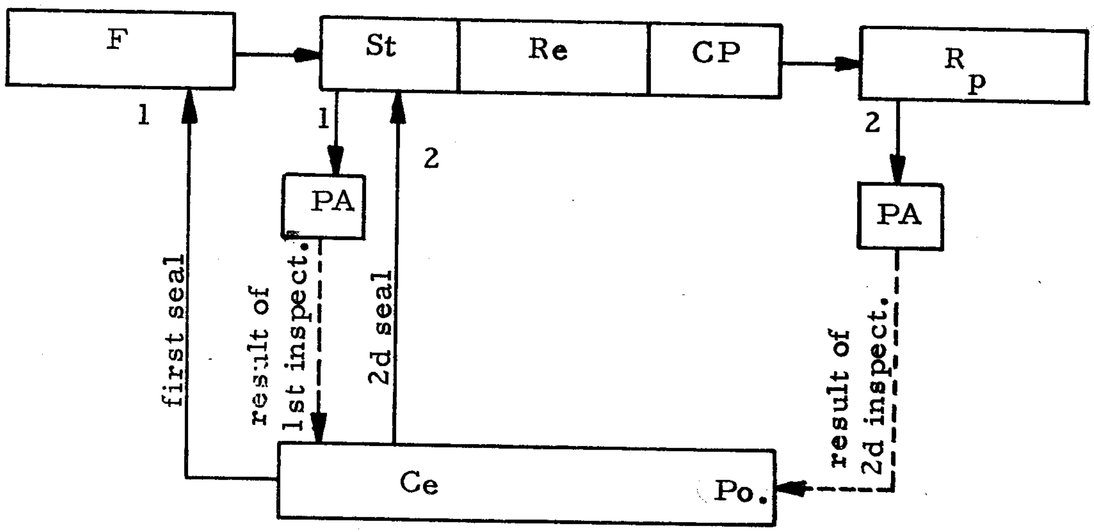


Fig. 13a

e) When two seals are put on the fuel element as was done for one element in HFR Petten (Cf. § 4.3.), the best scheme is: (Fig. 13b)

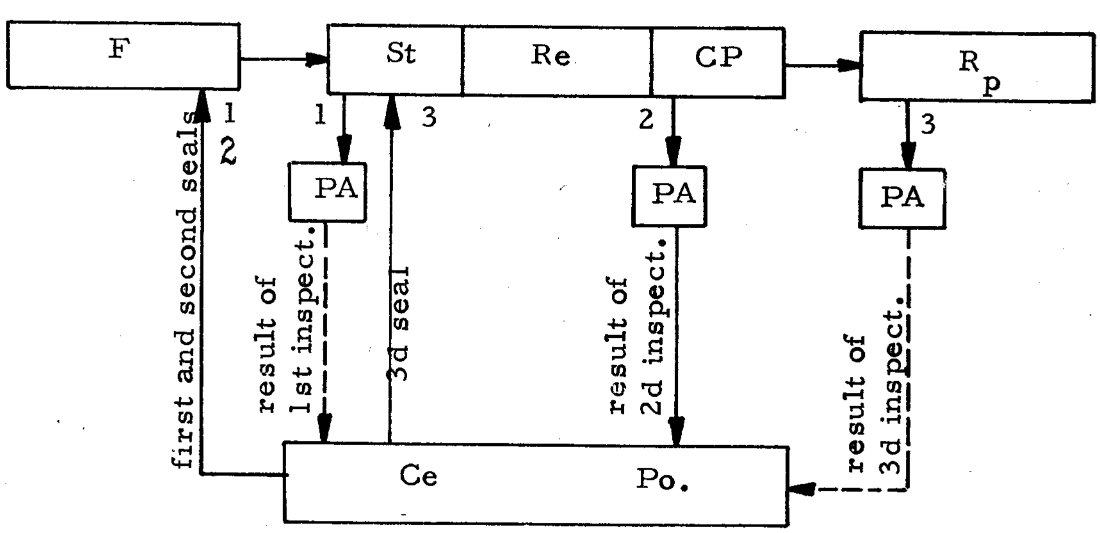


Fig. 13b

This optimum scheme does not require seals to be put on irradiated fuel elements under water.

Other simplified schemes are easy to imagine.
The choice of the scheme to be adopted depends on the philosophy adopted by the Safeguard Authority and on the delays that this Authority can accept between two controls.

3. FABRICATION OF THE SEAL

3.1. Materials used

As was said in § 2.2.2., the rivet seal is composed of two parts:

- one disc, bearing the identity,
- one foot, blocking the seal at a critical point of the bundle.

An example of the dimensions and tolerances is given on Fig. 14

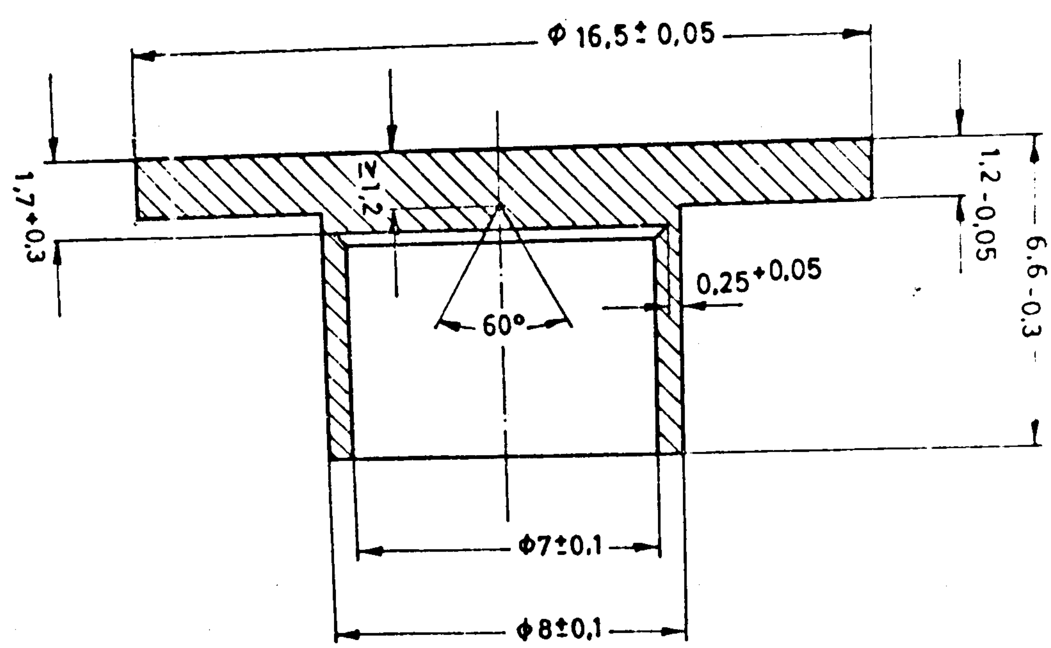


Fig. 14

These tolerances should avoid any gap or overlapping of the seal on the edge-plate.
The length of the foot depends on the thickness of the nozzle wall at the fixation point of the seal.

The weak-point of the seal (0.25 mm thickness) in the foot makes only a small effort necessary for taking the disc off the fuel bundle in order to verify the identity. (Extraction force : 50 kg $\pm$ 20%).
The chosen material is a SAP (Sintered Aluminium Powder (7)) 1% to 2% Al_2O_3. The inclusions are of tungsten and have a grain size of about 0,3 mm diameter and 1 mm length.
(Radiography of the seal on Fig. 15)

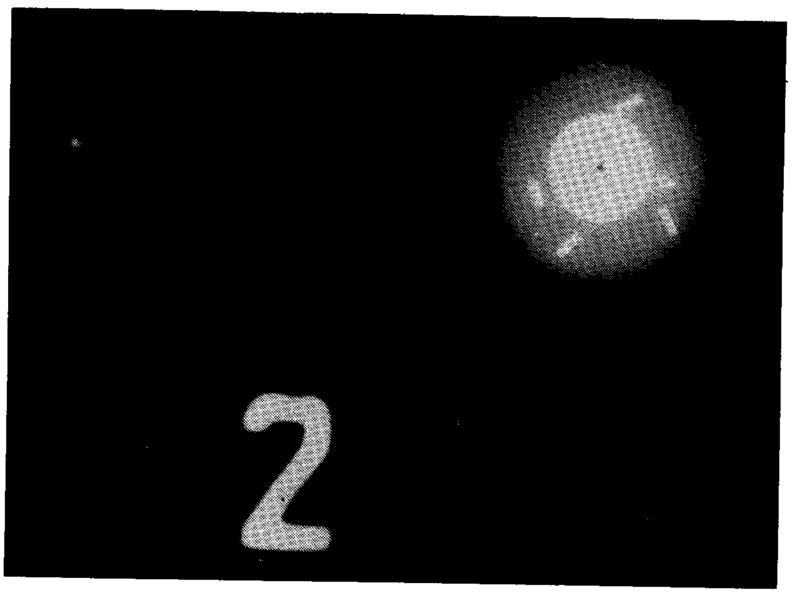


Fig. 15

This SAP material allows deformations for blocking the seal as a rivet but makes any recuperation impossible without breakage. Welding for re-use is difficult with this basic material and the identity of the disc would be changed even by small changes of the material structure due to temperature elevation.

3.2. Fabrication of prototypes

3.2.1. For prototypes, the SAP powder was put into the pressing matrix in two different steps:

- first quantity : 1/5 (volume)
- some inclusions (5 to 7) (5)
- second quantity : 4/5 (volume)

in order to obtain blocks with inclusions at the right position. (Fig. 16)

Fig. 16

3.2.2. After cold pressing at 50 kg/mm^2 during 1 minute and then hot pressing at $500^{o}C$ for 1,5 minutes at 100 kg/cm^2, the blocks are machined at the workshop.

No price evaluation is possible for this type of laboratory work.

3.3. Industrial fabrication of seals

The NUKEM firm (Hanau, Germany) has taken a licence for our patents(1) and has made a preliminary evaluation for the industrial fabrication of seals. (Cfr. § 9.4.5.).

4. PREPARATION OF THE FUEL ELEMENT AND SEALING

4.1. Principle

As said in § 2, concerning the fuel element itself, during its fabrication cycle a hole must be drilled right through to receive the foot of the rivet seal. This supplementary machining is made at the overlapping zone of the edge plate and the nozzle. (Fig. 17)

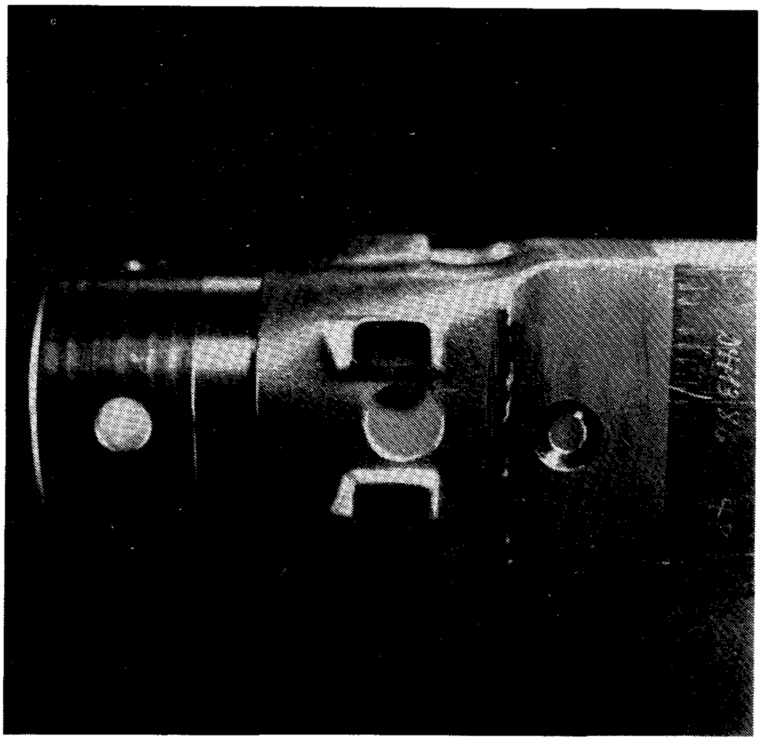


Fig. 17

The edge plate will have a second hole centered on the first one in order to have the disc inside the plate.
The tolerances are rather severe to avoid that the seal overlaps the edge plate; if not, the seal might be damaged when the fuel element is put into its channel or storage box. The holes have to be made at the fabrication plant as one of the last steps of the fuel fabrication cycle.

4.2. Tests made at NUKEM

Some seal seats were machined at NUKEM on a dummy element maintaining the normal fabrication operations, both in the workshop of the manufacturing plant and in the personnel in charge of the last steps of the fuel fabrication cycle. No difficulties occurred due to the imposed tolerances, and the quality of the fuel element remained unchanged.
The time required for this modification was estimated to be 1/2 hour.
Two drilling cutters were used for this work and no special devices were prepared for the exact positioning of the fuel on the bench. Having the correct prepared double cutter for making the seat in one operation, and having a blocking device for rapid and precise positioning of the fuel element on the bench, no time would be lost either for the measurement or for the selection of the reference surfaces.
The price of this operation, if it were a normal step in the fuel fabrication cycle, could then be much lower.

Seals were put on and taken off at the workshop by the NUKEM people with tools prepared at Ispra. The seal was strongly fixed onto the fuel element and was easily taken off by breaking the foot due to the machined weak point and to the choice of the most suitable material.

The tool used is a grip with interchangeable fingers: for placing the seal, a sphere; for taking it off, a punch. (Fig. 18)

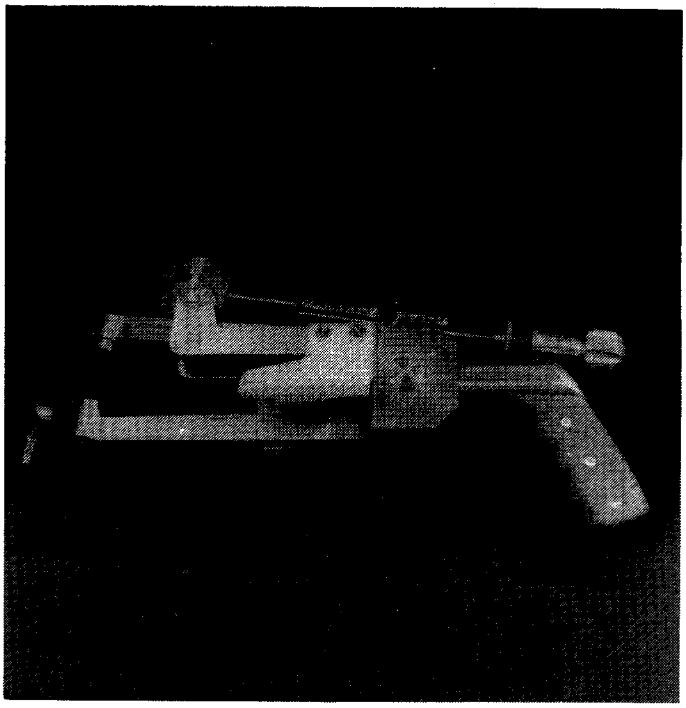


Fig. 18

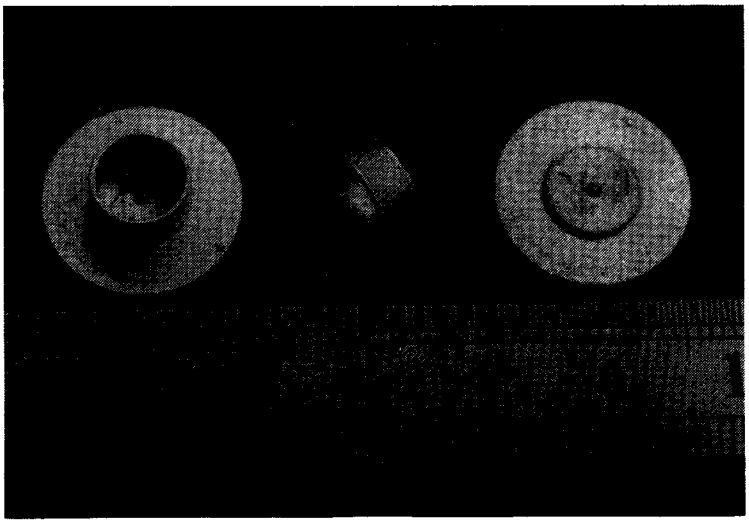


Fig. 19

Fig. 19 shows a new and a broken seal

No alteration of the seat in the element was visible after putting and taking off ten seals.

Sealing of five fuel elements at HFR Petten

For sealing, five fuel elements were prepared in the workshop of the HFR reactor.

Sealing was made with the tool described in § 4.2 and the five fuel elements entered the reactor on May 13, 1972.

One fuel elements received two seals.

Table 1 gives the schedule of the sealed fuel elements in the HFR reactor. Two of them followed a fast cycle (N783 and N789)

Element	Period in reactor	Burn-up (%)	Seal Nbr.
N783	14.5.72-14.6.72 15.6.72-30.6.72 31.7.72-15.8.72 16.8.72- 1.9.72	17,7 29,0 35.9	4 and 12
N789	14.5.72-28.5.72 2.6.72-14.6.72 31.7.72-15.8.72 1.9.72-14.9.72	14,6 24,3 34.9 42,4	7
N787	14.5.72-28.5.72 2.6.72-14.6.72 31.7.72-15.8.72 1.9.72-14.9.72 23.11.72-12.12.72	12,6 20,2 27,7 35,7 44,5	9
N788	ibid	13,0 22,7 32,8 39,9 45,4	13
N790		14,5 22,8 29,5 35,7 45,5	5

Table 1

5. EXTRACTION OF SEALS UNDER WATER AFTER IRRADIATION

5.1. Tools for extraction

In § 4.2., the extraction tool is described. This tool is used when a seal has to be removed in the fabrication plant, or at the dry storage of the reactor.

For taking off the seal in the pool under 3 to 10 m of water, it was necessary to modify this tool (Fig. 20).

These modifications are:

- remote control of the extraction punch,
- tube for guiding the extraction punch just in front of the seal, with a locking system,
- disc recovery pocket which can be opened at distance.

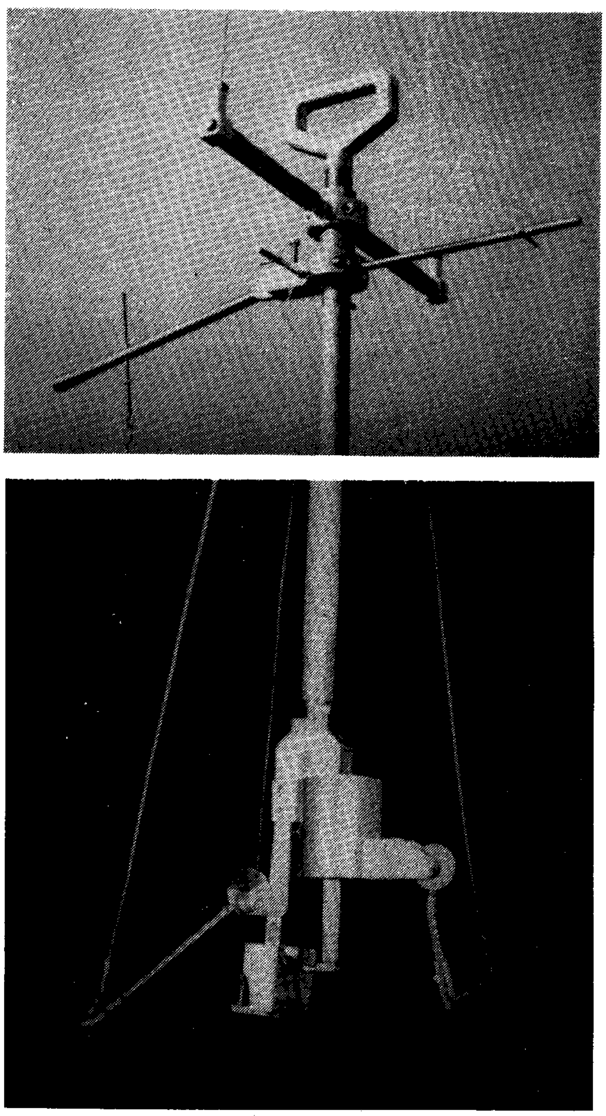


Fig. 20

Tests and simulations of the tool were made at Ispra using the dummy element. (Fig. 21)

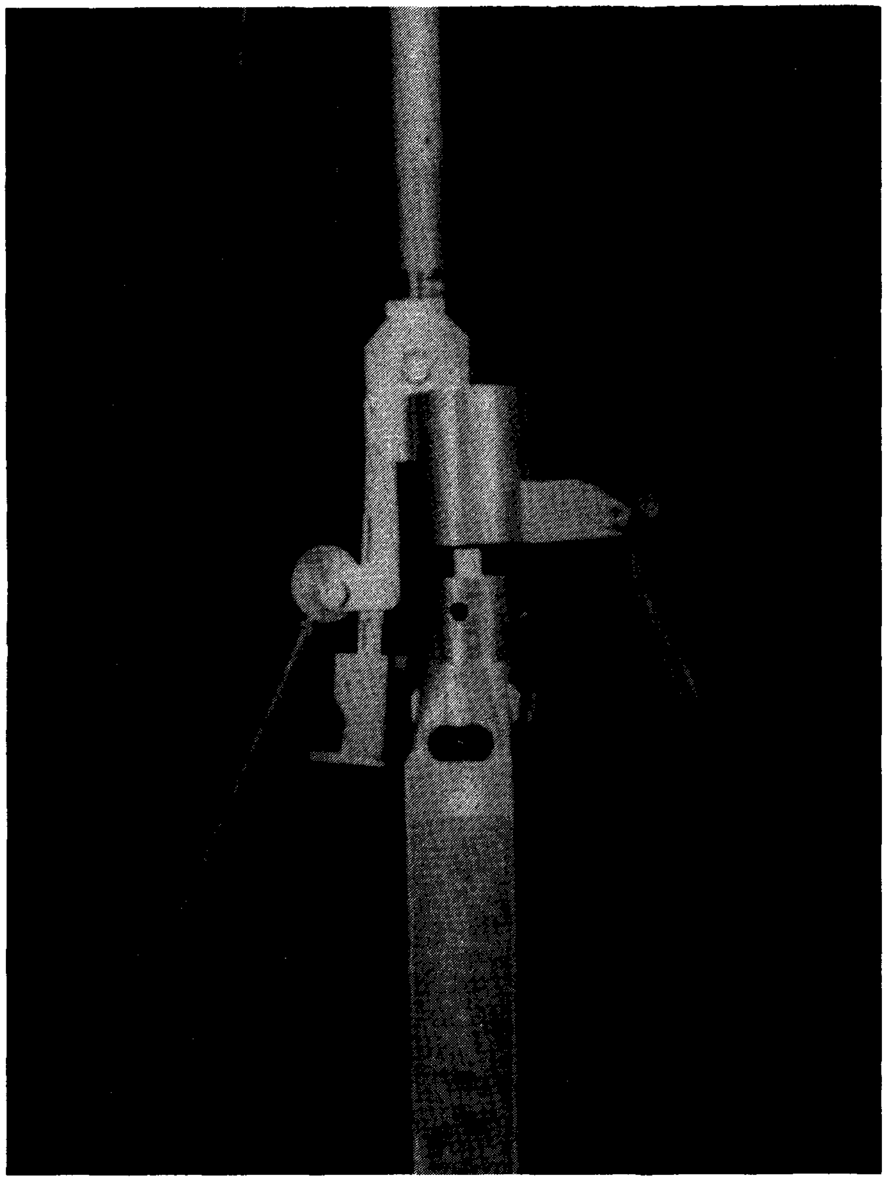


Fig. 21

The different steps of the operation are shown on the Figures 22, 23, 24, 25, 26, 27.

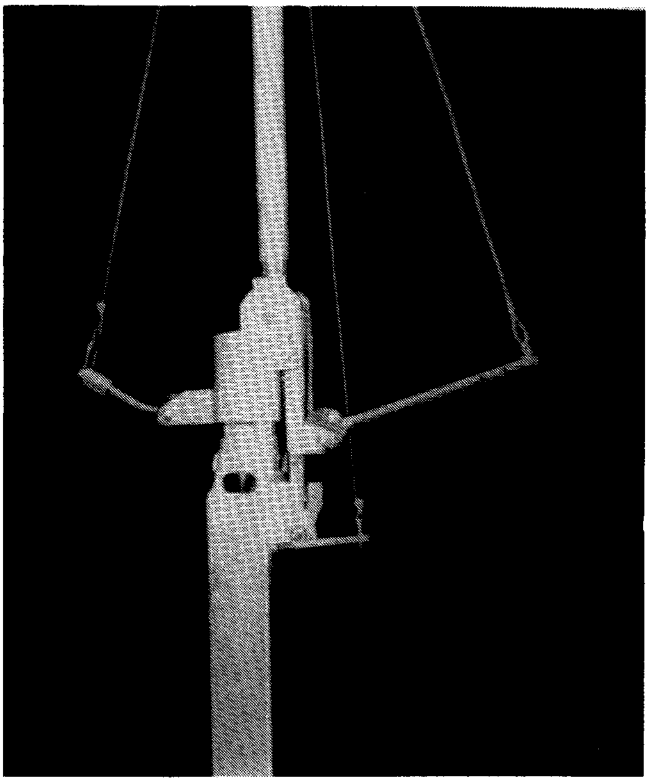


Fig. 22

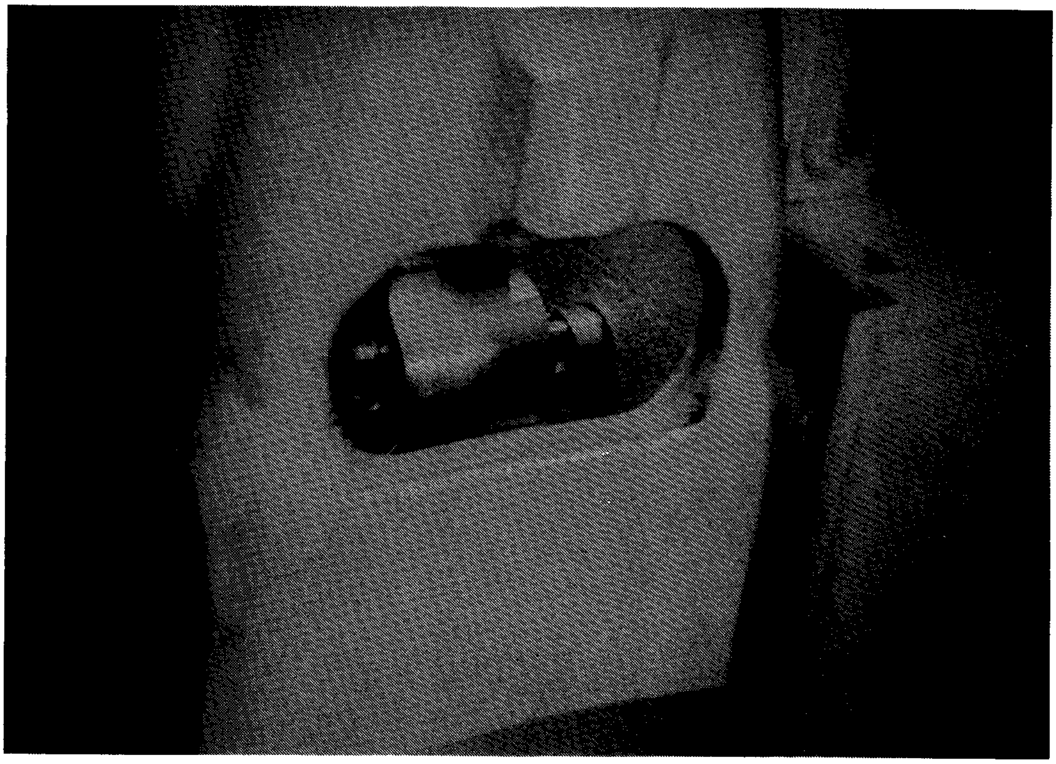


Fig. 23

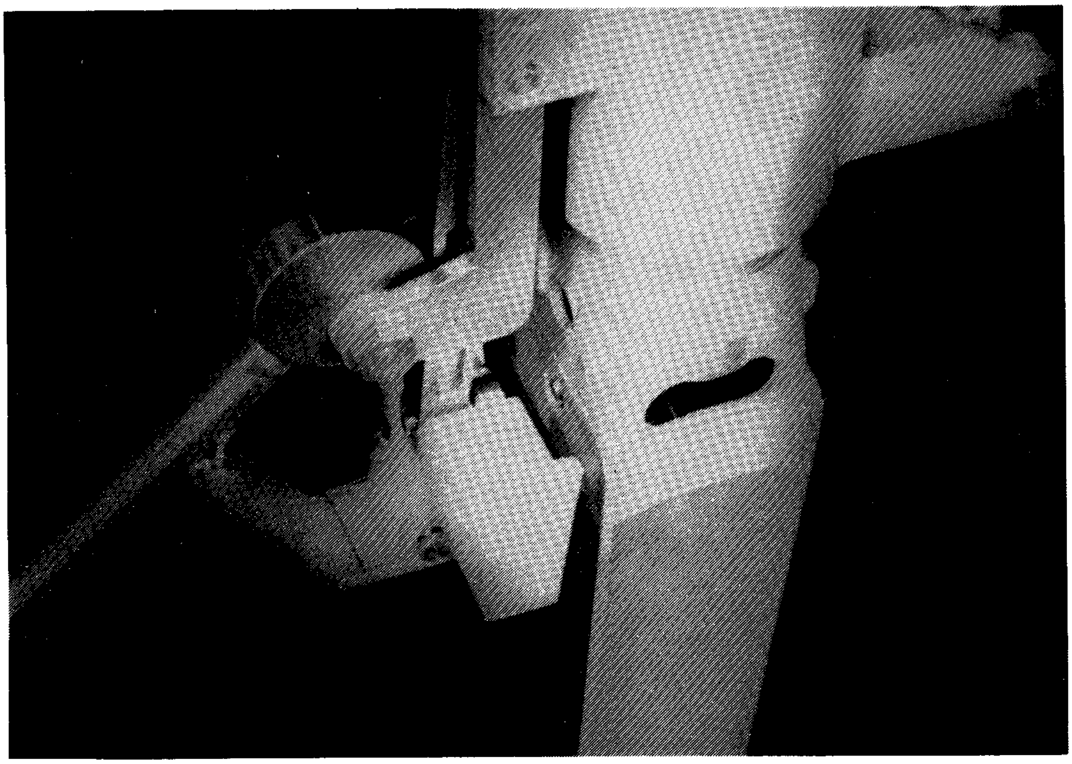


Fig. 24

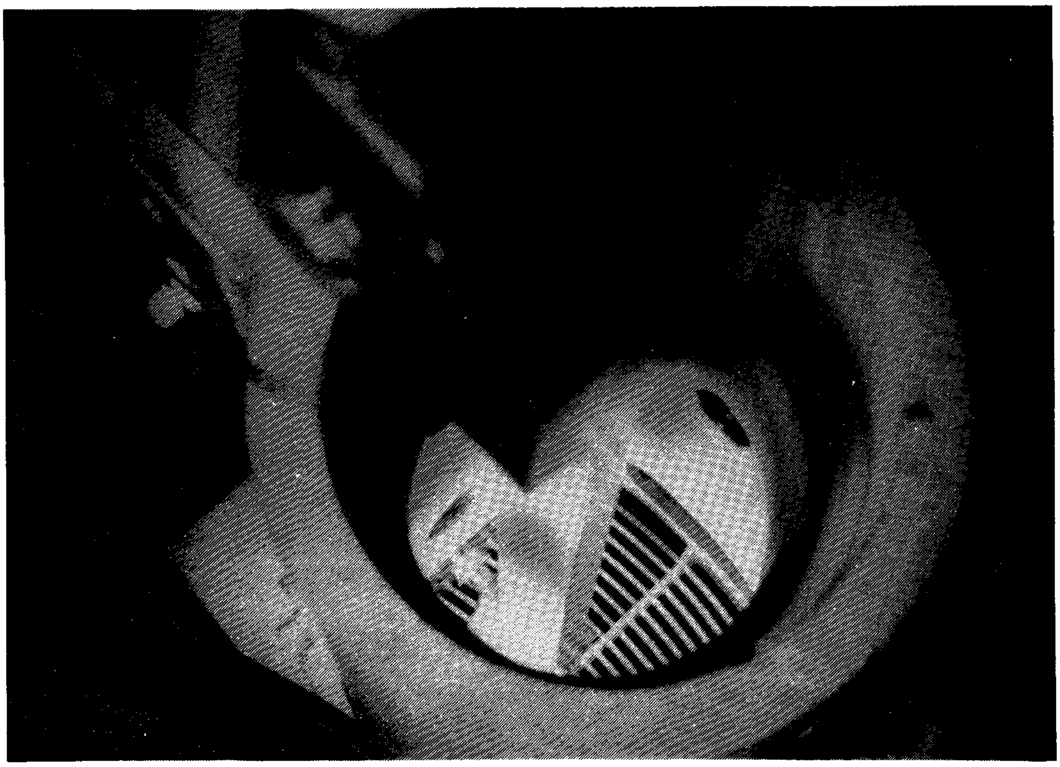


Fig. 25

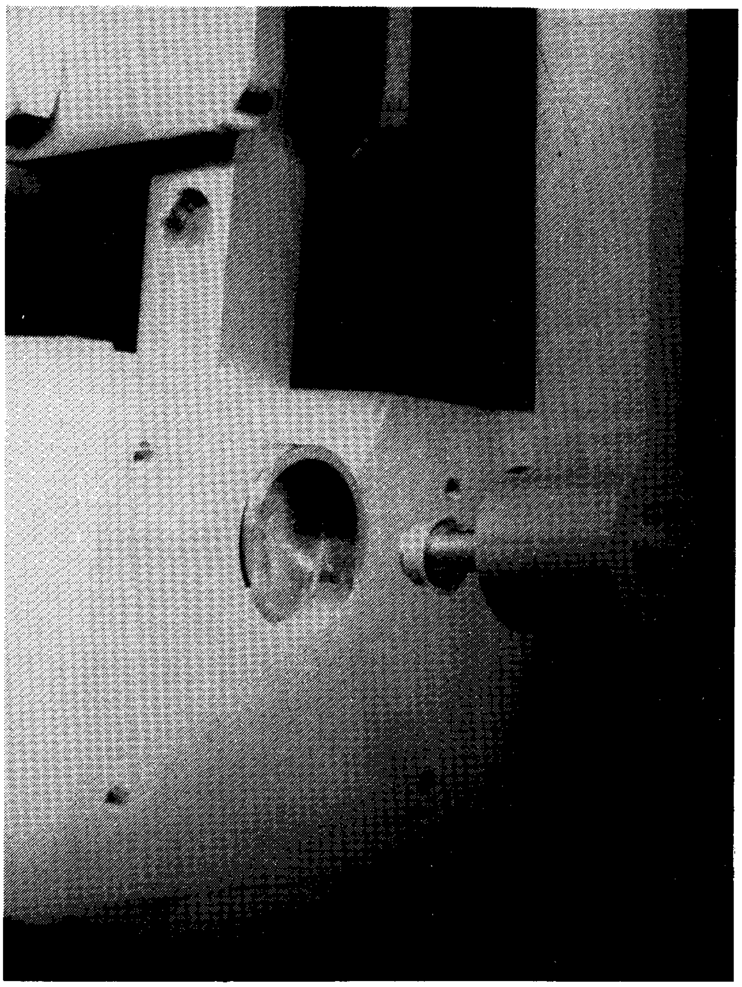


Fig. 26

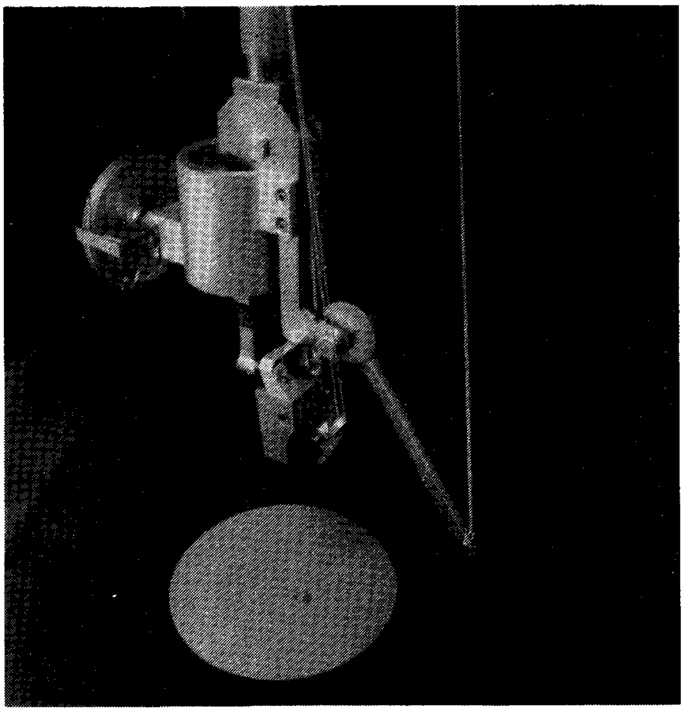


Fig. 27

Fig. 27 shows that the identified disc can be easily recovered.

The extraction was performed, for demonstration at 10 m distance and at 3 m distance, corresponding to the different extreme positions that the fuel element can adapt in the cooling pool.

These operations were also made in the HFR cooling pool in November 1972 for the seals 4, 12, and 7 and in February 73 for the seals 9, 13 and 5 (see Table 1).

5.2. Control of the seal identity, after irradiation

Figure 28a and 28b show the good reproduceability found for the identity measurements of seal n^{o}4.

The first identity was taken in May 1th 1972. The second one in December 1972, after irradiation. The schedule followed by the seal is the one given on Table 1.

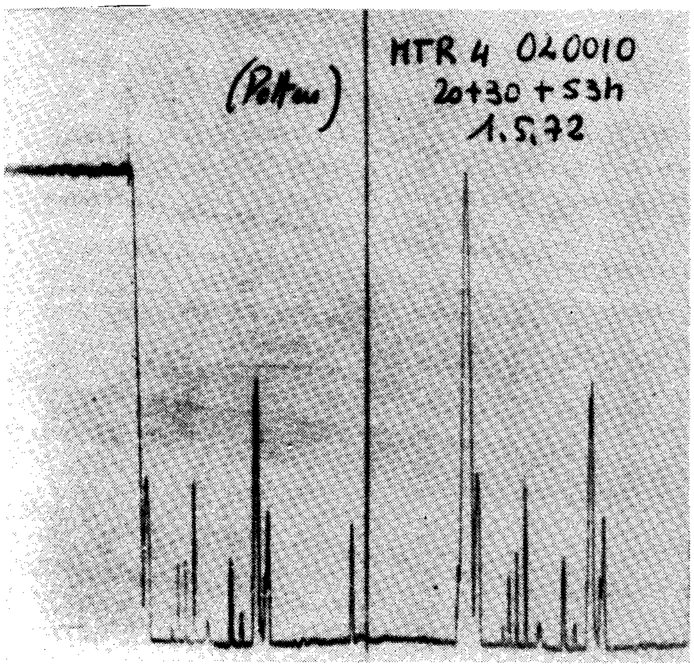


Fig. 28a

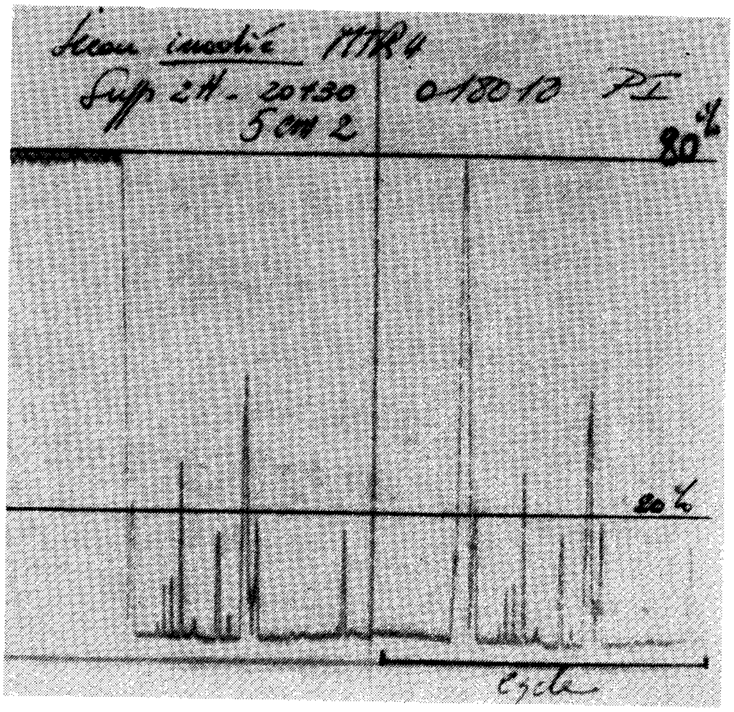


Fig. 28b

No alteration of the basic material is visible on the surface of the irradiated seal (Fig. 30).

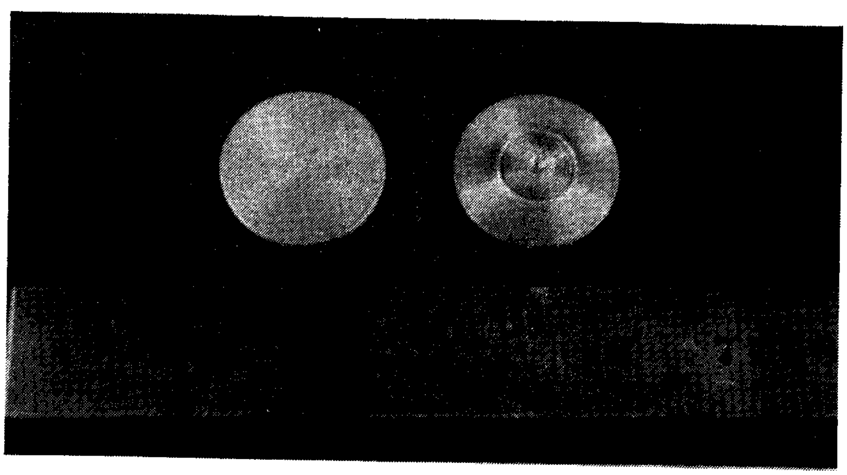


Fig. 29

5.3. Isotopic analysis of the irradiated seal and contamination of the identification apparatus

The analysis of seal n°4 was made by gamma spectrometry with a Ge(Li) detector and by examining the energy interval from 80 to 1 800 keV. The analysis made on 15.3.73 showed the presence of the following gamma emitter radio-isotopes. (Fig. 30)

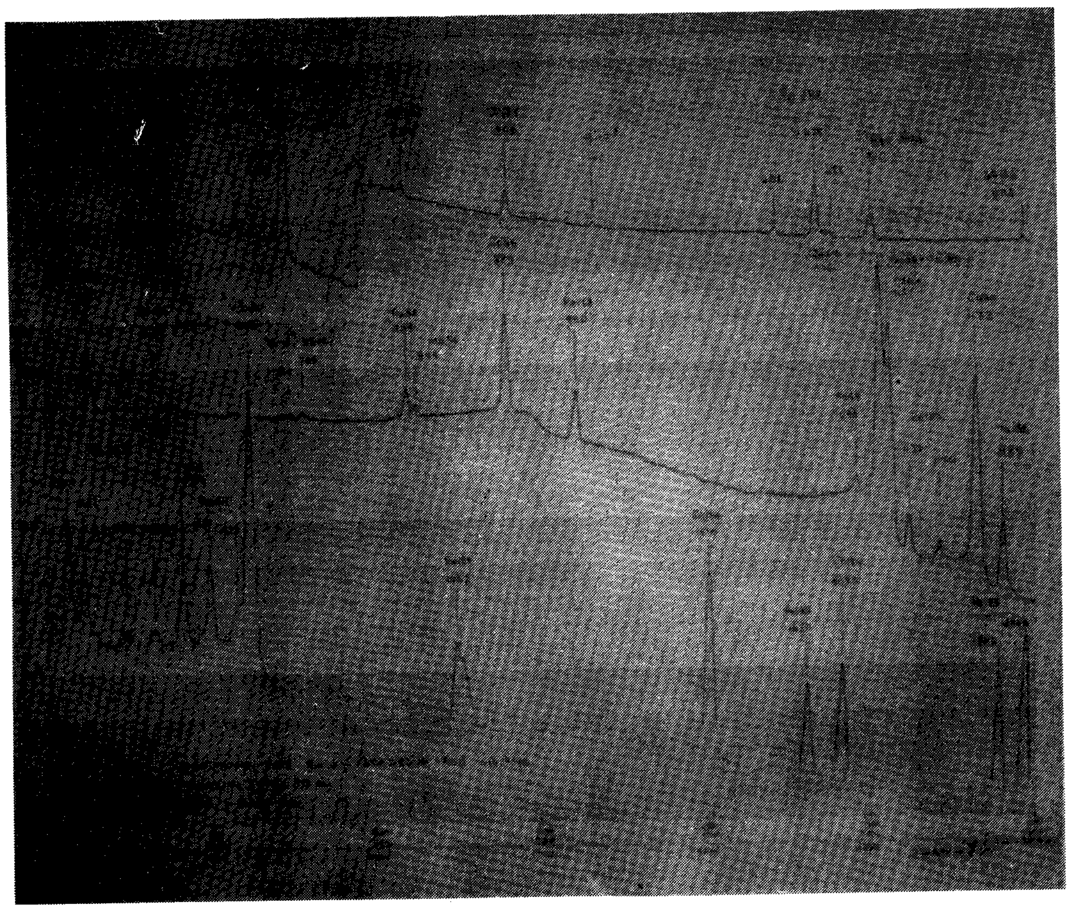


Fig. 30

The contact radiation intensity was about 1 mR/h when the seal was taken out of the water; no superficial contamination was found and the seals did not contaminate the identification apparatus. However, a rough sealing is necessary before identification.

The rather low activity and the small danger of contamination allow the use of a portable apparatus for identification of the seal in the reactor hall; the shielding is not complicated, the seal being identified under water in an identification device.

5.4. Cutting the nozzle before sending the fuel element to be reprocessed

Before transportation to the reprocessing plant, the two nozzles of the fuel element are cut. The normal cutting line is very near the position foreseen for the seal.

In such a case, the fuel would lose its identity if the seal were to be destroyed.

It is however possible, for several MTR fuel element types, to cut about 20 mm further towards the end of the box.

The transportation containers can accommodate this small increase in box length (HFR Petten, Ispra 1).

The cost of the reprocessing of the remaining material (corresponding to some mm length of the box) has to be added to the cost of the seal.

Figure 31 shows the end-box of fuel bundle n°783 as it is normally cut.

About 20 mm more will be sufficient for conserving the seal.

The approximate supplementary cost for reprocessing the extra 50 g. left on the box is equal to 6 US $ for each fuel bundle.

This cost must be added to the cost of the seal.

Fig. 31

6. RELIABILITY OF THE METHOD

6.1. Tamper-resistance of the identity of the seal (5)

6.1.1. As said in § 2, the identification chain is calibrated. The portable apparatus is automatically calibration to the greatest response encountered.
Although this calibration allows one to speak of absolute values, the identity is considered to be a collection of relative values (Cf. § 2.3). The codification of the identity is made on the basis of thorough knowledge of the confidence intervals associated with the elementary information of the identity. The confidence intervals were obtained by systematic identifications.

Assuming that the mechanical and electronic parts of the chain, as well as the transducer used, will always remain near the tolerances given and accepted during the statistical tests, we can evaluate the number of inclusions needed to be sure of being able to:

- identify uniquely the total amount of seals (K)
- take the confidence intervals into account (H)
  (uncertainty on the elementary information)

For example: when $K = 10^4$ (10.000 seals) with an uncertainty on a single response (H) equal to 5%, we need to identify 5 to 8 inclusions.

6.1.2. No important alteration of the seal can be accepted.
However, some superficial damage does not alter the identity (4). If a diverter tries to re-use a broken seal by gluing or welding the foot onto the disc, he will destroy the identity of the tamper will be easily detected when taking off the seal or by visual inspection.

6.2. Tamper-resistance of the identification of the fuel element

As said in § 2.2.2., the extraction of single plates from the box is impossible without machining (or destroying) the edge plates.
Cutting the plate around the seal is difficult but possible, to replace the seal on a new box is impossible due to the lack of ductility of the seal material when plastically deformed.

When an absolute tamper-resistance is required, all the plates of the assembly have to be identified (Cf. § 2.1).
To clarify this idea, it can be stated that an optimal choice exists between the complications that can be introduced to protect the fuel element and the chance of failure during control.

The probability (p_1.) of success in tampering with an element decreases with the increasing degree of complication of the application of the method (several seals + identification of the plates..); the probability (p_2) of making an error in identification and thus the probability of having a high degree of uncertainties, while verification increases with the complication of the system: Fig. 32

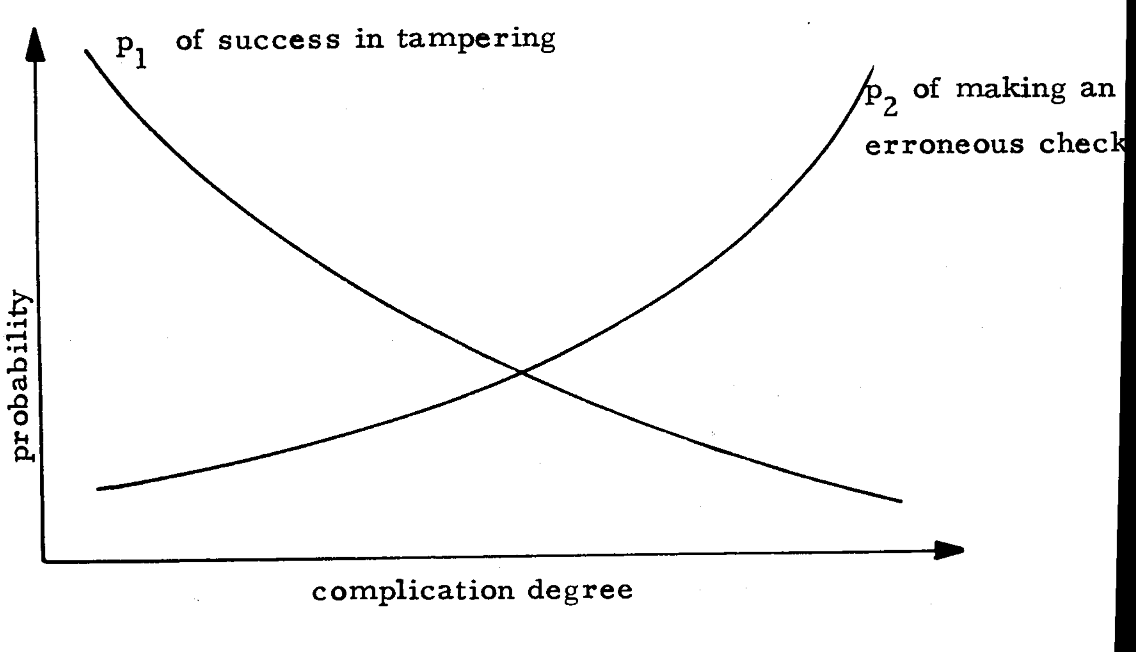


Fig. 32

7. OTHER APPLICATIONS OF THE RIVET SEAL

7.1. Identification of other types of MTR fuel elements

7.1.1. Fuel elements such as the bundle of the Geesthacht reactor can be identified in the same way.

These fuel bundles do not have the nozzle welded to the edge plate of the box, but it is mounted by screwing.

If the box has two screws on each end of the plates, the seal must be located between the screws. (Fig. 33)

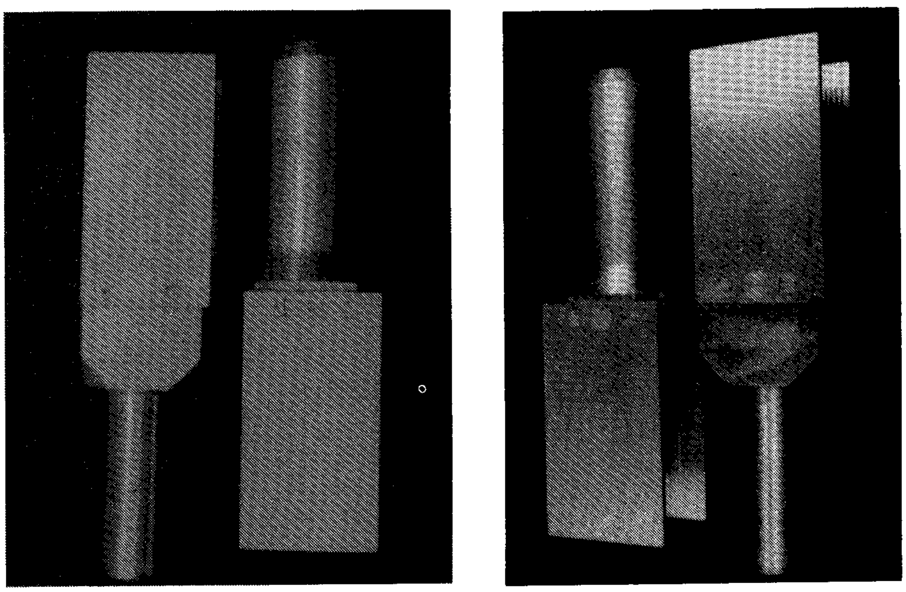


Fig. 33

If three screws exist, the central one can be replaced by a rivet seal. (Fig. 33)

7.1.2. For cylindrical fuel elements (Br_2, Essor, Dido), one or more of the combs blocking the curved or cylindrical plates can be sealed using a rivet seal. (Fig. 34)

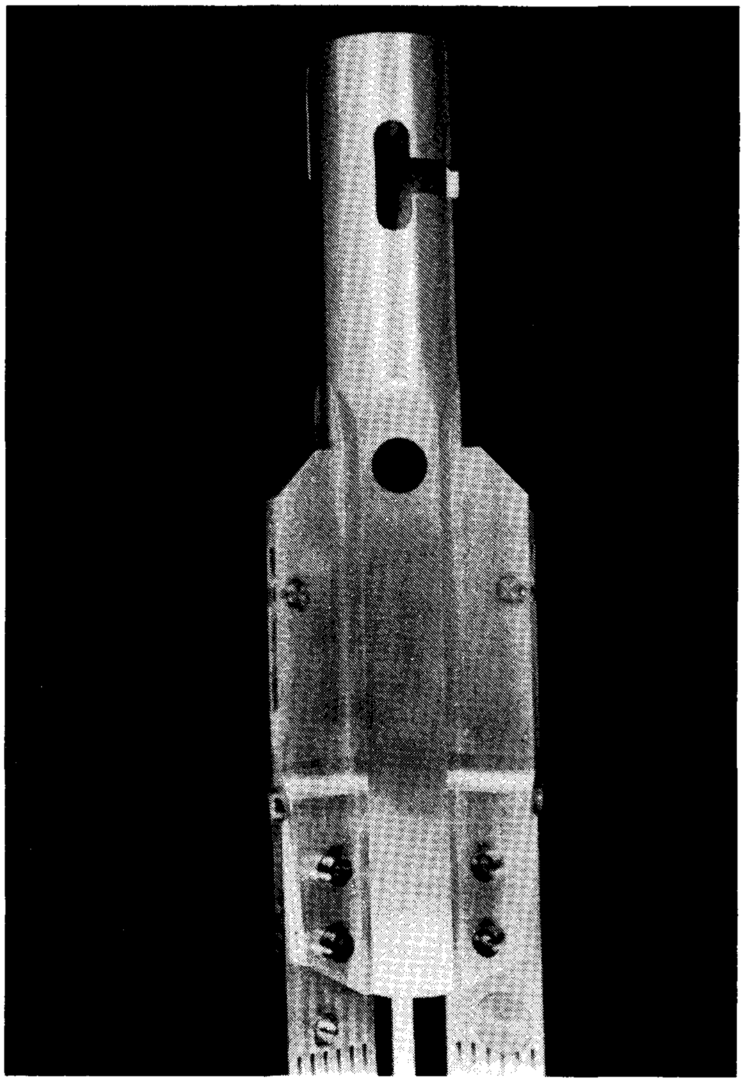


Fig. 34

7.2. General use seal with wire

On the same principle, a rivet seal can be used for blocking the extremities of a tamper-resistant wire. (Fig. 35)

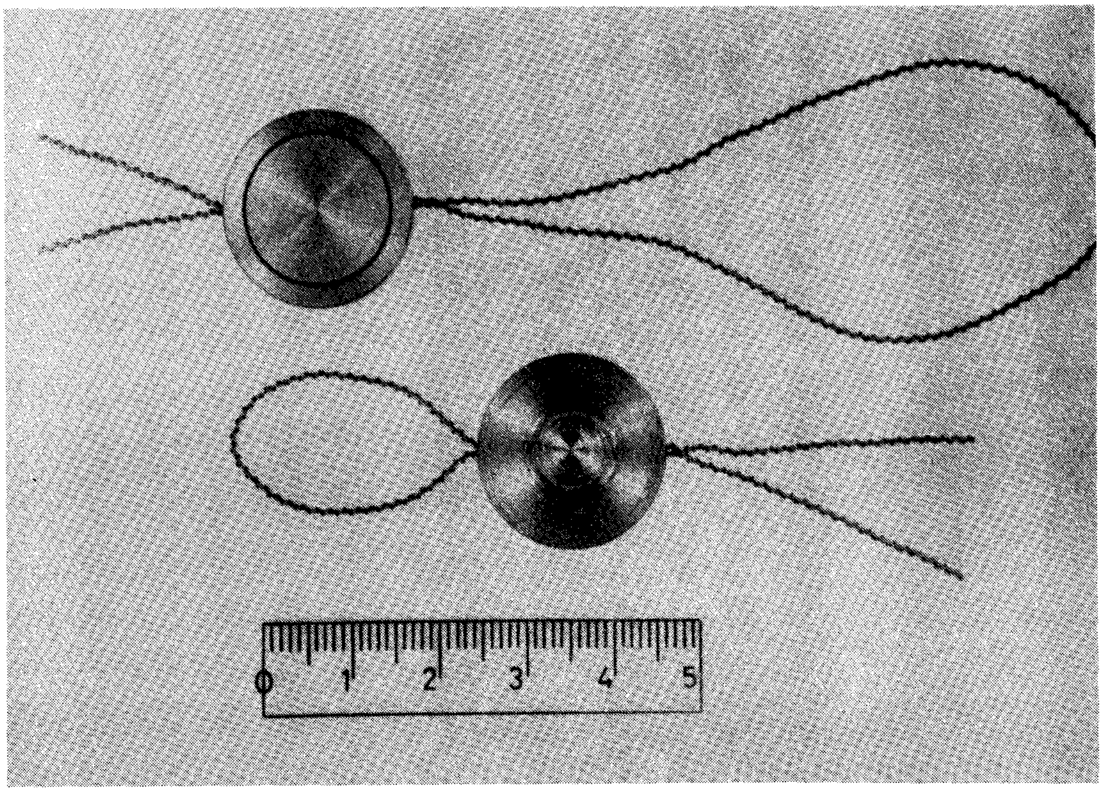


Fig. 35

This new type of general use seal has the same degree of tamper-resistance as the one designed for the MTR bundle.

8. CONCLUSIONS

8.1. The ultrasonic method for the identification of MTR plates and of rivet seals was extensively studied in our laboratories and the confidence limits were found statistically.

8.2. The modifications necessary to the fuel element b ox for applying the seal are simple and do not damage the fuel element.

8.3. Positioning and removing the seal are easy. Seals were extracted in the HFR reactor cooling pool even under 10 m of water.

8.4. The seal is not damaged by irradiation in the reactor. Its reidentification is easy, no contamination danger exists and the identity is reproduceable.

8.5. From our cost evaluations it appears that (§ 9.4.5) the total cost of the seal is rather high but the system offers the possibility of diminishing the inspection effort and thus the price of Safeguards. The identification apparatus used is the same for all types of seals. The fabrication cost of the seal cannot be reduced, due to the precision required in order to avoid any damage to the seal or to the fuel box.

8.6. Fuel element manufacturers (NUKEM, MMN, CERCA), reactor operators (HFR Petten, Ispra-1, Bh_2 Mol), reprocessers (Salluggia) and research or fissile material management people (GfK, RCN, CEN, CNEN, HARWELL) agree in principle with the technical feasibility of sealing the MTR fuel elements (§ 9.5).

9. MINUTES OF THE MEETING OF THE WORKING GROUP ON "SEALING AND IDENTIFICATION TECHNIQUES"

Held at Ispra on November 7, 1973.

9.1. Scope of this Meeting

This Meeting was the third of the Working Group on Identification and Sealing Techniques, which represents part of the European Community Safeguards Research and Development Association (ESARDA).
It permitted representatives of certain MTR reactors, and of fuel element manufacturing and reprocessing plants to express their opinions on the proposed method of safeguarding the MTR fuel elements by tamperproof seals which has been developed by the J.R.C. (Joint Research Centre) at ISPRA, as part of its Safeguards programme.

9.2. Participants

The list of participants is given below:

Belgium

MM.	Bobin K.J.	EURATOM	BR MOL	Reactor plant
	Van Maele L.	MMN	DESSEL	Fabrication plant

France

MM.	Dewez P.	CERCA	ROMANS	Fabrication plant
	Marguin J.C.	CERCA	PARIS	Fabrication plant

Germany

MM.	Brueckner C.	GFK	KARLSRUHE	Safeguards project
	Heger H.	KRB(VDEW)	GUNDREMMINGEN	Reactor plant
	Kuehn H.	NUKEM	HANAU	Fabrication plant
	Vietzke H.	NUKEM	HANAU	Fabrication plant

Italy

MM.	Di Palo L.	CNEN	ROMA	Safeguards project
	Hall A.	CNEN	SALUGGIA	Reprocessing plant
	Liscia A.	CNEN	SALUGGIA	Fabrication plant

Nederland

MM.	Harry R.J.S.	RCN	PETTEN	Safeguards project
	Schinkel J.	RCN	PETTEN	Reactor plant, HFR
	Jehenson C.	EURATOM	PETTEN	Reactor plant, HFR

United Kingdom

Mr.	Adamson A.	AERE	HARWELL	Safeguards project

Safeguards Directorate Luxemburg

MM.	Miranda U.	EURATOM
	Schleicher H.W.	"

Joint Research Centre ISPRA

MM. Prins A.	EURATOM	ESSOR Reactor
Wiederstein P.	"	ESSOR Reactor
Bresesti M.	"	Safeguards Project
Foggi C.	"	Safeguards Project
Borloo E.	"	Non Destructive Section
Bürgers W.	"	Materials Division
Crutzen S.	"	" "
Dal Cero J.	"	" "
Jehenson P.	"	" "
Marchal F.	"	" "

9.3. Agenda of this working group

9.3.1. Draft Document

" A rivet seal for safeguarding the MTR fuel elements"
S. Crutzen, P. Jehenson, E. Borloo, W. Buergers - JRC Ispra 1973
constituted the basis of the technical discussions of the Working Group. The main items of this paper were also the items on the agenda of the meeting; this paper was distributed two weeks before the meeting.

9.3.2. Agenda

9.30 Presentation of the participants and of the agenda (S. Crutzen)

9.40 Introduction (P. Jehenson)

9.50 Identification method of the MTR fuel elements (S. Crutzen)

- Criteria and difficulties
- Marking of the plates
- Sealing of the container (box)

10.25 Ultrasonic identity measurement (E. Borloo)

10.45 Fabrication of seals and preparation of seats in the edge plate of the box (S. Crutzen)

11.45 Experiments performed in HFR PETTEN (S. Crutzen)

- Irradiation of seals
- Extraction tool
- Reidentification of irradiated seals
- Contamination
- Cutting of the nozzles

11.45 Reliability of the method (S. Crutzen)

14.30 Discussions and other proposed items

15.45 Conclusions (P. Jehenson)

16.30 Demonstration of the apparatus (W. Buergers, J.Dal Cero, F. Marchal

9.4. Main points discussed during the meeting

After the several presentations listed in the agenda, which were made principally by Mr. Crutzen, some points were commented on and discussed.

9.4.1. Marking of the fuel plates

The marking of the fuel plates was abandoned in 1971 by the JRC, Ispra, due to several reasons which were confirmed during the meeting.

a) From a fabrication viewpoint it is not interesting to put inclusions in the fuel plate (M. Dewez).

b) It cannot be acceptable from a reprocessing viewpoint. Only those inclusions soluble in boiling $HN0_3$ could be accepted (M. Hall).

c) From a Safeguards viewpoint it is complicated to control in certain special cases, when loose plates are in circulation, marking of the plates might be accepted (M. Schleicher).
The use of a seal gives a positive answer to these problems.

9.4.2. Location of the seal

The chosen place for HFR elements was at the overlapping point of the edge plate and the nozzle, due to the fact that it is impossible to pull out the plates without destroying the edge plate and thus the seal: MM. Dewez, Van Maele and Vietzke confirmed this practical impossibility.
M. Schinkel insisted on the seal being placed at the lower part of the fuel, due to the direction of the cooling system. M. Crutzen added that this position should also be discussed as a function of the position of the bundle when in storage : the extraction of seals should be done without handling the fuel elements.

9.4.3. Properties of the seal

9.4.3.1. Nuclear Purity

M. Dewez asked if the nuclear regulations are respected concerning the material used. M. P. Jehenson answered that the materials used for the fabrication of the seals are the ones used for cladding materials in the ORGEL project (SAP powders with nuclear Aluminium).

9.4.3.2. Corrosion

In reply to a question from M. Di Palo, M.P. Jehenson (Ispra) answered that the choice of SAP for the fabrication of the seal and the position of the seal on the edge plate (Al alloy), the low temperature at this point of the fuel element avoid any corrosion problems. The good practical results obtained with seals on MTR fuel elements submitted to a normal irradiation cycle in the HFR reactor at Petten have confirmed that no corrosion problem arose. M. P Jehenson also pointed out that the conditions leading to corrosion or some detorioration of the seal, would have corroded and destroyed the plates already long before. This seal is prepared by sintering of SAP powders at 600°C. M. Schleicher confirmed that a great deal of work was done by him on that point at Ispra, for the ORGEL project.

MM. C. Jehenson and Schinkel also confirm that during the experiments at HFR Petten no corrosion appeared on the seals and that it seems impossible for it to occur, even if numerous scrams (question of M. Di Palo) occurred during the irradiation of these seals.

M. Bobin also confirmed this opinion.

9.4.3.3. Vibrations

In reply to a question from M. Bobin, M. Crutzen stated that, for the MTR fuel element seals, it is very difficult to have vibrations if the seal is well riveted (correct choice of the material).

9.4.3.4. Tamper-resistance of the seal

To the question of M. Brueckner concerning the possible reuse of a seal by rewelding or gluing the foot to the identified disk, MM. Crutzen and P. Jehenson answered that it seems to be impossible

a) to reweld without creating small changes in the identity, recorded by ultrasonics, due to the position and the dimensions of the weak zone (see Fig. 14),

b) to glue without visual detection, due to the same reasons as in a).

c) the tamper-resistance of the container has to be examined for each cases of application and its integrity has to be verified when the seals are checked (M. Harry).

9.4.3.5. Irradiation results

The experience gained on 6 seals placed on MTR fuel elements irradiated in the HFR Petten indicated

- no reactor problems
- no special problem for the extraction of the irradiated seals. If this method of identification is applied for the part of the cycle passing through the reactor, it will be necessary to use in the cooling pond an extraction tool better designed than the prototype used at Petten, in order to avoid any need to manipulate the irradiated fuel elements (M. Schinkel). The design of this extraction tool has already been modified.
- no special contamination on the seals. The seals have only to be cleaned with water before going to the identity measurement apparatus.
- that the identity is well conserved after irradiation.

9.4.4. Applications of seals on other MTR fuel elements

M. Dewez asked if the experiences gained at Petten are extrapolatable to other MTR fuel elements.

MM. Crutzen and P. Jehenson answered that this method of sealing by an identified rivet can be applied to all other types of MTR fuel elements.

Some small amount of design will have to be carried out in order to take into account the particular design criteria of each fuel type (see § 7.1.). The experience gained at Petten is very representative for MTR type fuel elements, since the HFR Petten reactor is a high flux material testing reactor.

9.4.5. Costs

In reply to a question from M. Van Maele about the price of the seal and who has to pay, M. Crutzen gave the following rough evaluation making some hypothesis:

9.4.5.1. Hypotheses

a. There are 1000 fuel elements to be safeguarded per year
b. 3 seals are necessary for each fuel element (§ 2.4.)
c. 1 static and 1 portable apparatus are used
d. The same identification apparatus is also used, for cap seals (LWR fuel elements) and for general use seals
e. All apparatus and tools are written off in 10 years
f. The checking is done in Europe (low travel costs for inspectors).

9.4.5.2. Cost of the seal

	U.C. (1 UC = 50 FB)
a. fabrication	6.00
b. 2 identification apparatus: 2 x 10.000 to 15.000 UC thus, following hypotheses a, b, d, e, for each seal	0.30
c. grip and extraction tools: about 1000 UC for each reactor, thus, due to hypotheses a, e	0.40
d. preparation of the seat of the seal (§ 4.1) 5 UC for one fuel element thus due to hypothesis b	1.70
e. supplementary reprocessing cost (§ 5.4) 6 UC thus due to hypothesis b	2.00
f. Total cost, including seal and technical devices	10.40 UC.

9.4.5.3. Inspection cost

From personal contacts with USAEC people, it appears that a minimum inspection cost reported on one seal (IAEA seal) (inspectors, travels, computer time) would be about 10 UC *

9.4.5.4. Total cost

The total cost of the one seal is thus about 20 UC.
Due to hypotheses a and b, safeguarding the MTR fuel elements during the considered part of the fuel cycle considered-will cost a minimum of 60.000 UC a year.

9.4.5.5. Who will pay ?

To this question, M. Schleicher answered that up to now, since no official decisions have been taken the application of such a technique has to be financially supported by the Safeguards Directorate of the European Community.

9.4.6. Licencing the application of this patented identification and sealing method

To the question of M. Dewez concerning the licence bought by NUKEM, M. Crutzen answered that this involved the two Euratom patents as well as all the know-how concerning the application of the method. MM. Kuehn and P. Jehenson pointed out that the licences given by the European Community are not exclusive.

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* From discussions on 30.11.73 at Brookhaven Lab, with M. C. Sastre this cost appears to be about 20 UC for the Euratom seal when controls have to be done in the reactor hall).

9.4.7. Problem of warranties concerning fuel elements and reactors

In reply to a question from M. Marguin, M. Schleicher answered that the responsability of using this method, if it is applied, will be taken by the European Commission according to the opinion of the Commission jurists.

9.4.8. Control philosophy

Several points were discussed, principally by M. Brueckner M. Schleicher and M. Miranda.
It is not intended to summarise this discussion here, because this point is not directly connected with the scope of this particular technical meeting.

Practically, as confirmed by the discussions, the proposed sealing technique seems a good tamper indicating technique to be used for insuring that fissile material inside the sealed container is not diverted during that part of the cycke between the fabrication plant and the reprocessing plant.
This method simplifies the checking procedures of the Safeguards Division and, in some cases, permits a control of non diversion where other methods may not be applicable.
This conclusion is also valid for other seals studied at Ispra for other types of fuel elements; for instance, cap seals for LWR fuel elements for which irradiation experiments have been made since mid-72 in the Lingen and Gundremmingen reactors.

9.5. Conclusions

The main conclusions, given by P. Jehenson, are:

9.5.1. The MTR fuel element:

The method of putting the rivet seals on the edge plates gives no complication to the fabrication palnt, the reactor plant or the reprocessing plant. The severe criteria imposed by these plants are all respected.

9.5.2. The seals:

They can be used on the type of MTR fuel element tested without any serious difficulties. They are manufactured from Nuclear Quality Materials, provide no difficulties in fabrication, and should withstand the vibration found in most reactors. The investigators are confident that there will be no problems from activity or contamination. The seals have been success fully tested in Ispra-1 reactor and in the high flux reactor at Petten. It is realised that conditions such as vibration and coolant characteristics vary.

9.5.3. The identity

After irradiation, the identities taken initially by ultrasonics are well preserved.

9.5.4. Interest of this identification technique

From a Safeguards viewpoint, the interest of sealing MTR fuel elements is the easy check on the circulation of fissile material from the fabrication plant to the reprocessing plant and while passing through the reactor. In this important part of the cycle, fresh MTR fuel elements are obviously more interesting than irradiated ones from a diverter's viewpoint. The rivet seal gives a unique tamperproof identity to these MTR fuel elements, from fabrication to destruction at the reprocessing plant.

9.5.5. Conclusion

We consider that we have finished our experimental work on the sealing of the MTR fuel elements, and we pass it on the Safeguards Directorate, in the hope that it will be applied as soon as possible.
We shall naturally give all help needed for these applications and we hope that the reactor and plant operators will collaborate.

These conclusions received the agreement of all those present and M. Schleicher expressed his wish that we shall arrive "at a situation in which all MTR elements are sealed".

S. CRUTZEN

P. JEHENSON

Secretary of the Working Group on
Identification and sealing techniques
of ESARDA.

Ispra, November 12, 1973.

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