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JOINT RESEARCH CENTRE
Ispra Establishment
Italy

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Service and Support Activities

High Flux Reactor (HFR)
Informatics
Fissile Material Control ◀
Training and Education
Technical Evaluations in Support of the Commission

PROGRAMME PROGRESS REPORT

January-June 1977

ABSTRACT

This document is the progress report of the Project Fissile Material Control of the Joint Research Centre for the period January-June 1977.

This project is part of the programme Service and Support Activities.

The project Fissile Material Control includes the following studies:

- Control Systems,
- Isotope Correlations,
- Bench-Mark Experiments,
- Non-destructive Assay of Fissile Isotopes,
- Destructive Assay of Fissile Isotopes,
- Surveillance.

Control systems for Safeguarding fabrication plants and reactors are under investigation.
In the framework of the Bench-Mark experiments the post-irradiation analyses of the Gundremmingen BWR fuel have been completed.
In the field of Non-destructive Assay progresses have been made in the preparation of reference materials and in the development of instruments and techniques (neutron interrogation, Pu-isotopic composition by gamma-spectrometry, automation of instruments).
Important improvements have been introduced in the ultrasonic instrumentation utilized in the field of sealing and identification. Sealing and identification techniques are being applied in a large number of Safeguards problems.

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Summary

1. SCOPE

The exploitation of nuclear energy at an industrial level leads to the utilization of very large amounts of fissile materials. The safe and economic management of these materials and the safeguards control against diversion from peaceful uses, require a continuous development and adaptation of techniques and procedures.

The Commission of the European Community is in charge, on the basis of the Rome Treaty, of the control of the fissile materials in the Member Countries. This task has been assigned to the Safeguards Directorate in Luxemburg.

In 1973 an agreement was established between EURATOM and the IAEA for the implementation of the Non-Proliferation Treaty in the Member States who signed the Treaty.

The Joint Research Centre has been active since 1969 in the field of R&D for Fissile Material Control, with the main objective of giving scientific and technical support to the Safeguards Directorate of the Commission and with the further aim of providing methods for more efficient fuel management within the nuclear industry.

The JRC activity is being carried out in close collaboration with the Safeguards Directorate.

The activity of the Joint Research Centre is also coordinated with similar work carried out in national organizations, within the framework of the European Safeguards R&D Association (ESARDA) which now comprises research organizations of 6 Member Countries.

Apart from this, direct collaboration in special fields has been established between the JRC and European industrial firms. Collaboration has also been established with IAEA and AECL (Canada).

This project is part of the JRC programme Service and Support Activities. The staff allocated to the project for 1977 consists of 52 research men, corresponding to about 5% of the total JRC-staff. The project is carried out mainly at the JRC-Ispra Establishment with some participation of the JRC-Karlsruhe Establishment, Institute of Transuranium Elements.

Collaboration is foreseen with the JRC-Geel Establishment, Central Bureau for Nuclear Measurements, which, in the framework of the METRE (Measurements, Standards and Reference Techniques) programme, will produce results relevant for the fissile material control.

The project includes the following studies:

- Control Systems
- Isotope Correlations
- Bench-mark Experiments
- Non-destructive Assay of Fissile Isotopes
- Destructive Assay of Fissile Isotopes
- Surveillance.

These studies concern the areas of activity which are generally considered the most important in the field of safeguards and fissile material management.

These studies are essentially a continuation of activities carried out in the past programme 1973-1976. However, the new programme is characterized by an increased emphasis on specific actions in view of the safeguards implementation in the nuclear fuel cycle.

2. OBJECTIVES

The objectives of the different studies of the project are the following:

Control Systems

Most of the activity is directed toward the support of the Safeguards Directorate in the definition of control systems for the nuclear fuel cycle and their actual implementation. Studies of the nuclear plants, evaluation of different control procedures and statistical studies are required.

The results of these studies will also indicate the lines to be followed in the various experimental activities.

Isotope Correlations

The isotope correlation techniques are an important supporting measure for the verification of the internal consistency of the isotopic data from fuel analysis. The isotope correlation techniques, as applied to Safeguards, find the most important use in the verification of the input measurements in reprocessing plants.

The JRC activity in this field includes theoretical and experimental studies and the setting up of a bank of isotopic composition data.

Bench-mark Experiments

The aim of this activity is to provide the European operators of nuclear power plants with a set of reference data on irradiated fuels (burnup, isotopic compositions, cross section ratios), to be used for the check and adaptation of the nuclear codes which are required for reactor fuel management.
The reference data are produced by accurate radiochemical analysis of fuels irradiated in nuclear power plants.

Non-destructive Assay of Fissile Isotopes

The main effort within the project is directed towards the development and application of non-destructive assay (NDA) techniques which are essential for the control of finished fuels and heterogeneous materials which cannot be subjected to classical chemical analysis. Neutron techniques (passive and active) and gamma-spectrometry techniques are extensively investigated.

Special attention will be paid to the problems of the standardization of NDA techniques.

Destructive Assay of Fissile Isotopes

The destructive assay, based on the use of analytical chemistry and isotopic measurement techniques, is the fundamental procedure for the determination of fissile isotopes because of the high accuracy and state of development of these techniques.
Our activity is mainly directed to the automation of mass spectrometry and to its adaptation to specific problems of the fissile material control. Special attention is also paid to the problem of calibration and representative sampling from the input accountability tank of reprocessing plants.

Surveillance

The major effort of the JRC in this field is directed towards the development of sealing and identification techniques which make possible a considerable reduction of the inspection effort in respect of safeguards.

The method developed at Ispra, for the tamper-resistant sealing and identification, is based on the ultrasonic detection of randomly distributed inclusions in different materials.
The method will be applied to various parts of the nuclear fuel cycle.

The planned activities for the first half of 1977 are shown in Table 1.

3. RESULTS

During the reporting period the main achievements of the project were the following:

Control Systems

The main part of the work was directed towards analyzing the fuel management system of the operators in a fabrication plant for highly enriched uranium. The study was carried out in cooperation with safeguards inspectors and plant operators.
The next step of the work will concern the definition of sampling plans for verification of the operators data by the safeguards authority.

A preliminary investigation has been carried out in order to evaluate the possible combinations of non-destructive assay and surveillance techniques in a fabrication plant for plutonium fuels.

An evaluation in terms of efficiency and effort, of alternative procedures for the control of the part of the fuel cycle between the exit of the fabrication plants and the input of reprocessing plants, has been started.

Isotope Correlations

The activity for the setting up of a bank of isotopic data has been continued at Ispra and Karlsruhe, by collecting analytical data from irradiated fuels and by improving the software required for the operation of the data bank.

Experiments are in preparation on the application of isotope correlations in reprocessing plants. The JRC is organizing, under the sponsorship of ESARDA, a symposium on the Isotope Correlation Techniques, to be held in May 1978.

Bench-mark Experiments

During the reporting period the post-irradiation examinations of the fuel of the Gundremmingen BWR, have been completed in the laboratories of Ispra and Karlsruhe.
Data of burnup, isotopic compositions of uranium and plutonium, build-up and depletion of uranium, plutonium, curium and americium isotopes have been determined for 16 fuel pellets taken from 2 fuel assemblies.

The experimental analysis has been started on the fuel of the Obrigheim PWR.

A fuel assembly of the Trino Vercellese PWR has been transported to Ispra and dismantled. The fuel analysis for Trino Vercellese will be carried out in 1978.

Non-destructive Assay of Fissile Isotopes

In the field of standardization of NDA techniques a considerable effort has been spent in a literature survey of the activities carried out in different organizations.
Lists of the NDA reference materials available within the EEC and at IAEA and of the NDA methods used within the EEC have been compiled in the framework of the relevant working group of ESARDA.
These compilations are important inputs for the JRC activity.

For the preparation of reference materials an experiment has been carried out at the FBFC fabrication plant (Belgium) on low enrichment uranium (LEU) fuel pins in collaboration with CEN (Mol) and the plant operators.

A planning for the characterization of batches of low enrichment UO_2, to be used as reference material for enrichment measurements, has been prepared.

In the field of the development of measurement methods several actions have been started after a detailed examination of the fuel cycle and on the basis of the requests of the Safeguards Directorate.

Various instruments, using neutron interrogation techniques, are under investigation.
PHONID, a photo-neutron interrogation device, using Sb-Be sources, developed at Ispra, has been made operational in a fuel fabrication plant in connection with physical inventory taking.

The SIGMA apparatus, installed at the HOBEG fabrication plant for the control of HTR fuel pebbles, has been adapted for the analysis of LEU powders and pellets.

In the field of gamma-spectrometry an extensive investigation has been carried out on the determination of the plutonium isotopic composition in fuel pins, using a Ge(Li) detector.

The work for the automation of gamma- and neutron techniques, using microprocessors, has been continued.

Destructive Assay of Fissile Isotopes

A support has been given to the Safeguards Directorate by executing analyses on samples taken by the inspectors during control operation and by constructing sampling devices for UF_6.
On request of the Safeguards Directorate an evaluation of the operators measurement methods has been started.
Development work has been continued for the automation of mass spectrometry (JRC, Karlsruhe) and for setting up a transportable mass spectrometer.

A review of the methods used for the input measurements in reprocessing plants has been completed and some experimental actions are in preparation.

Surveillance

During the reporting period an electronic scanning system has been completed, which makes possible the identity making of most of the ultrasonically identified seals, without any mechanical scanning. The new system will simplify considerably all the procedures for the seal utilization. The use of less expensive seals will be possible.

The know-how of the fully automated identification equipment, developed at Ispra, has been taken over by the Nukem for commercialization.

Various studies for the application of sealing and identification techniques have been conducted in collaboration with plant operators.
In particular it is worth mentioning the collaboration with AECL (Canada) for the sealing of the storage of the CANDU fuel bundles in the reactor pool, the completion of the irradiation experiments of sealed LWR fuel bundles in the Lingen and Gundremmingen reactors and the collaboration with KFA (Jülich) concerning the identification of TRIGA fuel elements and AVR fuel pebbles containers.

Table 1 : Planned activities for the reporting period

Activities 1977		J	F	M	A	M	J
Control systems	A						
Isotope correlations	B						
	C						
	D						
	E						
Bench-mark experiments	F	(1)					(2)
	G						
Non-destructive assay of fissile isotopes	H						
	I						(3)
	J			(4)	(5)		
	K						
	L						
Destructive assay of fissile isotopes	M						
	N						
	O						
Surveillance	P						(6)
	Q				(7)		(8)

A Study of control systems for fabrication plants and reactors
B Theoretical investigations
C Setting-up of a data bank of isotopic data
D Preparation of an experiment on the WAK plant
E Organization of a Symposium on Isotope Correlations sponsored by ESARDA
F Experimental analysis of the irradiated fuels
  1 Start-up of the analysis on the Obrigheim fuels
  2 Completion of the analysis of the Gundremmingen fuels
G Data analysis in terms of cross section ratios
H Assessment of the standardization problem
I Preparation of reference materials
  3 Completion of the experiment for the preparation of LEU fuel pins
J Development and application of neutron techniques (active and passive)
  4 Experiments with PHONID (Sb-Be) in HEU fabrication plants
  5 Adaptation of SIGMA (Cf-252) to the control of LEU fuels
K Isotopic composition of Pu by gamma spectrometry
L Automation of instruments
M Automation of mass spectrometry
N Setting-up of a transportable mass spectrometer
O Assessment of the problems connected with input measures in reprocessing plants
P Development of ultrasonic apparatus and seals
  6 Completion of the design of the new US apparatus with electronic scanning and start-up of its industrialization
Q Applications of sealing and identification techniques to LWR, MTR, FBR, CANDU, TRIGA, AVR reactors
  7 End of the irradiation tests on sealed fuel assemblies in the Lingen and Gundremmingen BWR
  8 Completion of the design specifications for TRIGA fuel elements and AVR fuel pebbles containers

4. CONCLUSIONS

In general the objectives of the reporting period have been fulfilled.

In the first half of 1977 the emphasis on very specific actions in view of the safeguards implementation in the nuclear fuel cycle has been increased and the support to the Safeguards Directorate has been enlarged considerably.

The increase of the staff allocated to the project Fissile Material Control made possible a larger effort, mainly in the field of the non-destructive assay techniques. However, not all the competences needed are actually available.

The delay in the distribution of the 1977 budget has not heavily affected the work in the first months of the year. The effect of this delay will be much more important in the second half of 1977.

For further information concerning JRC Programmes, please contact
the Directorate Genral JRC, Rue de la Loi 200, B - 1049 Brussels

Programme Progress Report

1. INTRODUCTION

The JRC activity in the field of Fissile Material Control is carried out in a strong collaboration with the Safeguards Directorate of the Commission.

The project is part of the JRC programme Service and Support Activities. The staff allocated to this project for 1977 consists of 52 research men.

The project is carried out mainly at the Ispra Establishment with some participation of the Karlsruhe Establishment.

Some activities which are carried out as direct support to the Safeguards Directorate or have a character of confidentiality, will be paid by the budget of this Directorate.

The project consists of the following studies:

- Control Systems
- Isotope Correlations
- Bench-mark Experiments
- Non-destructive Assay of Fissile Isotopes
- Destructive Assay of Fissile Isotopes
- Surveillance.

Sub-Projects

2. SUB-PROJECTS

2.1 CONTROL SYSTEMS

OBJECTIVES

The term "Safeguards", used in the context of fissile material control, covers all the procedures conceived to verify that those materials are not diverted from their intended use; or to obtain a timely indication of a possible diversion, or yield a credible assurance that a diversion has not occurred. The year 1977 has been marked by two events which are important for the European safeguards namely:

- the entry into force of the "Non-Proliferation Treaty" (NPT) for the "Non Nuclear Weapon States" of the European Community (22 Februaray 1977)
- the entry into force of the new "Safeguards Regulation" of the Commission (15 January 1977), directly resulting from the Treaty of Rome establishing the European Atomic Energy Community; this Regulation is relevant to the whole European Community, and results from a modification of the preceeding Regulation.

As a consequence of these two events, the Safeguards Authority of the Commission (Safeguards Directorate = DCS) has been faced with the problem of adjusting its procedures and techniques to the requirements of the new regulations. The objective of the work carried out by the JRC under the heading "Control Systems", is to support the DCS in evaluating, designing, and implementing safeguards systems for various types of nuclear plants. This is pursued by participation within four working groups, jointly established between JRC and DCS, dealing respectively with:

- general problems of safeguards,
- safeguards in fuel fabrication plants,
- safeguards in reactor installations,
- safeguards in reprocessing and enrichment plants.

The work is carried out in the divisions of System Analysis, Chemistry, Electronics and Materials.

RESULTS

General Problems of Safeguards

The working group has reviewed the main general problems and decided to give priority to the establishment of a calculation method for evaluating the "material unaccounted for" and the "limits of error of the material unaccounted for" in fuel fabrication plants. A survey of the existing literature has been done.

Safeguards in Fuel Fabrication Plants

The aim of the work performed by the group is to establish appropriate safeguards systems (or to improve the existing ones for those installa-

tions which process nuclear materials with the object of preparing nuclear fuels or manufacturing fuel elements).
The installations considered are those processing low enriched uranium (LEU), highly enriched uranium (HEU) and plutonium-uranium mixed oxides (PU).

A first analysis of the problem was performed and the following points considered worthy of further study:

- evaluation of the measurement system used by the operator for accountancy purposes,
- improvement of the quality of the measurement system used for verification purposes by the inspectors of the safeguards authority,
- definition of the sampling plans (one for each installation type) to be used by the inspectors for the verification of the operator's declaration on the flow of materials and the physical inventory.

1) The contribution given by the JRC to the work of the group is the following:
A detailed flow scheme of the chemical and mechanical processes carried out in a particular European fuel fabrication plant for highly enriched uranium has been prepared; a compilation of all the measurements made by the operator at each "key measurement point" (as defined by the Euratom Safeguards Regulation), together with the corresponding precision and accuracy, has been completed. The correctness of the flow scheme and of the compilation have been checked together with the DCS and the plant operator.
The "Physical Inventory Listing" (as defined by the Euratom Safeguards Regulation) prepared by the operator of the above mentioned plant has been examined and rearranged in order to create categories of materials having the same characteristics from the measurement point of view.

2) The contribution given by the JRC-Ispra also concerned the fabrication plants treating Pu-U mixed oxides.
A first solution of the safeguards problem was prepared, with a view to reducing interference with the operator activities. The scenario includes the combined use of surveillance techniques (with optical means), sealing and identification techniques, and non-destructive assay techniques. Discussions are still needed with the safeguards inspectors and the plant operators with a view to defining the phase at which the control has to be started, namely the pellets or the finished pins. Reasonable schemes of control have been proposed, including limited efforts in hardware, but they still need to be refined and assessed through demonstration experiments.

Safeguards in Reactor Installations

The work carried out consisted in the evaluation of the number of irradiated fuel elements to be stored and safeguarded in the next 8-10 years, under various hypotheses of availability of reprocessing capacity. The result was that the number of such elements will rise to several thousands (20,000 - 30,000 in the worst cases) if the reprocessing capacity remains low.

A study has also been carried out on various possible safeguards systems to be used for the nuclear fuels of light water reactors (LWRs), in that portion of the fuel cycle which goes from the exit of the fuel fabrication plant to the input of the reprocessing plant. The following techniques were considered for application (either in combination between them, or as alternatives): containment by means of tamper-proof permanent seals on the fuel elements, containment by means of tamper-proof temporary seals on the fuel elements, optical surveillance by means of cameras, visual surveillance by the inspector. The inspection effort to be deployed in the various cases has been calculated.

CONCLUSIONS

The activity in support of the DCS has been started according to the lines set down in the agreements between the JRC and DCS; however the manpower support given remains lower than necessary. The following additional items should be undertaken:

- The setting up of a complete safeguards system requires the systematic analysis of the nuclear fuel cycle that is to say: number and types of installations, processes carried out, flow schemes of the materials, operator's measurement procedures, inspector's measurement procedures, assessment of the achievable accuracies, definition of the actions to be taken by the inspectors for verification, etc. A detailed analysis should also be made of the safeguards regulations, in order to translate the basic concepts contained therein into practical operational rules.

  These activities would be possible only if a team of people were allocated to provide a systematic analysis of the various problems. At present, only one person is allocated full-time to the work; contributions of other people represent only small fractions of their time.

- The analysis of the measurement systems requires deep knowledge of statistics, specially when calculating the measurement error propagation in complex systems; these studies would therefore require the assistance of a statistician.

PLANNED ACTIVITIES

General Problems of Safeguards

The work for establishing a calculation method for evaluating the "Material Unaccounted For (MUF)" and the "Limits of Error of the MUF" in a fuel fabrication plant, will be initiated if adequate statistical support can be provided either by the JRC-Ispra or by an external source.

Safeguards in Fuel Fabrication Plants

1) It is planned to make the statistical elaboration of all data contained in

the "Physical Inventory Listing" provided by the operator of the HEU plant (as mentioned in the description of the results). The goal of this elaboration is twofold: a) to evaluate the total measurement error of the operator, and b) to define a detailed sampling plan to be used by DCS for the verification of the declared physical inventory.

An assessment of the inspectors' capability to perform an accurate verification of the inventory will be made, based on the precision and accuracy of the instruments in use at present; procedures for the use of the equipment utilized during the inspection, will be put in written form.

2) The study of a control system for a specific fuel fabrication plant processing Pu-fuels will begin before the end of the year; it is expected to apply the experience already gained in the problems concerning the HEU plants.

Safeguards in Reactor Installations

Assistance will be given to the DCS in order to define the safeguard system of the SNR-300 Kalkar reactor. This is a German fast breeder reactor due to start in 1980-1981; it is planned to safeguard the fuel present in the station by means of an automatic system for the observation of the fuel elements.
The study concerning the various possible safeguards systems to be used for the nuclear fuels of LWRs, in that portion of the fuel cycle which goes from the exit of the fabrication plant to the input of the reprocessing plant, will be continued.

2.2 ISOTOPE CORRELATIONS

OBJECTIVES

The irradiation of a nuclear fuel causes important and complex changes in its isotopic composition, namely:

- depletion of the isotopes of uranium initially present (and, where applicable, of plutonium),
- build-up of artificial isotopes of heavy elements (e.g. U-236, Pu-239, Pu-240, Pu-241, Pu-242),
- build-up of fission products (isotopes of light elements, resulting from fission of heavy elements).

These changes are often correlated in a very simple manner; in many instances the relationship representing the correlation is a simple proportionality between depletion and build-up of selected groups of isotopes.

The correlation technique was born and developed in the framework of safeguards studies for the purpose of verifying the Pu-content of spent fuel assemblies; subsequently, application of this technique was extended to the verification of the consistency of the isotopic analyses performed at the reprocessing plant input. In addition, one should mention that comparison of the results of these analyses with already established correlations provides an additional means of guaranteeing the identity of the dissolved fuel elements. Many of these applications can prove to be useful also to reactor operators (due to their impact on fuel management, burn-up calculations, etc.) and to reprocessors (as a means of checking consistency of input analyses).

Research and development in the field of isotope correlation techniques is being carried out at the JRC, Ispra and Karlsruhe Establishments; the main actions undertaken in the past six months are:

a) to carry out theoretical studies on correlations,
b) to collect experimental data on irradiated fuel isotopic compositions in the form of a Data Bank,
c) to participate in experiments on the application of isotope correlations in reprocessing plants,
d) to promote the organization of a symposium on the isotope correlation techniques.

The JRC-Ispra is also charged with the secretariat of the ESARDA Working Group on Isotope Correlations and Reprocessing Input Analysis.

RESULTS

Theoretical Studies

Various correlations based on isotopes of fission products have been analyzed in order to define the accuracies needed for the various nuclear parameters influencing the calculations.

The correlations considered are those between the concentrations of the heavy elements (isotopes of U and Pu) and the concentrations of various isotopes of Kr, Xe, Nd, Cs, Eu in Light Water Reactor fuels.

We have reached definite conclusions on the accuracy needed for such parameters, in order to produce results which are valuable for the isotopic correlations technique. It has also been shown that the accuracy required for some parameters is determined, to a large extent, by the final burn-up of the fuel considered.

The results of these studies will be possibly used for publication at the IAEA panel to be held in September 1977 on the subject "Fission Product Nuclear Data".

Acquisition of Isotopic Composition Data

Although the fields of application for the correlation techniques have been singled out and exploitation has already started, further experimental effort and theoretical interpretation are needed for improving confidence in the technique. In this respect ESARDA has taken the initiative of collecting, on a European scale, data on fuel isotopic composition generated during a number of reprocessing campaigns or post-irradiation fuel analyses.
The task of gathering these data into a Data Bank has been entrusted to the JRC-Ispra. The work for the preparation of the Data Bank has started in 1975.

The software of the Bank has been based on the IBM Data Management System "STAIRS". Some difficulties were encountered in establishing input-output procedures and in linking the system to other scientific programs: this is due to the fact that "STAIRS" is a system conceived for documentation rather than for scientific data banks. The work concerning the input-output procedures and the linkage to other programs, is still in progress.

The present structure of the Data Bank (content and formats) is very much similar to the one of the Bank received from JRC-Karlsruhe three years ago. A transformation of the structure is under way, in order to make it similar to the IAEA data bank MARK-I, the content and formats of which have been set up by an international committee of experts.
The 126 data sets of the former JRC-Karlsruhe data bank have been incorporated into our data bank. In addition, other data from DODEWAARD, SENA and GUNDREMMINGEN reactors have been codified. A final input form for codification of data to be included in the bank has been prepared.

The JRC-Karlsruhe is collaborating with the IAEA on data bank preparation, in the framework of an R&D coordination programme. The present version of the data bank (prepared by the IAEA) has been installed at the Safeguards Directorate, Luxemburg, for testing.

Experiments on the Application of Isotope Correlations in Reprocessing Plants

In the framework of ESARDA an experiment is in preparation on the application of isotope correlations during the reprocessing of the OBRIGHEIM fuel at the WAK-plant, Karlsruhe.
Most of the experimental work will be carried out at the WAK-plant and JRC-Karlsruhe.

JRC-Ispra will contribute in the planning of the experiments and in the analysis of the results.

In the framework of a collaboration between the Joint Research Centre and CNEN (Italy), an experiment is in preparation on the EUREX-plant, Saluggia. The experiment will be carried out on the occasion of a campaign of reprocessing of CANDU fuel.
The experiment aims at verifying the procedures of calibration of the accountability tank for safeguards purposes, but, at the same time, an attempt to using the isotope correlation technique for the verification of the accountability could be made.

Symposium on Isotope Correlation Techniques

A symposium on this subject has been proposed since last year by the JRC-Ispra to the Steering Committee of ESARDA. Scopes of the symposium will be:

- to present new basic data and to summarize the experience of application already gained,
- to inform potential users about the advantages of isotopic correlation techniques, with special reference to those fields which are new,
- to highlight any areas where additional work may be required.

Preparatory documents on various aspects of the symposium have been produced and presented to the ESARDA Project Leaders (January 1977) and to the ESARDA Steering Committee (May 1977). After discussion of the documents, the Steering Committee has decided to entrust the organization of the Symposium to the JRC-Ispra.

CONCLUSIONS

Theoretical studies were slowed down with respect to the programs established in the past years, due to the lack of personnel.
It would be advisable to deploy more effort in this area, since the Ispra Centre has always been the leader of the theoretical research on isotope correlations. A number of requests for more research on various fuel types (issued by several organizations) have been dropped in the past, due to the lack of personnel.

The Data Bank at Ispra is based, at present, on a Data Management System which is not the best for our purposes. The acquisition of a new system, fit for scientific problems, is planned by CETIS; then the new system will be available, we will use it for the Data Bank.

The experiments in preparation will make possible the identification of the possibilities and difficulties in the use of isotope correlation techniques in reprocessing plants.

The fact that the organization of the Symposium on Isotope Correlations has been entrusted to the JRC-Ispra, is an international recognition of our experience in this field.

PLANNED ACTIVITIES

Theoretical Studies

In the next six months period it is intended to carry out the following work:

- to prepare a report containing the results of the analysis performed on the correlations based on fission product isotopes; the details on the analysis have been reported in the chapter "RESULTS" of this report;
- to start, if enough manpower will be available, the theoretical study of the correlations in heavy water reactor fuels.

Acquisition of Isotopic Composition Data

In the next half year it is intended to carry out at the JRC-Ispra the following work:

- to modify the structure of the Bank (content and formats) in order to make it similar to the IAEA MARK-I Bank,
- to complete the input-output procedures of the Bank,
- to link the Bank to the statistical evaluation program CORRELATIO, already used at the System Analysis Division for similar purposes,
- to compare the performances of the Bank to the JRC-Karlsruhe Bank in our possession.

Experiments in Reprocessing Plants

Participation in the experiment on the WAK-plant to be started in October 1977 and in the experiment on the EUREX-plant.

Symposium on Isotopic Correlations

The Symposium is planned for Spring 1978 at Stresa, Italy. The work to be performed in view of the organization of the symposium includes:

- meeting of the organizing Committee for establishing the details of the organization,
- to contact all possible contributors of papers,
- to make appropriate advertisement of the symposium, either by letter or by announcement,
- to read the papers for acceptance,
- to decide procedures for editing and publishing all the documents.

2.3 BENCH-MARK EXPERIMENTS

OBJECTIVES

The scope of the bench-mark experiments is the production of a set of reference data on burn-up, isotopic compositions and cross section ratios for irradiated fuels.

Radiochemical analyses of fuel samples irradiated in well known conditions deliver the raw data which are further analyzed. These reference data are made available to power reactor operators and fuel management groups of the Community for the control and adaptation of nuclear codes.

The planning for the reported period included:

- completion of the experimental analysis of the Gundremmingen BWR fuel
- Start of the experimental analysis of the Obrigheim PWR fuel
- Elaboration of the data on Trino Vercellese PWR and Gundremmingen BWR.

RESULTS

Experimental Post Irradiation Analysis

1) Gundremmingen Reactor

The analyses of samples taken from spent fuel elements irradiated in the Gundremmingen reactor have been completed.

The reactor is a dual cycle BWR of 801 MW thermal output, loaded with U-235 enriched fuel. The reactor core consists of 368 fuel assemblies and 89 cruciform control rods. Each fuel assembly has 36 fuel rods in 6 x 6 square array. Sixteen samples chosen for the chemical analysis were obtained from the assemblies B 23 and C 16 which were unloaded at the end of the 5th cycle.

The chemical analyses of the 16 samples, 9 from B23 and 7 from C16, were carried out at Ispra (10 samples) and Karlsruhe (6 samples) Establishments of the JRC.

The samples were cut at 2680 mm from the bottom of the fuel active zone for 10 rods and at 440 mm from the bottom for 2 rods.

Four samples were used for checking the analytical results between Ispra and Karlsruhe Laboratories.

The raw analytical results obtained in the two laboratories by alpha, gamma and mass spectrometry techniques were collected at the Ispra Establishment and treated in order to produce a set of data in a form suitable to be used by the reactor utilities, to the scope of the experiment. The main data produced are:

- Isotopic composition of U and Pu isotopes at reactor shut-down
- Build-up and depletion of U, Pu, Cm and Am isotopes
- Burn-up of the analyzed fuel samples.

The results of the analysis are being examined with KRB-Gundremmingen and KWU-Frankfurt.

A consistency check of the most important quantities determined, was carried out by using the isotope correlation technique. In the case of BWR the most significant correlations are those between Pu/U mass ratio and U-235 depletion and those between burn-up and U-235 depletion.

2) Obrigheim Reactor

In the ADECO laboratory of the ESSOR reactor six rods of the Obrigheim Reactor fuel elements BE 124 (2.83 wt% enrichment) and BE 210 (3.0 wt% enrichment), discharged after the fifth irradiation cycle are ready for cutting into 27 samples. Six samples of the rod E3 from BE 124 fuel assembly have already been prepared for the chemical analysis and forwarded to the Chemistry Division for dissolution.

The Obrigheim Reactor is a PWR type of 1050 MW thermal output, loaded with U-235 enriched UO_2 fuel. The reactor core consists of 121 fuel assemblies and 32 control rod clusters. Each fuel assembly has 180 fuel rods and 16 control rod tubes in a 14 x 14 square array.

3) Trino Vercellese Reactor

In the framework of the bench-mark experiment, a comparison between experimental and theoretical data of build-up of Am and Cm isotopes and their parent nuclides (Pu-241 and Pu-242) has been performed in cooperation with ENEL. The experimental results obtained by the JRC for the samples irradiated in Trino Vercellese PWR were compared with those calculated by means of the RIBOT computer code [3] suitably modified.

This work has been presented during the First Technical Meeting on Nuclear Transmutation of Actinides held at Ispra on March 16-18, 1977 [4].

The transport to Ispra of the fuel assembly no. 509-091 of the third Trino Vercellese reactor core, formerly foreseen for 1976, has been done in April 1977. The fuel element has been dismantled in the pool of the ESSOR reactor and seven fuel rods removed. Twenty eight samples will be cut for the analyses to be performed during 1978.

The Trino Vercellese reactor characteristics are described in the references [5, 6].

Elaboration of Experimental Data

The isotopic compositions measured on TRINO-1 and TRINO-2 fuel samples have been analyzed with the one-group cross section ratio technique [7, 8], modified with respect to the original version, for taking into account the Pu-240 absorption cross section variation with the burn-up.

Tables 1 and 2 give the one-group cross section ratios for the two fuel sample sets (TRINO-1: 2.719% and TRINO-2: 3.13% initial enrichment) compared with the values utilized by ENEL.
In fig. 1 the $\sigma_a^{-40} / \sigma_a^{-25}$ cross section ratio versus burn-up deduced from TRINO-1 data is plotted.
Capture cross-section ratios of various nuclides over U-235 absorption are normally well reproduced by our code THEORY, while the absorption cross section ratios show some disagreement with the values given by ENEL.
Further discussions with ENEL are required on this subject.

Interesting is the evaluation of the initial content of U-236 (tables 1, 2): the amount computed by THEORY for the TRINO fuel is similar to the amount of initial U-236 content measured in fuels fabricated in the same period in the USA [9].

Preliminary results indicate that with the simple model based on one-group cross section ratios, it may be difficult to interpret BWR data, since this model does not take into account spatial and time dependence of neutron spectrum in BWR lattices.

From the experimental data on the concentration of the actinides present in the spent fuel samples [5, 6, 10], at reactor discharge, the total neutrons produced by α-interaction with light elements and spontaneous fission, have been calculated. The evolution of the total neutrons after a cooling period has been computed and plotted vs. the burnup reached by each sample during the irradiation. Figures 2 and 3 represent the various graphs obtained for PWRs and BWRs fuel samples. At discharge (cooling 0 yr) a linear relation is observed between the total neutrons (n/s) and the burnup over a range of 15,000 - 27,000 MWD/MTU; after a cooling period the relation is still linear over a smaller range (18,000 - 27,000 MWD/MTU).
A further development of this study to evaluate which actinide contributes to the neutron production at different burnup and cooling times could give interesting additional information for reactor operators and for people concerned with waste problems.

Also the possibility of a non-destructive determination of fuel burnup, by means of neutron measurements, can be envisaged.

CONCLUSIONS

In spite of the complexity of the post-irradiation analysis, requiring the intervention of several laboratories, the work is proceeding in a satisfactory agreement with the planning.

The accuracy of the analytical measurements has been checked by comparison of the results obtained in the laboratories of Ispra and Karlsruhe and by using isotope correlation techniques.

The accuracy of our measurements resulted to be adequate for the verification of the nuclear codes used for fuel management.

PLANNED ACTIVITIES

The planned activities for bench-mark experiments are reported in Table 3.
Contacts have been made in order to obtain irradiated fuels from the Doel power station.

COLLABORATION WITH EXTERNAL ORGANIZATIONS

Collaborations have been established with ENEL (Italy), KRB-Gundremmingen (FRG), KWO-Obrigheim (FRG), KWU-Frankfurt (FRG).

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TABLE 1 - TRINO-1 (2.719%) Comparison between one-group cross section ratios computed with THEORY and given by ENEL

	THEORY	ENEL B.U. = 0	ENEL B.U. = 12,360 MWD/TU
$\bar{\sigma}_a^{28}/\bar{\sigma}_a^{25}$	0.0184	0.0168	0.0173
$\bar{\sigma}_c^{28}/\bar{\sigma}_a^{25}$	0.0160	0.0149	0.0154
$\bar{\sigma}_a^{49}/\bar{\sigma}_a^{25}$	2.737	3.16	2.90
$\bar{\sigma}_c^{49}/\bar{\sigma}_a^{25}$	1.166	1.175	1.065
$\bar{\sigma}_a^{41}/\bar{\sigma}_a^{25}$	3.817	2.82	2.72
$\bar{\sigma}_c^{41}/\bar{\sigma}_a^{25}$	0.748	0.715	0.690
$\bar{\sigma}_a^{42}/\bar{\sigma}_a^{25}$	1.013		
$\bar{\sigma}_c^{25}/\bar{\sigma}_a^{25}$	0.196	0.190	0.190
$\bar{\sigma}_a^{25}/\bar{\sigma}_a^{25}$	0.290	0.175	0.151
N_o^{26}/N_o^{25}	0.0105		

TABLE 2 - TRINO-2 (3.13%) Comparison between one-group cross section ratios computed with THEORY and given by ENEL

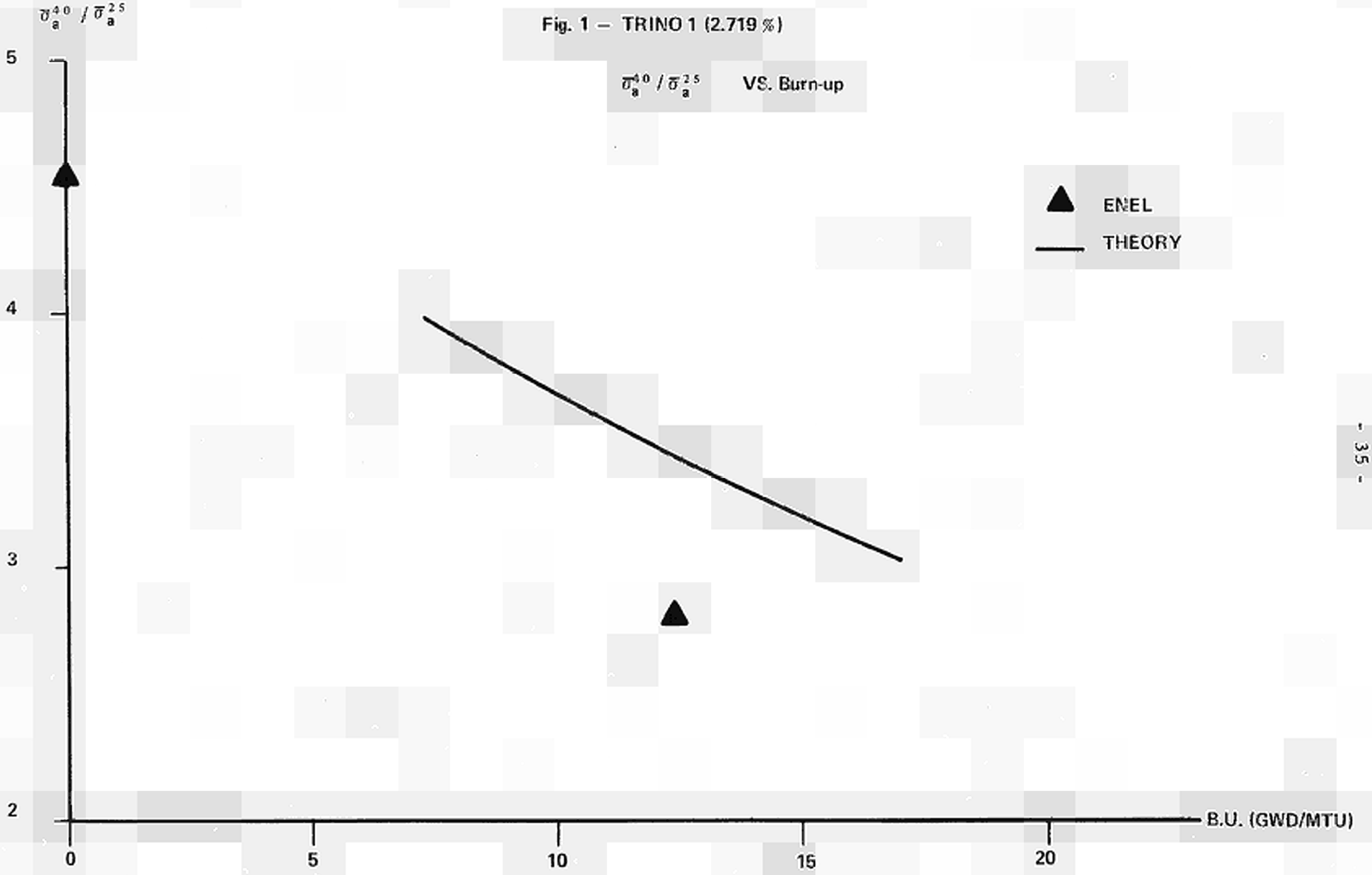
	THEORY	ENEL (B.U. = 0)
$\bar{\sigma}_a^{28}/\bar{\sigma}_a^{25}$	0.0204	0.0193
$\bar{\sigma}_c^{28}/\bar{\sigma}_c^{25}$	0.0180	0.0173
$\bar{\sigma}_a^{49}/\bar{\sigma}_a^{25}$	2.646	3.191
$\bar{\sigma}_c^{49}/\bar{\sigma}_a^{25}$	1.184	1.186
$\bar{\sigma}_a^{41}/\bar{\sigma}_a^{25}$	3.807	2.835
$\bar{\sigma}_c^{41}/\sigma_a^{25}$	0.775	0.720
$\bar{\sigma}_a^{42}/\bar{\sigma}_a^{25}$	1.398	1.021
$\bar{\sigma}_c^{25}/\sigma_a^{25}$	0.209	0.190
$\bar{\sigma}_a^{26}/\sigma_a^{25}$	0.294	0.180
N_o^{26}/N_o^{25}	0.007	

TABLE 3 - Planned Activities for Bench-Mark Experiments

	1977	1978	1979	1980
A. Experimental Post-Irradiation Analyses	16 samples Gundremmingen			
	27 samples Obrigheim			
		28 samples Trino III		
			Samples from Doel I, II and III	
B. Elaboration of Experimental Data	DATA ANALYSIS IN TERMS OF CROSS SECTION RATIOS			

Fig. 1 — TRINO 1 (2.719 %)

$\bar{\sigma}_a^{40} / \bar{\sigma}_a^{25}$ VS. Burn-up



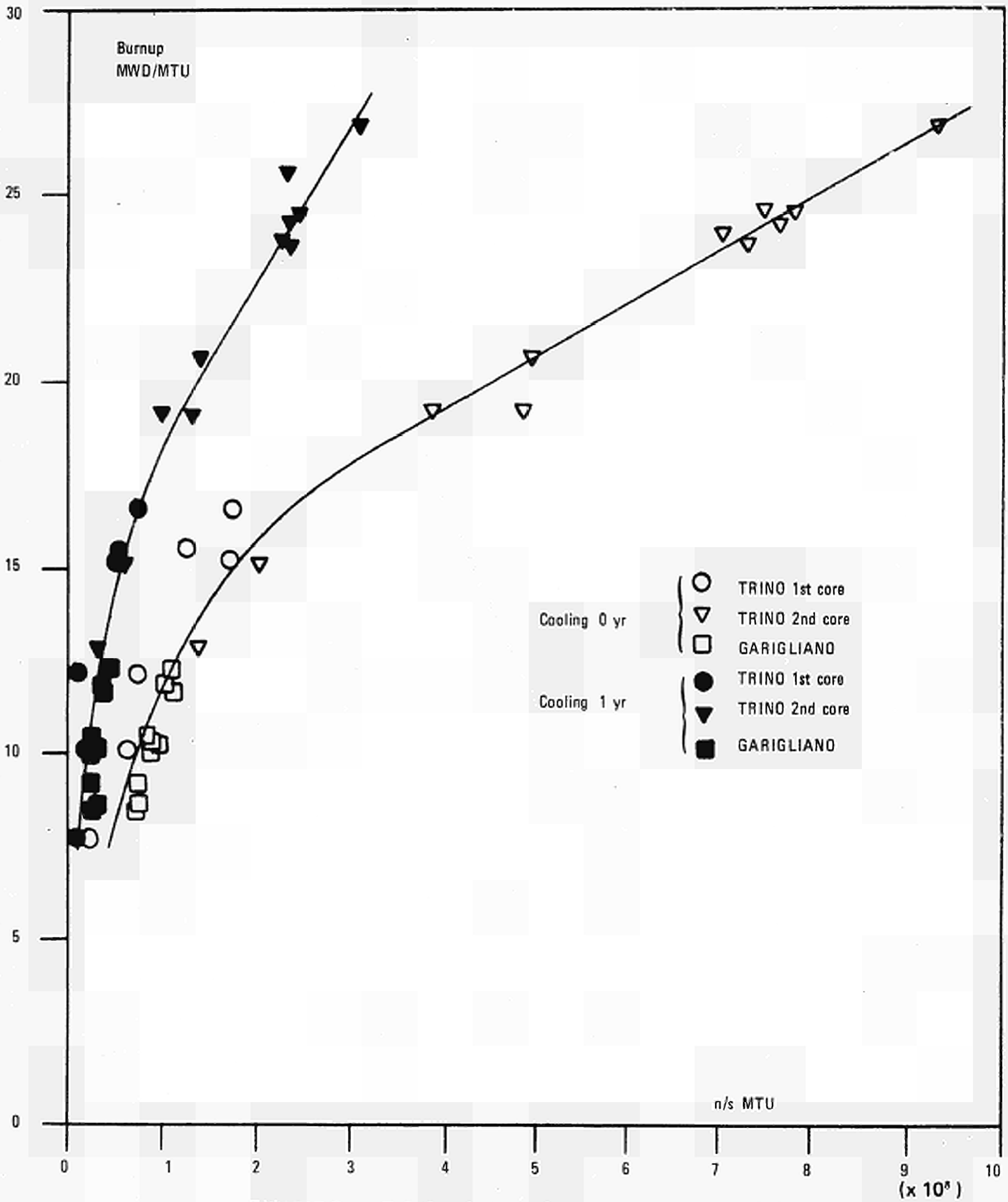


FIGURE 2 — Relations between burn-up and neutron emission

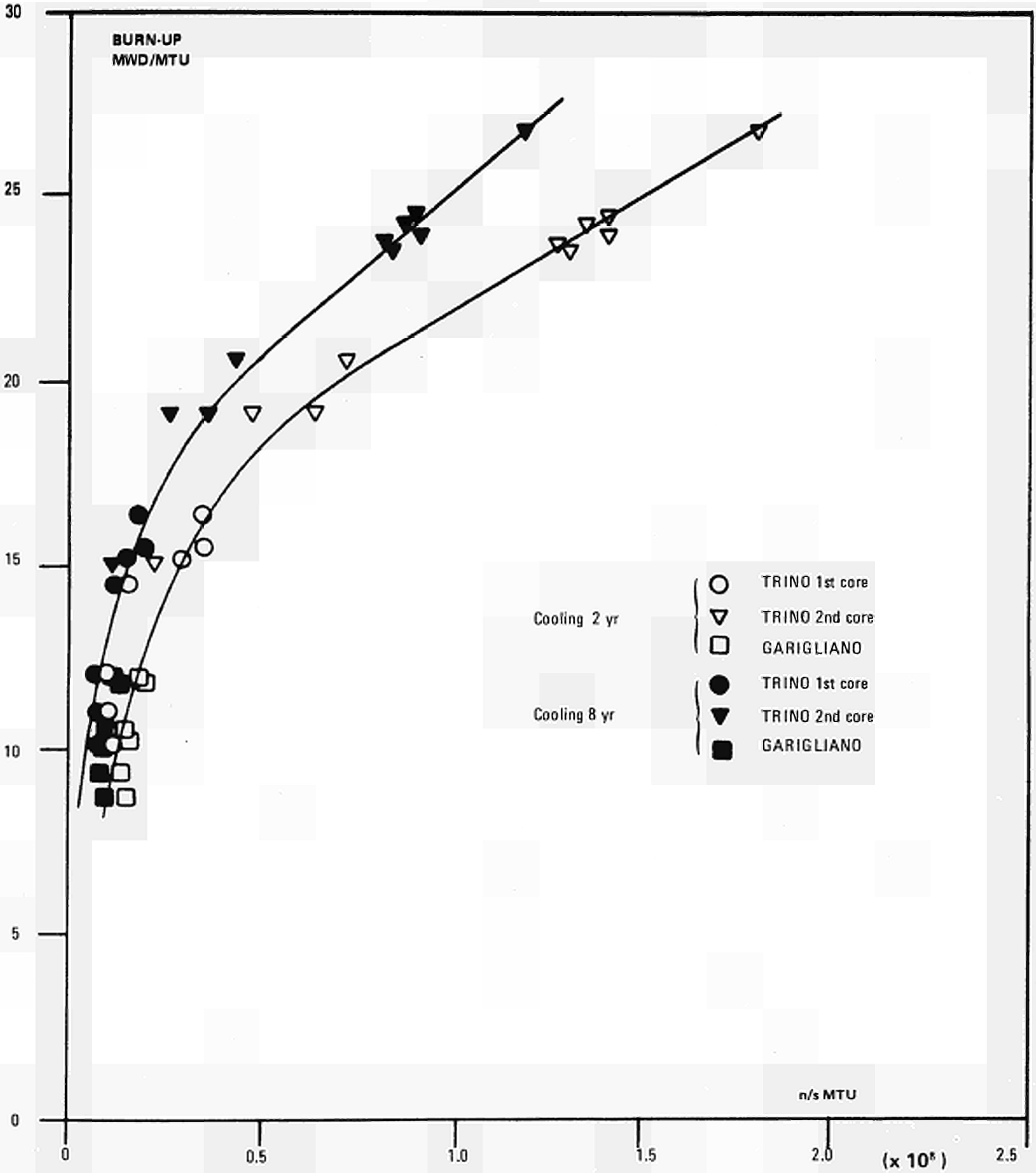


FIGURE 3 — Relations between burn-up and neutron emission

2.4 NON-DESTRUCTIVE ASSAY OF FISSILE ISOTOPES

OBJECTIVES

During 1976 an analysis of the fuel fabrication cycle has been made with the scope to identify the needs of application of NDA techniques. This analysis, which has to be continuously updated in strict contact with plant operators and inspectors of the Safeguards Directorate, has permitted to establish a number of priority actions.

Our major fields of activity are the following:

A. Standardization of methods and physical standards in view of making the work performed within EEC acceptable outside

B. Development of NDA methods, oriented to the final installation of important equipment in field, redesign or adaptation of existing equipment and finally feasibility study of certain techniques

C. Development of instrumentation with a special emphasis on the automation of existing equipment and its direct data treatment using microprocessors

D. Direct support to the Safeguards Directorate of Luxemburg, which results in a series of very specific actions on the calibration of certain instruments, maintenance of equipment or the preparation of project design of small equipment.

RESULTS

A. Standardization

Standardization in NDA is intended here as:

1) the standardization of NDA methods, including the study of their acceptance criteria at different technical levels;

2) the preparation and characterization of physical standards.

1) Standardization of NDA Methods

The need of standardization of NDA methods has been expressed very clearly in Europe and the USA and at the IAEA for fissile material management and Safeguards reasons.

A literature survey has been made on the effort spent in the world in the standardization of the NDA methods and on the definition of physical standards needs. A draft paper on the actual status in the field of standardization is now completed and will be finalized before November, 1977. From here conclusions should be drawn for the JRC programme how to distribute the effort in this field.

The JRC participates in the ESARDA working group on NDA. In the framework of this participation, one of the actions completed by the

JRC during the reporting period is the compilation of a list of NDA reference materials available within the EEC and at the IAEA (data made available by the individual partners of ESARDA and by IAEA observers in the working group). Two draft versions were circulated and the final paper will be ready before the end of July, 1977.

Within the framework of ESARDA, the JRC made available to the working group a description of the NDA methods developed at Ispra and of the methods used by the Safeguards Directorate of the Commission. A compilation of all NDA methods used within the EEC, prepared by UKAEA representatives, will be available in October, 1977.
The two above mentioned compilations are important inputs for the definition of the future work at Ispra in the field of standardization.

Finally, a JRC representative was invited by the IAEA in a consultants' meeting to prepare a document on "Use of Physical Standards in Inspection and Measurements of Nuclear Materials". This document will serve as a basis of discussion for a larger meeting between representatives of the Member States on the same subject to be held in August, 1977, in Vienna.

During the next reporting period it is intended, if the manpower is made available, to start a systematic study of the existing certification mechanism for physical standards and NDA methods within and outside Europe (IAEA, INMM, ISO, National Normalization Institute).

2) Preparation and Characterization of Physical Standards

The NDA laboratory of the JRC is now very much involved in the acceptance process of low enrichment uranium (LEU) standard fuel pins of three enrichments prepared by a fuel fabrication plant (FBFC, Belgium). The three pins will be used by the operators for their quality control and by Euratom and IAEA as a physical standard for verification. The laboratory of NDA of the JRC has assisted to the preparation of the three reference pins plus 17 other test pins and has performed gamma-spectrometric measurements on the feed material (UO_2 powder), the pellets and all the pins. The measurement procedure was previously submitted to the IAEA. On the basis of these measurements the general acceptance of the pins as standard is expected.
A detailed documentation of these measurements, requested by Euratom and IAEA, is to be prepared before the end of the year.

In the framework of the ESARDA working group on NDA, a proposal was made by the JRC in collaboration with the GfK and CEN, to acquire and to characterize very carefully uranium oxide powder batches of 5 kg, having each a different enrichment (between 1 and 4%). This material will serve as a physical standard for the enrichment measurement by gamma-ray spectrometry. The JRC is now going to buy the material from a fabrication plant and to implement, in collaboration with CBNM (JRC-Geel) and other national centres, the characterization method described in the proposal.

A one year effort, after receipt of the material, is expected to reach the final stage of the establishment of this physical standard. The NDA laboratory has to perform, hopefully from November on, the analyses by gamma-ray spectrometry of 200 samples with an error of less than 0.4%.

The NDA laboratory obtained 500 g of well characterized UO_2 powder and 50 pellets from the ECSAM group (European Commission Safeguards Analytical Measures). This material will serve in the future as a secondary standard for the enrichment measurements by gamma-ray spectrometry.

B. Development of Measurement Methods

As a consequence of the formation of a new group which has to treat problems related with the utilization of neutron techniques for fissile material determination, the first three months of the reporting period were devoted to the establishment of a new laboratory and to formation courses of the new personnel.
After a detailed examination of the fuel cycle and more particularly of the fabrication plants and on the basis of the specific requests made by the Safeguard Directorate and by plant operators, a number of actions were started for the construction of new NDA instrumentation and for the establishment of the calibration procedures of existing instrumentation for a large variety of nuclear materials.

1) Neutron techniques

Three existing instruments are under study:

- Photo-neutron interrogation device (PHONID) using an Sb-Be source
- Random driver, both utilized for the analysis of bulk material during physical inventory taking in fabrication plants
- Sigma

- PHONID (Sb-Be source)

This instrument is based on the subthreshold neutron interrogation (~26 keV) of large size uranium samples (typically 100 g to 1.5 kg) and prompt fission neutron counting by an array of 18 He^4 recoil detectors.
After a long interruption of activity, due to staff problems, the prototype instrument has been made operational in a nuclear fuel fabrication plant and has been used during physical inventory taking. Several measurement campaigns were organized to define the geometry of the two irradiating sources and to install a system for more reliable operation of the neutron detectors and electronics under the existing plant conditions (large temperature variations and high de-

gree of humidity).

A further run of experiments started with the purpose of calibrating the device for its final use by inspectors, namely to establish the relationships between corrected neutron counting and amount of U-235, for the different materials dealt with in a nuclear fuel fabrication plant. In this framework materials have been measured such as highly enriched uranium metal, highly enriched uranium and thorium mixed oxide, uranium aluminium compounds, the contents of the U-235 in the samples being in the range from 50 g to 1500 g.

The preliminary results confirm the validity of the method under the condition that specific calibrations, U-235 mass versus counting, are established for each kind of nuclear material.
A detailed analysis of the calibration curves is now being made and a report will be issued in September, including the procedure of operation of the machine by safeguards inspectors.

The need of U-235 standards must be emphasized, in order to be able to normalize the experimental conditions, pulse height discrimination threshold, detection efficiency, source strength decay, irradiation geometry, etc.

At the same time the experience acquired during the operation of the prototype device has been utilized in defining the specifications of a more advanced device which is under design at present.
The accurate study of this new version will lead to more automatic operation, higher stability in the physical features, better protection of the operator against gamma and fast neutron radiations.

The construction of this device is expected to start at the end of 1977. The final choice on the electronics to be utilized will be made before November, 1977.

- Random Driver

This instrument (USA fabrication) is based on the subthreshold neutron interrogation (Pu-Li source) and prompt fission neutron counting with four plastic scintillators. The discrimination between source and fission neutrons is based on coincidence counting. The utilization of this instrument by the Safeguards Directorate has proved to be unsatisfactory, due to some basic malfunctioning of the electronics and of the detection heads. Comparative tests were made between different electronic chains.

Furthermore experiments are now being performed to measure the relative counting efficiencies of the different detectors and also its relative efficiency in function of the location where the interaction of the radiation with the detector takes place.

On the basis of this information a decision has to be taken what effort in manpower and budget should be spent to make the apparatus functioning. It is expected that in September a proposal will be ready to be submitted to the Safeguards Directorate for approval.

- Sigma

The Sigma apparatus, installed at Hobeg for the control of the U-235 content in THTR and AVR fuel pebbles, has been adapted for the analysis of LEU powders and pellets. It is based on the thermal neutron interrogation of the sample and delayed neutron counting. Tests were performed to establish the optimum sample size in function of the enrichment. It results that with a ~20 g sample of UO_2 one may determine the U-235 content with an error of 1% in one minute. This method will now be applied by inspectors for routine measurements on LEU material. The final report on these experiments will be issued before the end of the year.

Neutron techniques utilize mostly BF_3, He^3, He^4 and plastic scintillator detectors. As an extention of the formation course on neutron techniques, a more systematic study was made for the determination of the counting characteristics of BF_3 and He^3 detectors. At the same time a test chain was mounted and will be kept for the systematic control of all new detectors in respect of resolution and relative efficiency.

2) Gamma Techniques

Gamma techniques have been applied on mixed oxide $(U, Pu)O_2$ and LEU material. Concerning the LEU material one has to refer to point A. on the characterization of fuel pins.

- Mixed Oxide Materials

A large effort was put on the determination by gamma-ray spectrometry of the relative Pu-239/241, Pu-239/238 and Pu-239/240 mass ratios in fuel pins. The systematic study for the choice of the photopeaks in the spectrum, the determination of the relative efficiency curves was continued for fast reactor and thermal recycle fuel pins. The results show that, for consistency checks between a number of pins of the same physical characteristics, the relative Pu-239/241 ratio can be determined with an error of ~0.5% in 10 minutes using a 10% Ge(Li) detector. The absolute Pu-239/241 ratio can be obtained with an error of 1-2% in a 30 minutes counting using the same detector.

These data have been tested on 10 different fuel pins for fast reactor and thermal recycle fuel. The detailed working procedure for the assay of Pu-239/241 is now under preparation, together with the instrumentation for these measurements. As to the Pu-239/238 and Pu-239/240 ratios, the analysis of the data is more difficult due to the complexity of the peaks originated by the Pu-238 and Pu-240 isotopes. The error in the determination of those ratios vary between 5 and 25% depending on the sample type. A detailed analysis of the gamma spectrum above 500 keV is going on now. It is also planned to apply a more sophisticated gamma-spectrum analysis programme, before the end of 1977, in order to improve the results.

A major difficulty encountered in this study is the obtaining from NBS and CBNM of reference material of know isotopic composition for plutonium. A university thesis was prepared on the "Détermination de la composition isotopique du plutonium par spectrométrie gamma".

C. Development of Instrumentation

1) Study on the Microcomputer Development System

As the trend in electronic instrumentation goes towards an ever increasing usage of microprocessors and more and more sophisticated data processing is required for the purposes of the Fissile Material Control Programme, the availability of powerful and new means becomes a must for an efficient development of both hardware and software. The problem has been solved by the purchase of an Intel MDS-800 Microprocessor Development System. We experienced the powerful resources of the machine especially concerning the Diskette Operating System (DOS) and the In-Circuit Emulator (ICE). The operating System ISIS-II with relocation and linkage capability allowed us to develop independent program modules organized in libraries which can be used in future programs. In particular a floating point mathematical library has been organized from our previously designed absolute routines with the addition of new ones.

In-circuit Emulator was used in debugging the new software for the microprocessor-based gamma-scanning system (see below).

2) Automation of Gamma-Spectrometry

New features have been added to our Microprocessor-based gamma-scanning system: magnetic cassette recording and x-t chart recording. The design of the complete equipment involved both hardware and software.

Hardware consists mainly of a 4 K ROM memory module that has been assembled to allocate the new programs.
Software contains principally the two following items:

- A Cassette Operating System. This program, called CASIS (Cassette Software Implementation System), supervises the data transfer between the microcomputer memory and the magnetic tape. Either energy spectra or activity profiles can be stored; words are accordingly grouped with different formats. Data are organized in files. A track directory allocated on the tape itself, makes it possible to search automatically a specified file. Each of the three tracks of the tape can allocate up to 50 spectra or 130 activity profiles.

- A Chart Recorder Handler. It transfers all or part of the micro-computer data memory on the x-t plotter. Scaling on both axes is provided.

A Double Threshold Digital Integrator has been assembled and will be tested soon. A new program which handles this module has also been developed. It will be loaded in the system as soon as the micro-computer which is now being utilized by the Chemistry Division people, will be available. We emphasize the fact that the improved system will be able to detect fuel non-homogeneity both under and over the normal activity profile.

3) Automation of SIGMA Equipment

The design of an automated version of the machine now operating at Nukem, has been started. The use of a microprocessor is foreseen for controlling the measurement and processing data. Some software modules have been already developed, among which: a calibration routine based on a third degree polynomial least square fitting; an expansion of the mathematical library including log, exp, 4x4 linear system.

D. Direct Support to the Safeguards Directorate

Several requests were made by the Safeguards Directorate for the calibration of instruments:

- Sigma with the new set of Cf-252 sources,
- Gamma-ray detection chain for Pu-239/241 determination on thermal recycle fuel,
- Sam-2 dual channel analyzer for the enrichment measurement of UO_2 pellets.

Several mechanical parts have been designed in connection with the use of NDA instrumentation and cameras by the Safeguards Directorate.

CONCLUSIONS

The description of the work performed shows clearly that most of the work is oriented to very specific actions in view of the implementation of NDA in plant conditions for direct use by the Safeguards Directorate. The emphasis on these actions may be explained by the fact that Safeguards under NPT started in the EEC countries in April 1977 and that its implementation imposes an important work load very specific, including an important effort to make, at the technical level, the proposed solutions acceptable to the IAEA.

As a consequence, the time schedule for the major planned objectives, which were oriented to the elaboration of standardization schemes for NDA and the systematic study of NDA methods (gamma-technique for enrichment and Pu isotopic composition), had to be modified.

The work for the application of NDA methods more specifically for control purposes (Sb-Be, preparation of standard LEU pins, Random Driver study etc.) and the direct support to the Safeguards Directorate, as mentioned in section D., increased very much during the last three months and will continue during the rest of the year.

PLANNED ACTIVITIES

The planned activities in the four major fields described earlier are:

A. Standardization

1) Preparation of a final report on the international activities in the field of NDA standardization: November 1977

2) Completion of the compilation of physical standards in the EEC and IAEA: July 1977

3) Final discussion at IAEA, together with Member State representatives, of the paper on "Use of physical standards in inspection and measurement of nuclear material": August 1977

4) More effort on the study of the certification mechanisms of NDA after comparison of existing schemes.

5) Preparation of the final report on the characterization of LEU fuel pins: December 1977

6) Start of the characterization of uranium oxide powder: November 1977

7) Characterization of SNEAK platelets: starting October 1977

8) Characterization of mixed oxide fuel pellets and fuel pins at Belgonucléaire; experiments in September, data treatment finalized December 1977.

B. Development of Measurement Methods

1) Calibration procedures for a number of highly enriched uranium materials to be finalized by October 1977

2) Project design of the mechanical part for a new version of Sb-Be will be completed in December 1977

3) Random Driver modification proposal: September 1977

4) Final report on calibration procedure of Sigma and its use for uranium determination in powder and pellets

5) Completion of characteristics study of BF_3 and He^3 detectors

6) Test, calibration and preparation of working procedure for various passive neutron counting heads for Pu fuel pins and bulk materials with VDC system

7) Study of a portable passive neutron detection system and of a small sample assay system by active neutron interrogation. Design data will be available in November 1977.

8) Preparation of a working procedure for the determination of Pu-239/241 ratios in fuel pins: October 1977

9) Intercomparison of passive neutron counting and gamma-scanning for fast reactor Pu fuel pins (experiments in September 1977)

10) Implementation of a new gamma-spectrum analysis programme: December 1977.

C. Development of Instrumentation

1) Study of PL/M high level language

2) Test of Double Threshold Digital Integrator and software driver (end of 1977)

3) Hardware design of microprocessor based system (end of 1977). Preliminary development of software package, including magnetic cassette handler

4) Design and test of a breadboard containing timer circuitry (October 1977).

D. Direct Support to the Safeguards Directorate

1) Working procedure on the utilization of the Sam-2 equipment for LEU powder, pellets and pins will be written (September 1977) and formation courses addressed to inspectors will be given for these instruments (dates to be defined)

2) Design projects for mechanical hardware will be continued.

Ispra Courses

In October 1977 a one week course on the application of NDA techniques will be given by the NDA laboratory staff.

COLLABORATION WITH EXTERNAL ORGANIZATIONS

As was already mentioned earlier, most of the activity is now performed in support and in collaboration with the Safeguards Directorate of the Commission. In the field of standardization, actions are undertaken in the framework of the ESARDA association and of a collaboration contract between CEN, Belgonucléaire and the Commission.

2.5 DESTRUCTIVE ASSAY OF FISSILE ISOTOPES

OBJECTIVES

The activity aims at the development and research in the field of destructive analytical chemistry of the fuel cycle. A considerable effort is also spent in support to the Safeguards Directorate.

The activity includes the following areas of work:

A. Analytical support to the Safeguards Directorate

B. Evaluation of operators measurement methods

C. Automation of Mass Spectrometry

D. Setting up of a transportable mass spectrometer

E. Calibration of Input Accountability Tank of reprocessing plants.

METHODS AND RESULTS

A. Analytical Support to the Safeguards Directorate

Control analyses on routine basis are to be performed for safeguards purposes. The methods routinely used include surface ionization mass spectrometry, controlled-potential coulometry, potentiometry, spectro-photometric methods and especially developed subsampling devices.

On request of the Safeguards Directorate a number of control samples, taken by the inspectors for verification purposes, were analyzed on a routine basis in the laboratories of Karlsruhe and Ispra.

The analytical work required for the preparation of reference U-Al cores (MTR fabrication) was completed and a report is in preparation.

The participation to ECSAM* activities continues and the most recent result was a common procedure for data handling of verification measurements (doc. ECSAM 30). A collection of analytical methods applied to the analysis of fissile materials in the JRC-laboratories is in progress.
The two subsampling devices for UF_6, ordered by the Safeguards Directorate, are approaching their completion.

B. Evaluation of Operators Measurement Methods

Analytical measurement methods, used by the operators, must be "latest international standard or equivalent to it". For this reason the Design Information, forwarded by the operators to the Safeguards Directorate, are reviewed critically.
The information taken from the Design Information is compared to the rele-

*ECSAM (European Commission Safeguards Analytical Measures), working group on Safeguards analytical problems, formed by the analytical laboratories of Geel, Ispra and Karlsruhe and by the Safeguards Directorate.

vant literature. The operator's laboratory is to be inspected and the scientific staff to be interviewed.
Demonstrations of measurements on reference samples are yielding further elements for critical evaluation.

The first document, including a general philosophy and definitions of the aims of this work and an evaluation of Nukem analytical methods, has been completed.
The second operator, Alkem, has been visited, the staff interviewed and the appropriate document is currently in progress.

Design information of the next operator, Dounreay, UK, has been studied and the laboratory is to be visited during July.

The method chosen seems suitable for achievement of the elements necessary for evaluation in many cases. Sometimes, however, progress of work is somewhat hampered by extremely poor design information available.

C. On-line Data Evaluation Used in Automatic Mass Spectrometric Isotope Dilution Analysis of Nuclear Fuels

The production of nuclear energy is accompanied by a genesis of new nuclides leading to a steady change in the isotopic abundance of elements involved in the process. The isotopic content in the fuel has to be known for several reasons: reactor operation, safety, economics and safeguards.

Mass spectrometry is the predominant tool in isotope analysis. Radiometric techniques (alpha- and gammaspectrometry) are of less importance. The high sampling frequency of nuclide inventories as well as the small batches of the fuel (for criticality reasons) lead to a large number of samples to be analyzed. This justified the development of an automatic laboratory, AL*.

The AL consists of two modified CH-5 Varian Mass Spectrometers each controlled by a Varian 620 computer. One of the instruments is equipped with an automatic lock for continuous sample feeding. The instrument has been described [1, 2]. Two automatic alpha-spectrometers supplement the mass spectrometric isotope analysis and an automatic balance is used to measure aliquots of spikes and samples for isotope dilution analysis.
The data handling is completely automatic. Mass spectra data are reduced directly by the Varian Computers to isotopic ratios before being collected by a PDP 11/10 computer. Weights (of the isotope dilution) and alpha-spectra are fed directly to this computer, which then transmits all information for evaluation to an IBM 370 (fig. 1). The type of analysis, characteristics of the sample, addresses of measured data are filed via a terminal prior to the analysis and determine the analysis matrix which indicates the expected data. As soon as the matrix has been filled, the evaluation which comprises the usual operations described earlier [3], starts automatically.

* The work was sponsored by the German Project Spaltstoffflusskontrolle of the Kernforschungszentrum Karlsruhe.

The on-line data evaluations are just recently in operation and are still under test. Several interfaces coupling the computer and the instruments had to be developed.

The set-up described is the final step of a long development. The advantage of the AL with regard to higher sample throughput, faster analyses and lower costs have been demonstrated. The on-line data handling gives, in addition, data security and the confidentiality required in nuclear material safeguards.

D. Setting up of a Transportable Mass Spectrometer

The objective of the first part of the work was to realize the possibility of an ion source capable of generating ions from samples in solution with its coupling with quadrupole mass spectrometer. This is important for the analysis of solids or species present in solutions originating from nuclear fuel cycles, and to enhance the capability of Safeguards verifications.

The work consisted of designing and construction of the ion source along with its sample feeding system. The system involves the formation of a capillary arc plasma in a containment of appropriate materials with the possiblity of controlled flow of argon gas at various inlet-outlet points. The feed system is either nebulizers (both pneumatic and ultrasonic) or direct evaporation of solid material under the influence of an electric potential.

Both the above mentioned systems were designed and constructed in our laboratory and are now undergoing preliminary trial runs. Preliminary results have indicated that the plasma ion source is generating plasma in a satisfactory manner with argon.

Better performance is expected with a few modifications in various auxiliary systems. The solid evaporation system has been tested with standard copper-nickel alloys and found to work appropriately.
Further results are expected in due course of time.

E. Calibration of Input Accountability Tank of Reprocessing Plants

The objective was to evaluate the methods of volume/weight calibrations of the Input Accountability Tank and to suggest the modifications for higher accuracies. Another objective of this work was to review the existing techniques of sampling and analysis applied at the Input Accountability Tank of the reprocessing plants for the accurate control of the fissile material.

For improvement in the accuracy of calibration of the Tank, experiments are to be performed at the reprocessing plant. For this purpose the results of routine methods calibration obtained with conventional techniques are to be compared with those obtained by isotopic dilution mass spectrometry with Li, Mg and deuterium. Appropriate modifications at the plant could be suggested for this purpose.

Review studies of various techniques and their respective evaluation are in progress. Also procedures and evaluations for the calibration techniques are under evaluation.

CONCLUSIONS

In general, the achievements during the reported period are in agreement with our planning.
However, considerable difficulties are expected for the next period due to the financial situation and to a staff reduction. Delays will be introduced mainly in the activity on the transportable mass spectrometer.

PLANNED ACTIVITIES

A. Analytical Support to the Safeguards Directorate

Besides the continuing activity in support to the Safeguards Directorate, the methodology for the UF_6 concentration and isotopic measurements methods will be reviewed.

For future routine analysis of UF_6 the most suitable methods will be selected and experimentally verified.
The completion of the UF_6 subsampling devices, is foreseen for the end of October 1977.

The construction of two further devices for other external organizations is foreseen.

B. Evaluation of Operators Measurement Methods

Before the end of the year the documents concerning the German plants and one or two UK plants will be completed. The single documents are then to be revised by a group of JRC specialists and the final judgements forwarded to the Safeguards Directorate.

C. Automation of Mass Spectrometry

Development of interfaces coupling the computer and the instruments.

D. Setting up of a Transportable Mass Spectrometer

The plasma source is to be tested for a large number of samples of diverse nature to establish its validity. Preparations are underway to use the pneumatic and ultrasonic nebulizers as feed systems for solutions. Design and construction of the coupling intermediating system is to be performed soon. This matter has been discussed and cleared with the manufacturers of the quadrupole mass spectrometer. Part of this work is expected to be presented in the Mass Spectrometry Conference, to be held in Catania in September this year.

E. Calibration of Input Accountability Tank of Reprocessing Plants

Experiments will be performed at the input accountability tank of Eurex reprocessing plant, using Li, Mg and deuterium tracers. The procedures will be standardized in the light of the results obtained for these experiments. The calibration values will be compared with those obtained with physical methods.

COLLABORATION WITH EXTERNAL ORGANIZATIONS

The activity for the automation of mass spectrometry is carried out in collaboration with the German Project Spaltstoffflusskontrolle of the Kernforschungszentrum, Karlsruhe.

A collaboration has been established with the Eurex plant (CNEN, Saluggia) for the study of the calibration of Input Accountability Tank.

REFERENCES

[1] KOCH, L., et al. 7th Int. Mass Spectrometry Conference, Florence. August 30 - September 3, 1976

[2] WILHELMI, M. et al. EUR 5504, 1977

[3] BRANDALISE, B. EUR 5669, 1976.

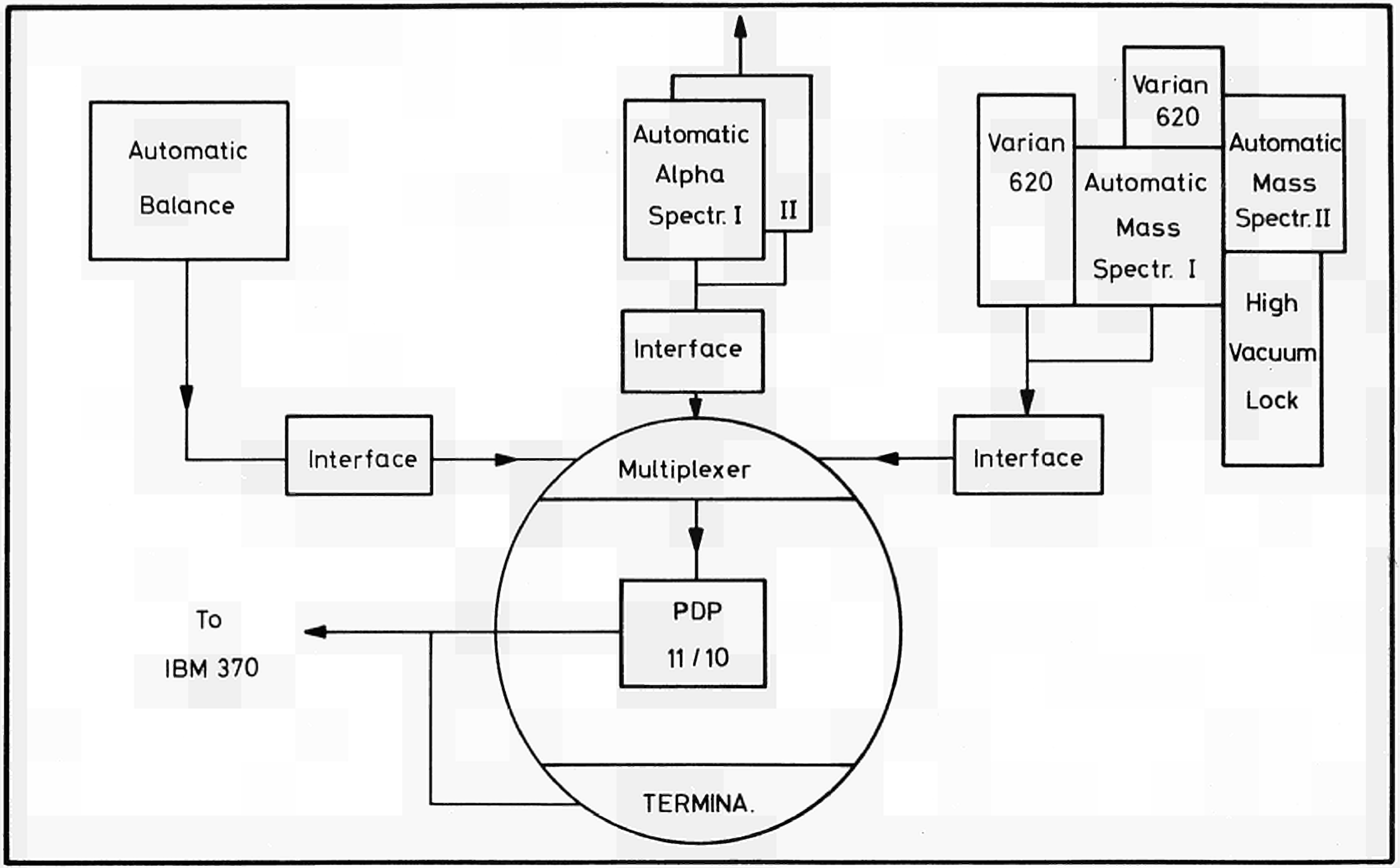


Fig. 1: Automatic On-Line Data Evaluation

2.6 SURVEILLANCE

OBJECTIVES

The activity of the first half of 1977 was mainly focused on five main topics:

- Portable identification equipment and new identification method, using electronic scanning instead of mechanical scanning
- Completion and improvement of the seals to be used for CANDU spent fuel
- Completion of the 5-years experiment on BWR fuel bundles sealing and preparation of a more general work concerning LWR bundles sealing
- Definition of the identification methods requested by KFA, Jülich on:
  - . AVR spent fuel containers,
  - . TRIGA (München) element identification
- Seals identification for the Safeguards Directorate of the Commission.

METHODS AND RESULTS

1.) General Remarks on the Portable Equipment (figs. 1 and 2)

The electronic developments enable now to define the identity of most of the ultrasonically identified seals without any mechanical scanning.

The portable apparatus, built at Ispra will be industrialized by Nukem (Germany) and, besides the electronic scanning of the seals, will have the following advantages:

- digital output,
- automatic gain control.

Electronic scanning simplified all the seals identification procedures in reactor or reprocessing pools. The tools to be used in plants will now be very simple.

The reliability of the identity made using the new method has to be improved by changing the design of the seals. The new designs are leading to cheaper and easier usable seals.

Mechanical and electronic scannings are described in figs. 3 and 4.

2.) Portable Identification Equipment (SIPE 1)

Figs. 1 and 2a show the equipment. The use of it is easy: when the key number is put on the digit switches (number to be known for each type of seal: general use, cap seals, rivet seals), only two actions are to be done:

- power on,
- press start measurement button.

Automatic gain control and automatic search of the first echo (independent of distance between seal and transducer and of material of the seal: plastic, steel, aluminium) are shown in figs. 5 and 6 for each type of scanning chosen and defined by the last figure of the identification key number.

The digital output is given on the small printer of a pocket computer (fig. 2b). The identity (suite of 3 or more numbers of two figures AB, CD, EF) could easily be recorded on a compact cassette recorder.

Reproducibility of the identity at the present time and in most cases:

AB $\pm$ 1, CD $\pm$ 1, EF $\pm$ 1.

3) <u>General Use Seal Identification</u>

The previous design of the seal is shown in ref. [1].
The new design of the seal is shown in fig. 7a. Assembling of the two parts is made on the spot by glueing.

Identification is done on the spot without (or with) removal of the seal. The "contact transducer" is made of a flat transducer corrected and centered in a reference system (fig. 7b). Duration of the identity defining: 2 sec.
Coupling is effected by a small amount of oil or water between the seal and the lens.

4) <u>Cap Seal Identification</u>

The previous design of the seal, using powder metallurgy is given in references [1] and [2].
Using brazing methods for the fabrication of seals, the design is simplified and the price of the seal is much lower.

All previous mechanisms, shown in ref. [1] and [2], to be used either at the headquarters or in the plants, in the very near future, will be simplified. Relating mechanisms are not necessary any more. A scheme of the identification device is shown in fig. 8.

The criticisms against these cap seals, up till now, are:

- possible vibration,
- use of sintered material containing tungsten,
- modification to be made on the extremes of the tie-rods (low cost, if made on all fuel bundles),
- extraction of the seal for identification in the non-active part of the cycle,
- handling of rather complicated tools for verification of the seal in the irradiated part of the cycle.

The new design we try to introduce (collaboration with Exxon Nuclear Company), the fabrication procedure using Nicro-Brass and the identification without mechanical scanning of the seal eliminate the weak points (all, except the third point).

5) Rivet Seal for MTR Bundles

Previous identification procedure is reported in ref. [1]. Since 1976 the identification is made as shown in fig. 9. This enables the identification of seals on irradiated fuel bundles staying in the pool without removal of the seal, as shown in ref. [2].

The future identification method will be the same as for general use seals or cap seals. The global identity will be made without mechanical scanning (fig. 10). This requires the suppression of the first echo (fig. 4), due to the very small thickness of the seal.

6) T.U.I.D.

Tamper resistant unique identification devices such as the one used for the Kalkar SNR 300 bundle identification proposal, ref. [2], should also be modified for what concern their internal marking in order to enable the global identification without mechanical scanning. A simple contact transducer, nearly the same as the one used for general use seals (fig. 7b) will be used.

7) Other Specific Seals

Other specific seals to be used with or without safety wire for spent fuel bundle storage (collaboration with Atomic Energy Canada Ltd.), spent fuel containers (proposal for AVR), plutonium boxes, safeguards equipments to be made tamper-resistant, will be designed following the new method.

8) Collaboration with AECL (Canada)

AECL needs to develop a Safeguards system for CANDU reactors. An agreement was signed between AECL and Euratom for the development of a seal for underwater application to verify the storage of the CANDU fuel bundles in the pool.

The Euratom task in this context was to provide seals together with seal application tool and scanning plus recording equipment necessary to identify uniquely each seal.

The draft report on the collaboration [3] states that:

"The equipment demonstrated that it is practical to install and verify seals, with an ultrasonic identity, under water in a spent fuel storage bay. The signature obtained ultrasonically is adequate for establishing the unique identity of a particular seal."

If the IAEA agrees, the technique will be included in the Safeguards system developed by IAEA-AECL for the CANDU reactor type. A new design of seal was proposed for easier sealing provided that the fuel trays are prepared for the sealing procedure. This new cap seal will be included in the final report on the collaboration.

9) BWR Fuel Bundles Sealing

In 1972, four fuel bundles were sealed with two seals each in two German reactors:

- KWL, Lingen,
- KRB, Gundremmingen.

As those fuel bundles had reached the maximum burn-up, the seals were detached this spring. The reidentification and correct observation of those seals have still to be made at Ispra in hot cell, but some conclusions could be drawn already:

- the mechanical fixation of the seal on the tie-rod is good enough; vibration could not detach the seal
- the external aspect of the seals after 5 years in the reactor is good
- the extraction of the seal was difficult for two seals due to the crud (too narrow tolerances of the extraction tool) and one seal was destroyed during extraction.

If new seals have to be used, powder metallurgy will not be the fabrication process any more, the brazing method demonstrates to be much better for:

- ultrasonic identification,
- fabrication cost,
- mechanical resistance,
- shape of the seal.

A collaboration agreement is in preparation with GfK, for LWR (BWR + PWR) fuel bundle sealing experiments taking benefit of the five years long experiment, the new fabrication method of seals and the new identification method of seals (see point 4)).

10) TRIGA Fuel Element Identification

As explained in most of our publications /1/, /2/, identification of the items can be done using:

- seals,
- artificial marks detected by ultrasonics,
- natural marks detected by ultrasonics.

The third method was used to define the identification procedure of the TRIGA fuel element in general and of the TRIGA, GFSS München, in particular.

Technique: A transducer angularly positioned reads the rear shape of the end plug welds; the element is rotated around its axis.

The project was defined at Ispra (fig. 11) and the prototype will be fabricated and tested by the reactor staff.

11) Identification of AVR Fuel Pebbles Containers

Using the TUID technique with the electronic scanning method (see fig 6), the cover of the container sealed on the box can be identified. Tests and definition of the parameters of the method have been carried out at Ispra (fig. 12).

12) Automation of Camera Control System

A digital clock for the Camera Control System of the Safeguards Directorate has been designed and assembled. It displays months, days, hours and minutes simultaneously on 8 liquid-crystal digit indicators in order to record on the picture the time when it was snapped.

As far as the development of timers for the camera control is concerned, a recent discussion with people of the Safeguards Directorate suggests a solution with low power consumption in order to make the whole system autonomous (C-MOS logic).

CONCLUSIONS

After one and a half year of work we succeeded in designing and building at Ispra a prototype of a fully automatized identification equipment. The Nukem has taken over our know-how for industrialization of the equipment.

This apparatus will make possible simplification of all the seals to be identified on the spot. The mechanical devices are reduced to a minimum. New types of seals can be envisaged: seals to be closed on the spot and for which the identity is only valid after closure (seals which can be put by the operator).

Satisfactory answers were given to the requests of the KFA (Jülich) concerning TRIGA elements and AVR containers identification.

PLANNED ACTIVITIES

For the second half of the year it is foreseen:

- to go on with the industrialization of the portable equipment at the Nukem,
- to go on with the modification of the identification methods of the existing seals,
- to perform demonstrations of sealing and identification techniques at Savannah River (USA) where the sealed fuel elements of the Petten Reactor (HFR) have to be reprocessed,
- to collaborate with GfK, VDEW, KWU on LWR fuel elements sealing,
- to answer questions from AECL (Canada) concerning a further application of our method on the CANDU fuel elements.

COLLABORATION WITH EXTERNAL ORGANIZATIONS

Our main collaborations are with the following firms:

- AECL (Canada) collaboration agreement, CANDU,
- KRB Gundremmingen (BWR),
- KWL Lingen (BWR),
- HFR Petten (MTR),
- MERLIN Jülich (MTR),
- GfS München (TRIGA),
- BR_2 Mol (MTR),
- NUKEM (Industrialization of our methods - fabrication of seals),
- KFA Jülich,
- GfK Karlsruhe (VDEW),
- ENEL (Italy) Rome and Piacenza,
- ECN (The Netherlands) Statistics - reliability of seals,
- EXXON Nuclear Company (sealing of BWR elements).

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[1] BORLOO, E., CRUTZEN, S., "Ultrasonic Signature", EUR-5108 e, JRC-Ispra, 1974

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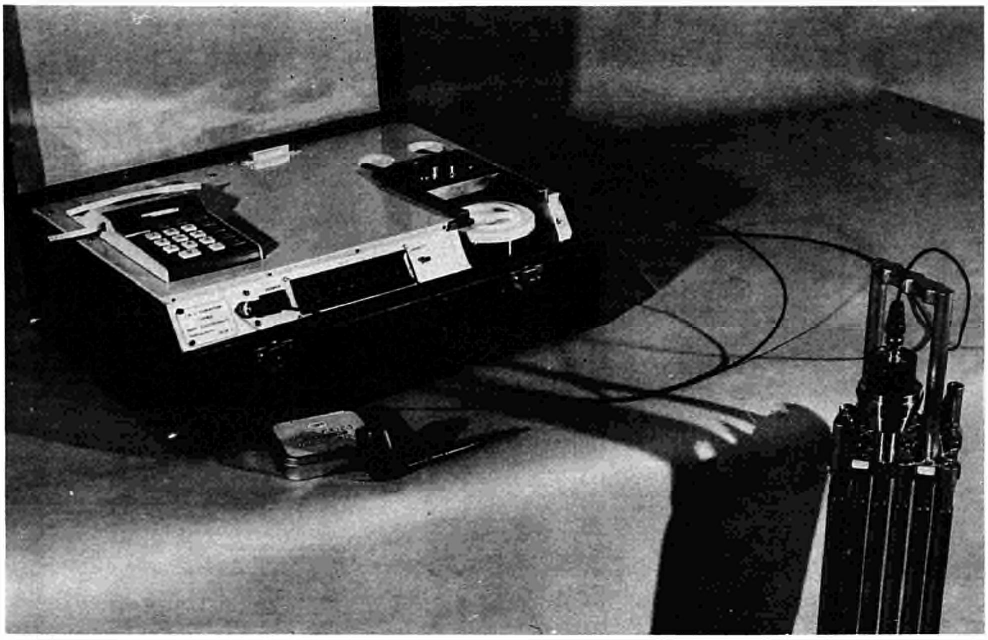
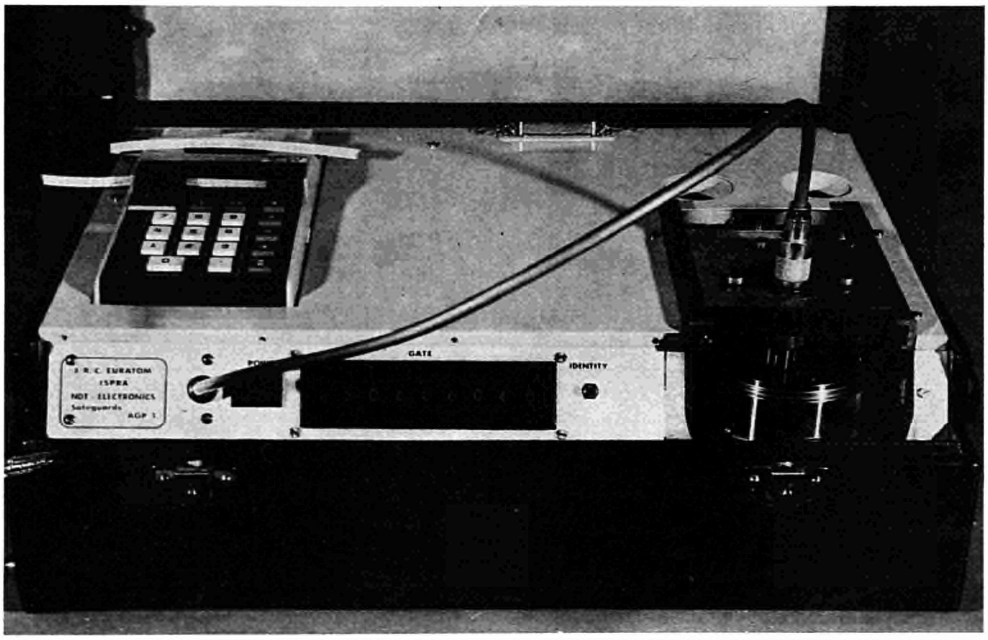


Fig. 1 — Portable equipment



Figs. 2a, 2b

Details of the portable equipment

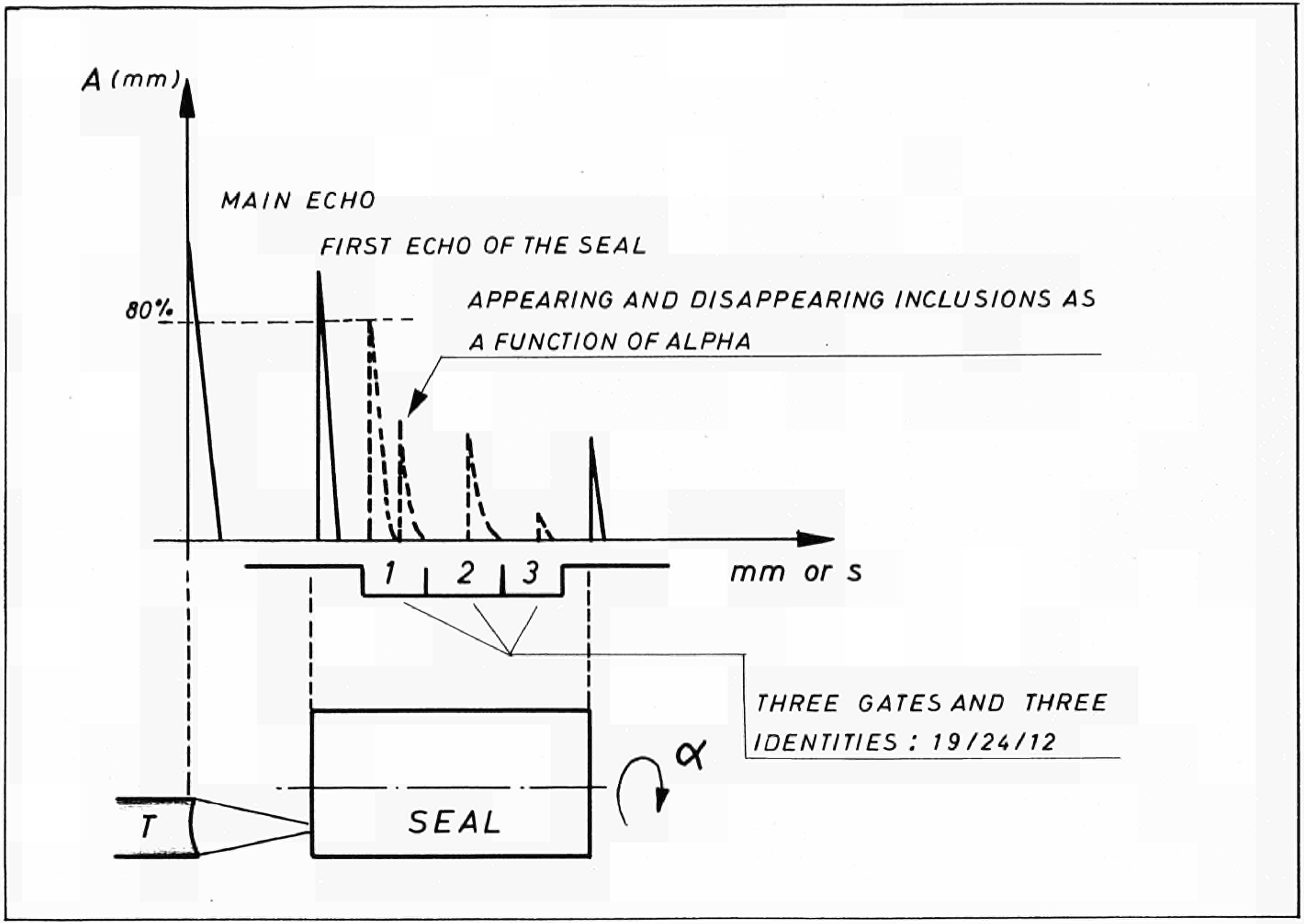


Fig. 3 - MECHANICAL SCANNING OF THE SEAL

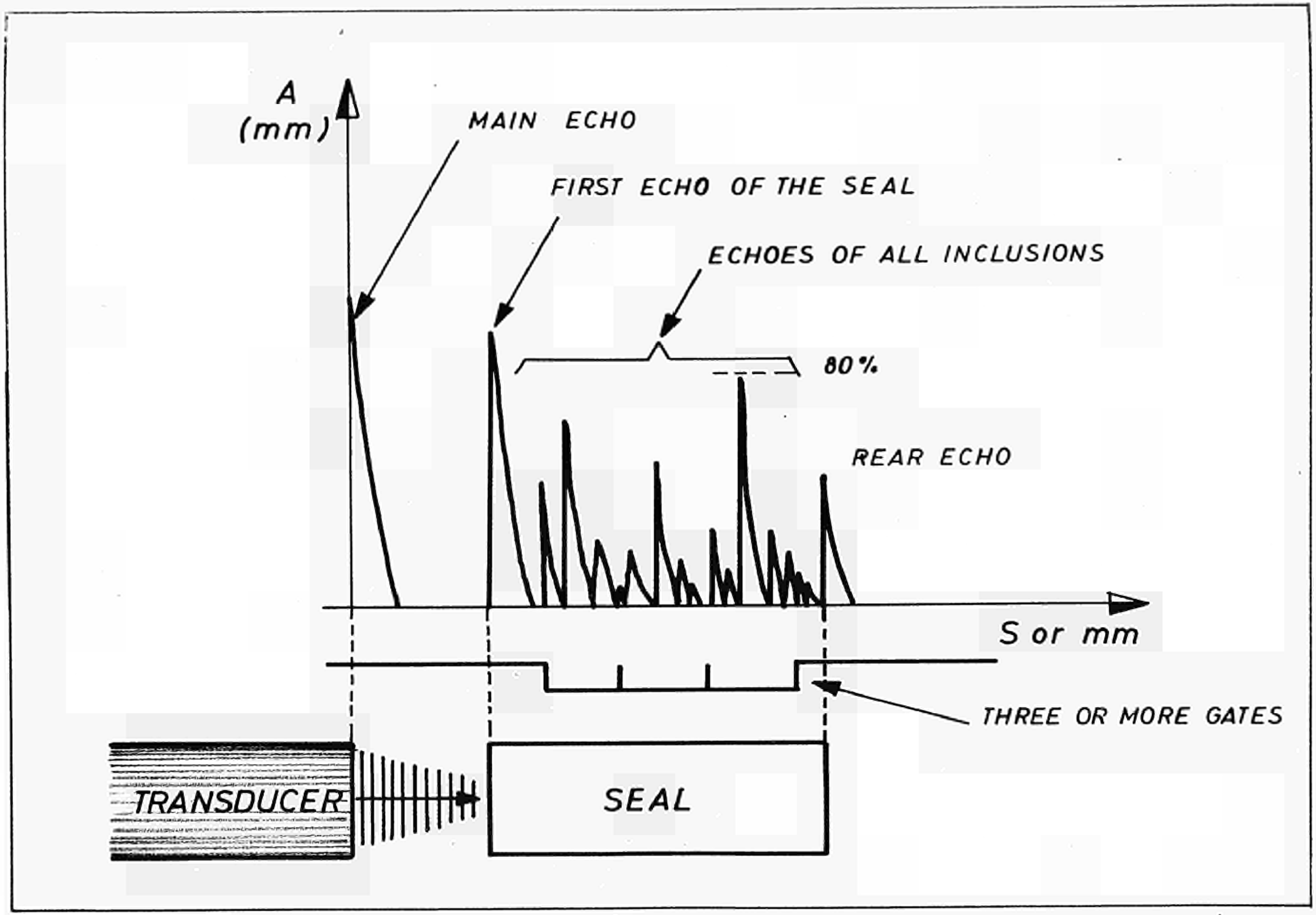


Fig. 4 ELECTRONIC SCANNING OF THE SEAL BY SHIFTING THE GATE

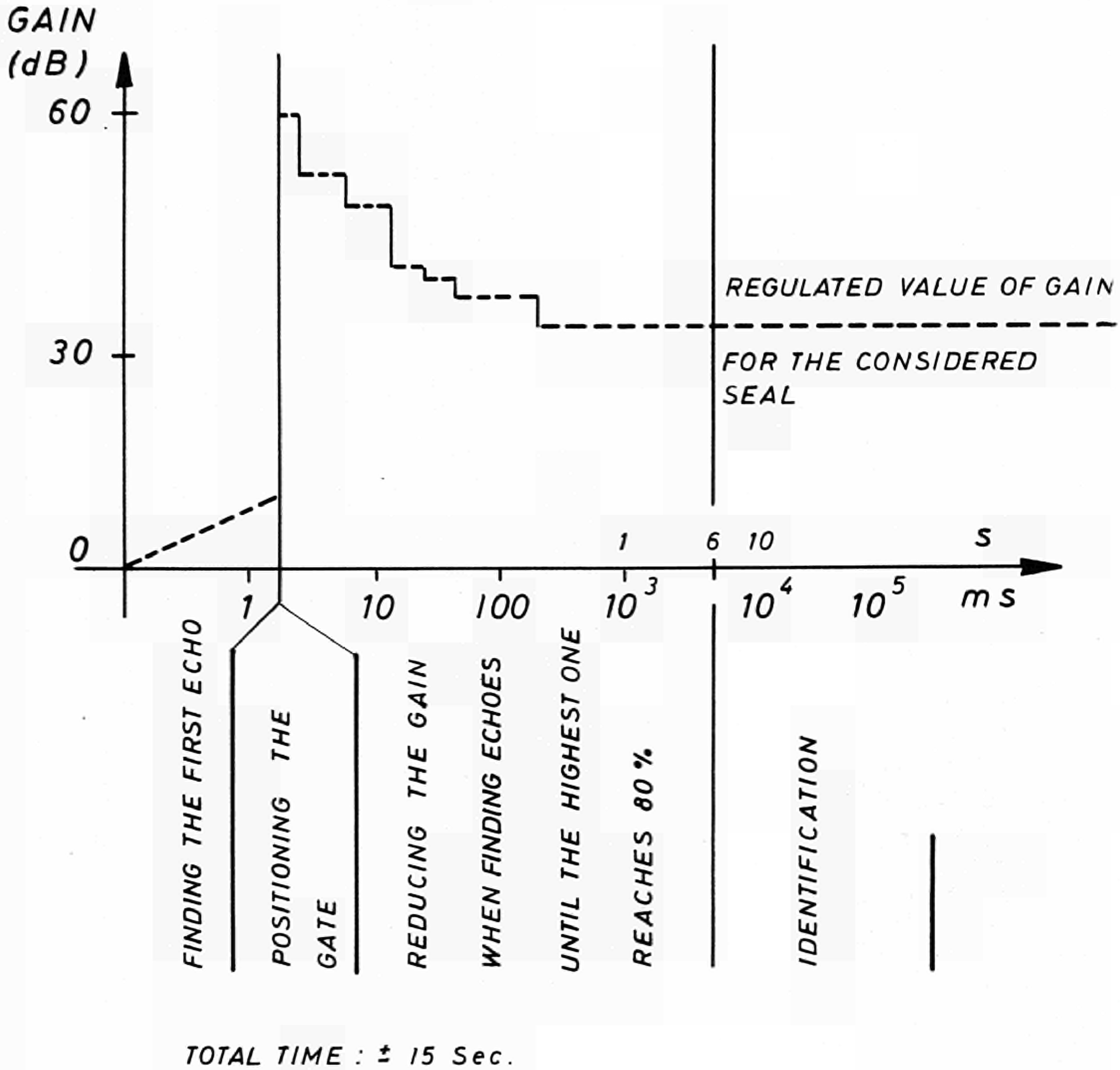


Fig. 5 - AUTOMATIC GAIN CONTROL WHEN MECHANICAL SCANNING

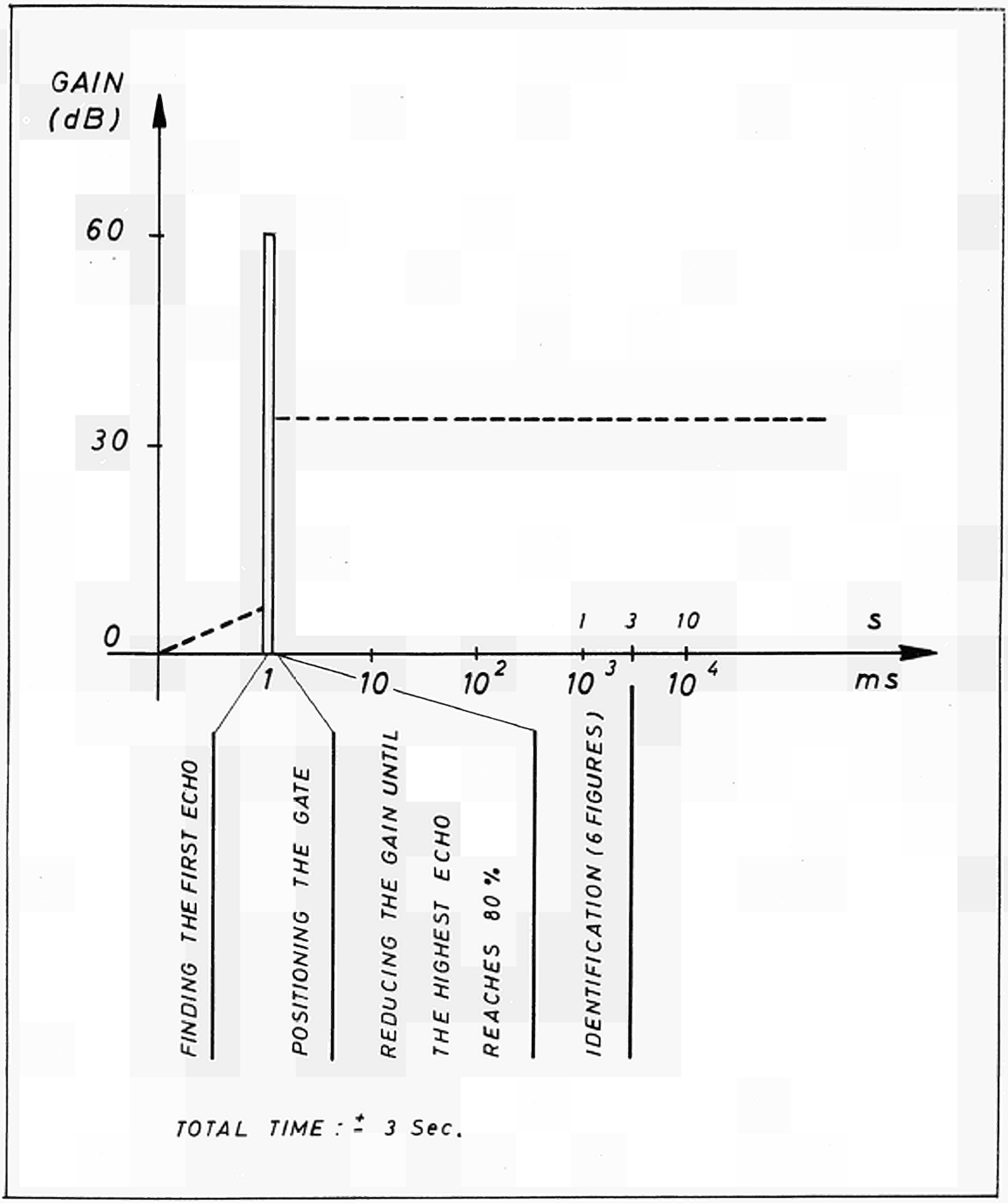


Fig. 6 - AUTOMATIC GAIN CONTROL WHEN ELECTRONIC SCANNING

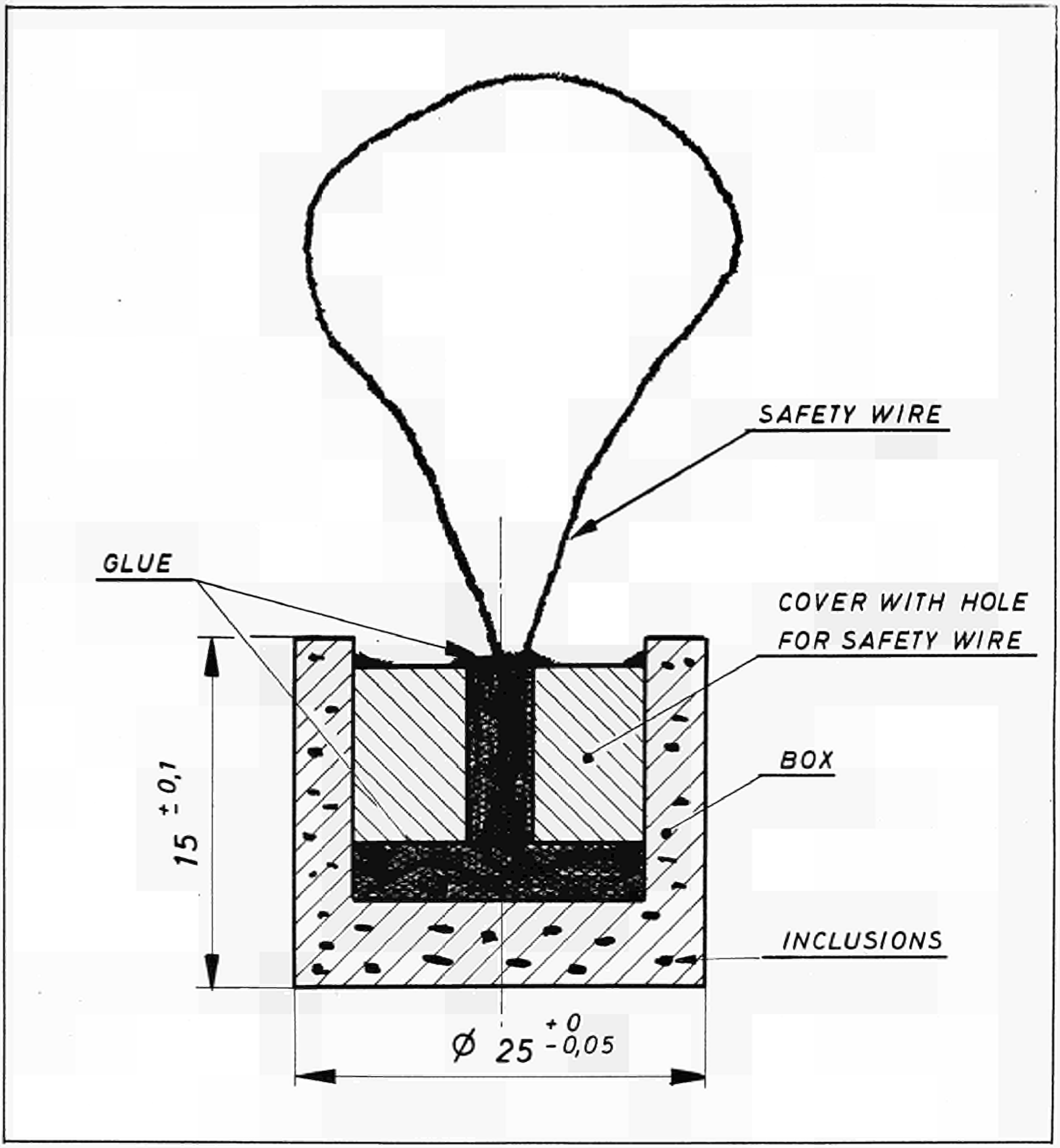
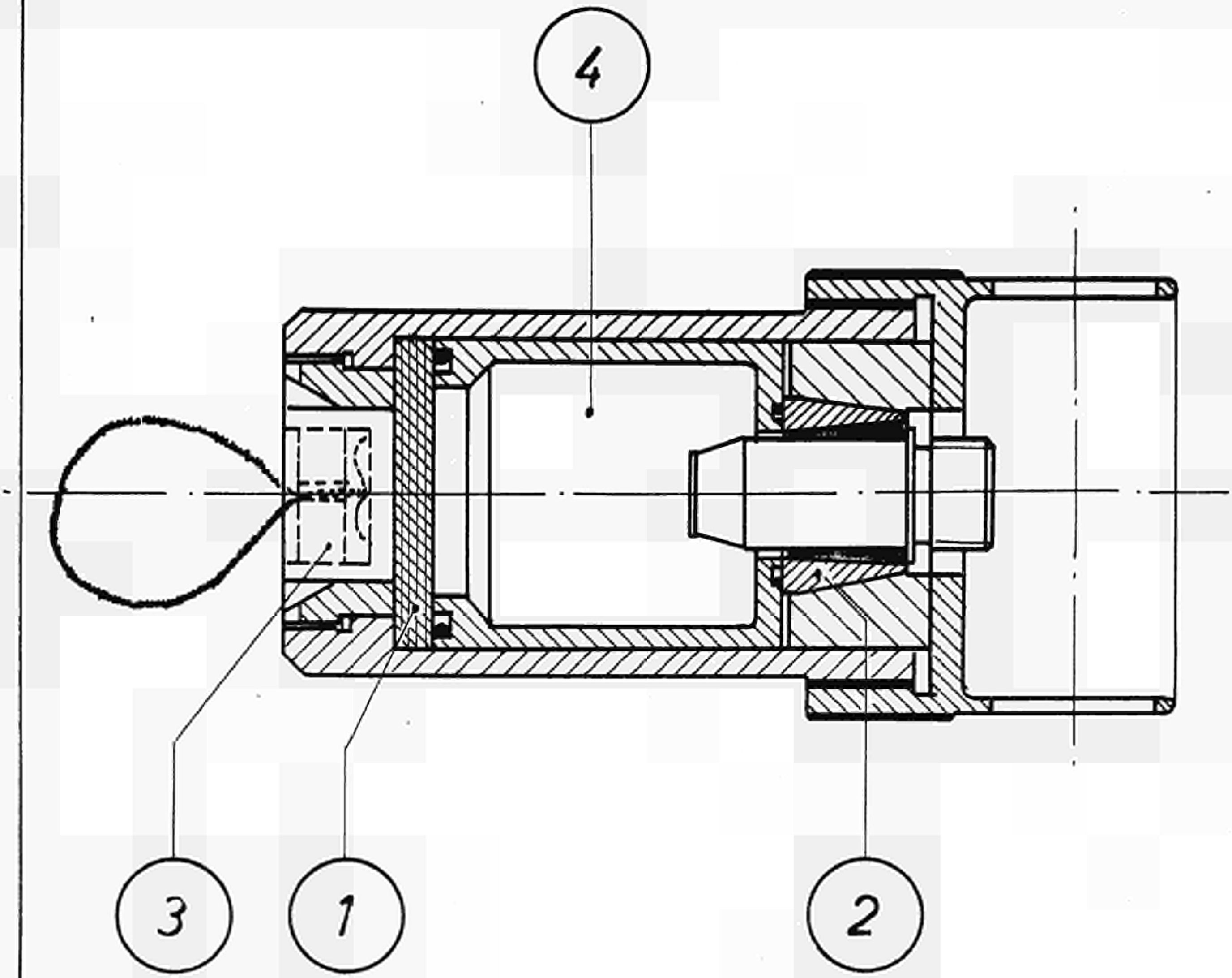


Fig. 7a - GENERAL USE SEAL, NEW DESIGN



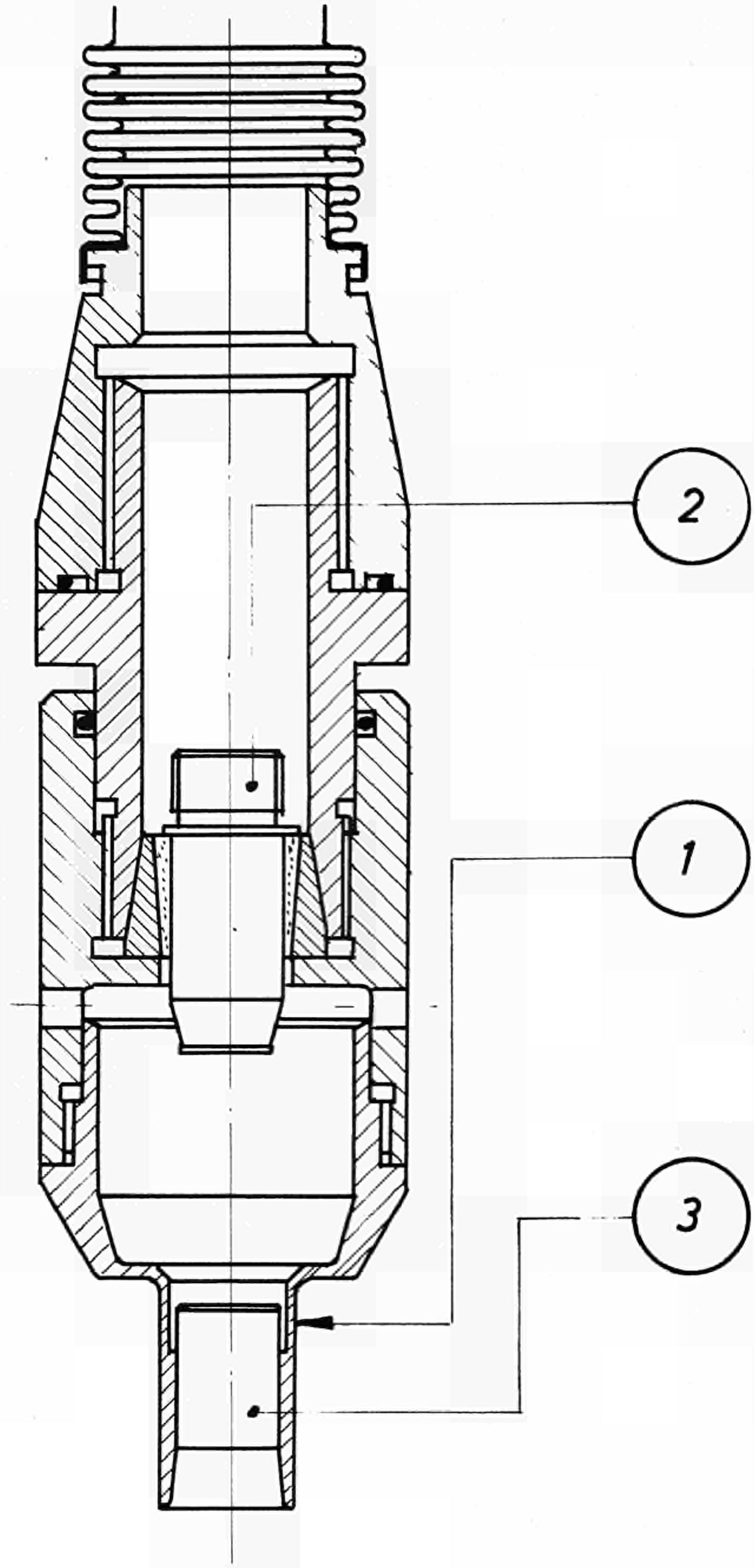
1 - LENS

2 - CENTERING DEVICE FOR THE FLAT TRANSDUCER

3 - SEAL

4 - OIL OR WATER

Fig. 7b - CONTACT TRANSDUCER FOR SEAL IDENTIFICATION



1 - SEAL CENTERING DEVICE
2 - FIXED FLAT TRANSDUCER CENTERED IN ITS CORRECTION RING
3 - CAP SEAL ON THE EXTREMITY OF A TIE-ROD

Fig. 8 - IDENTIFICATION DEVICE FOR CAP SEALS ON BWR BUNDLES.

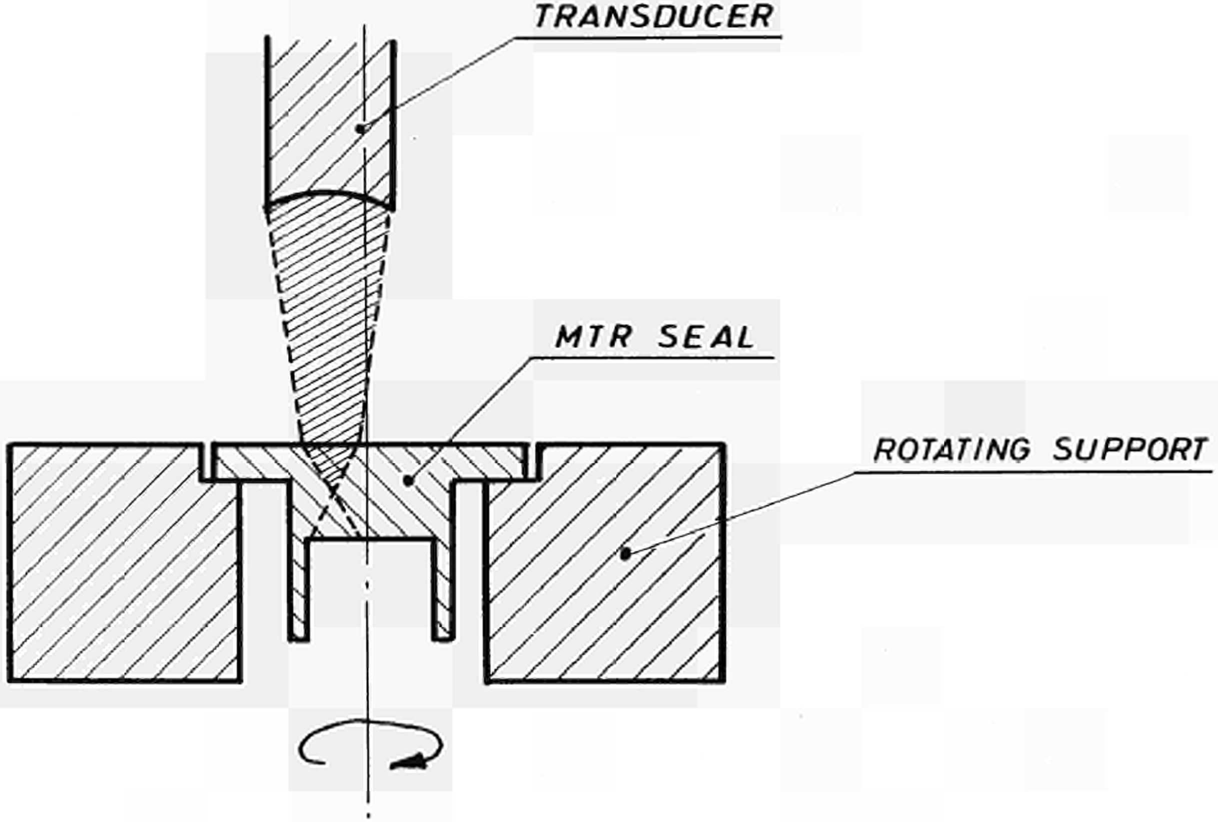


Fig. 9 - MTR RIVET SEAL IDENTIFICATION DEVICE

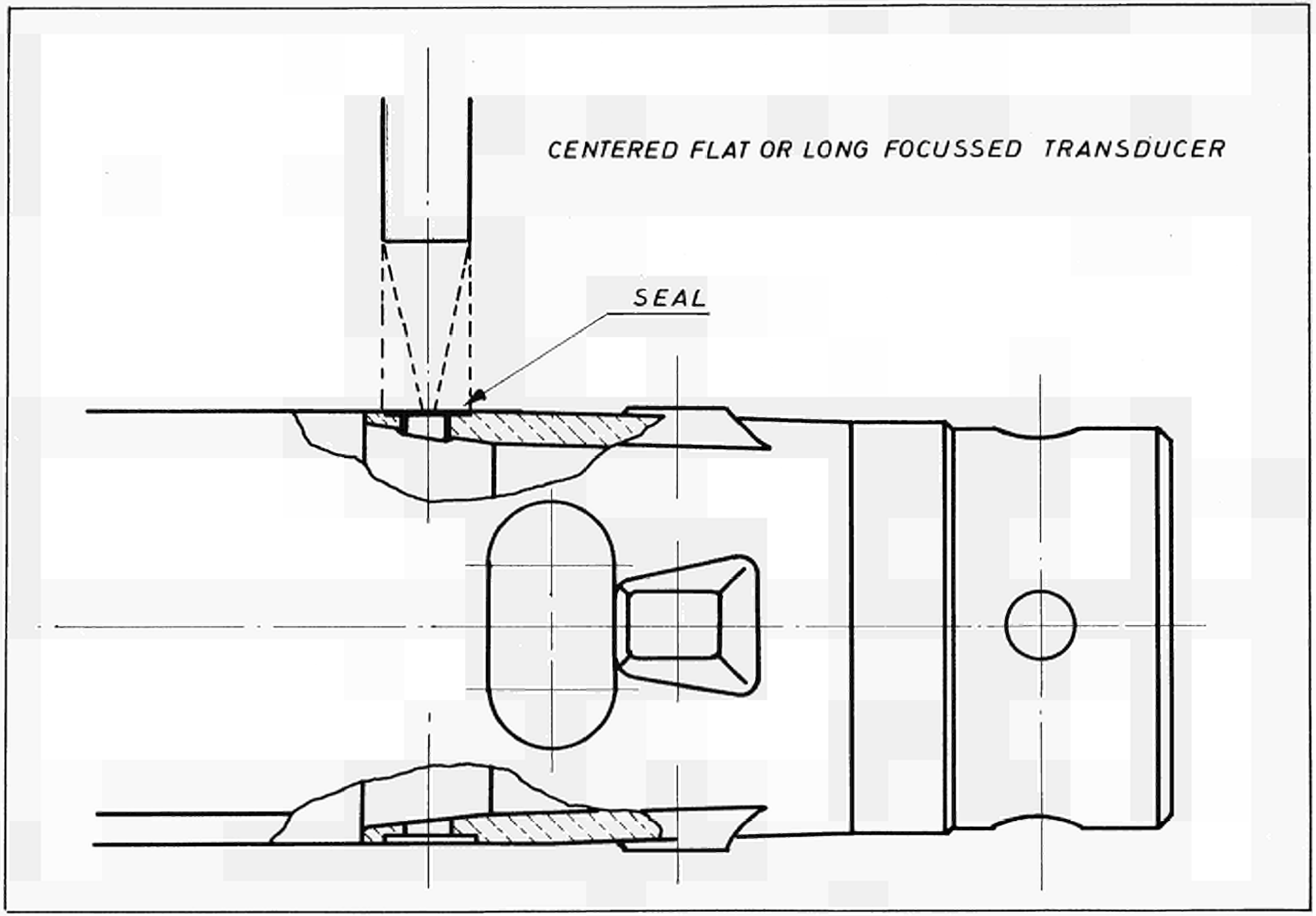


Fig. 10 - MTR RIVET SEAL IDENTIFICATION PROCEDURE WITHOUT MECHANICAL SCANNING

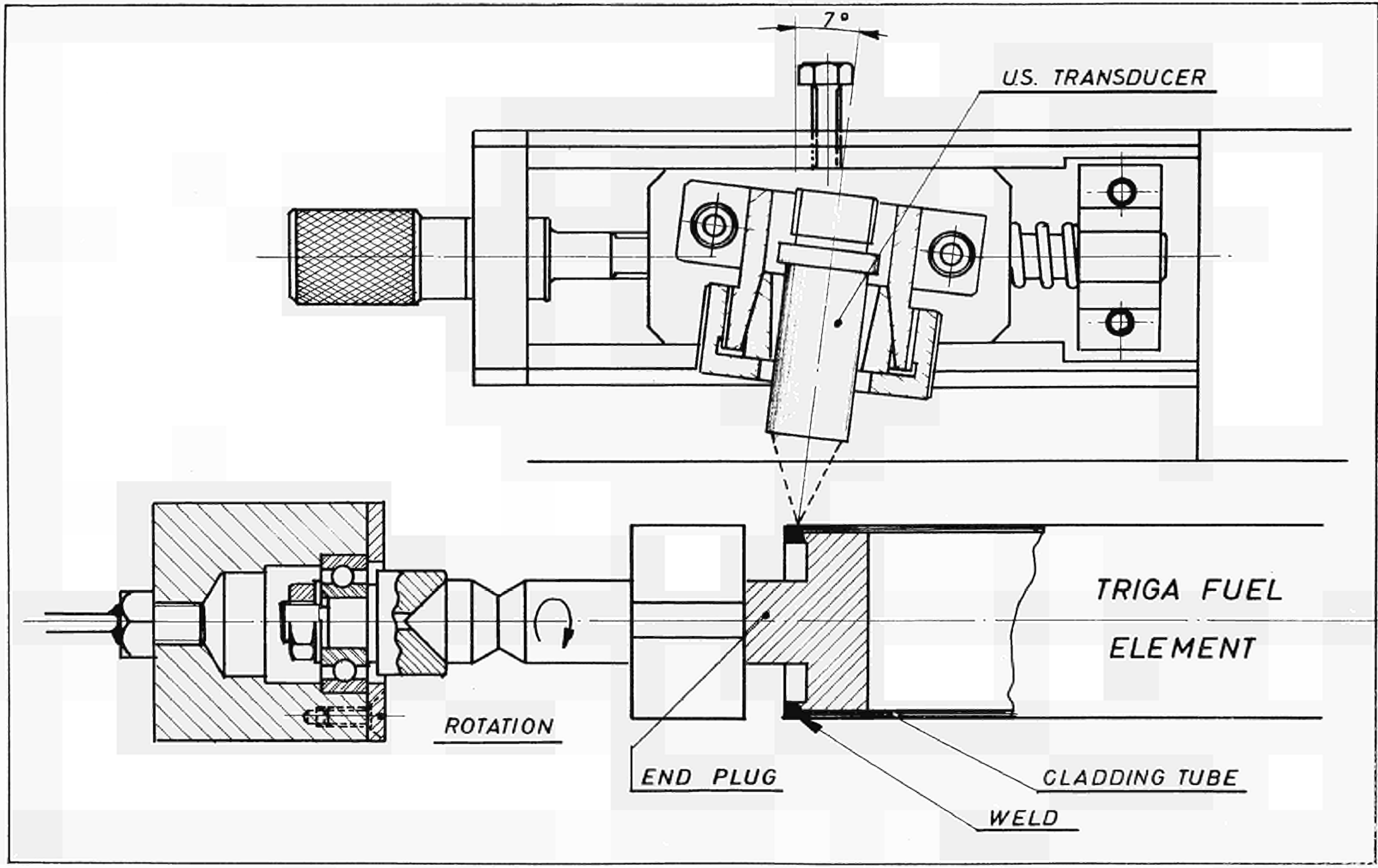


Fig. 11 - IDENTIFICATION OF THE TRIGA FUEL ELEMENT

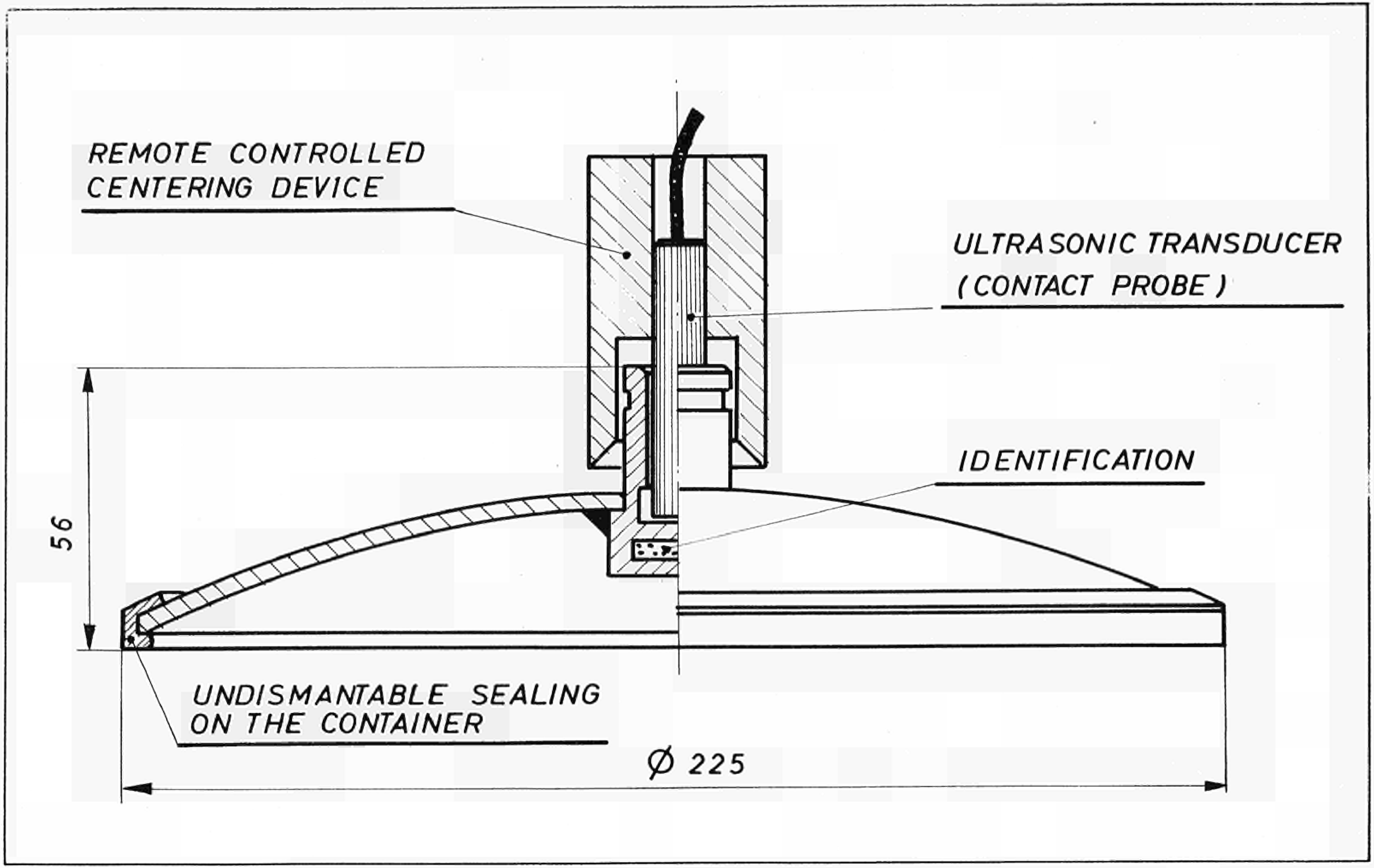


Fig. 12 - AVR FUEL CONTAINER IDENTIFICATION

Conclusions

3. CONCLUSIONS

The 1977 activity of the Joint Research Centre in the field of the Fissile Material Control is essentially a continuation of the activity carried out under the same heading during the 1973-1976 plan, with an increased emphasis on the problems of safeguards implementation in the nuclear fuel cycle.
The Bench-mark experiments, previously carried out in the framework of the programme Technical Support to Nuclear Power Stations, were included in the Project Fissile Material Control after this programme was discontinued at the end of 1976.

The increase of the staff allocated to the project made possible in the first half year of 1977 a larger effort in the field of the non-destructive assay of fissile isotopes, particularly for the development and application of neutron techniques. However, not all the staff problems are actually solved. There is a need to reinforce the studies on Control Systems and Isotope Correlations.

Due to the limited possibilities of new recruitments, we plan to solve the problem by internal rearrangement of the staff and by contracts with external organizations.

The delay in the distribution of the 1977 budget has not heavily affected the work in the first months of the year. The effect of this delay will be much more important in the second half of 1977.

The following main comments on the obtained results apply to the various studies. The planned activities are reported in Tab. 1.

Control Systems

The work carried out in collaboration with inspectors of the Safeguards Directorate and plant operators, has been mainly directed to study control systems for fuel fabrication plants. An increase of staff is required in order to accelerate the present activity and to extend the study to other parts of the nuclear fuel cycle.

Isotope Correlations

Also the work on isotope correlations has to be speeded up by an increase of staff, mainly in the field of theoretical analysis necessary to establish the validity of the isotope correlation technique in several cases which can not be investigated experimentally.

Bench-Mark Experiments

The work which requires the intervention of several laboratories at the Ispra and Karlsruhe Establishments, is proceeding in a satisfactory agreement with the planning. The accuracy of our analytical determinations resulted to be adequate for the verification of the nuclear codes used for reactor fuel management.

Non-Destructive Assay of Fissile Isotopes

The increase of the staff made possible in the first half of the year a con-

siderable enlargement of this activity.
The work is mainly oriented towards very specific actions in view of the implementation of NDA techniques under plant conditions.

Several lines of work have been defined concerning standardization of methods and materials, development and automation of techniques.
The activity of support to the Safeguards Directorate has been considerably increased.

Our activities take advantage of large collaborations involving various JRC-Establishments, the Safeguards Directorate, members of ESARDA and plant operators.

Destructive Assay of Fissile Isotopes

The important activity on the automation of mass spectrometry has been continued by the JRC-Karlsruhe Establishment in collaboration with GfK Karlsruhe.

A detailed analysis is in progress on the techniques used for input measurements in reprocessing plants.
Support has been given to the Safeguards Directorate by execution of analyses and by evaluation of the analytical methods used by plant operators.

Surveillance

The recent developments in the field of ultrasonic detection will make possible an important simplification in the use of the seals utilized for different applications.

Our experience is made available to safeguards inspectors and plant operators to solve various problems of fissile material control.

For further information, please contact the Programme Manager.

Table 1 : Planned activities for the Project Fissile Material Control

Activities		Next period for 1977 (month) 7	8	9	10	11	12	1978	1979	1980
Control systems	A							1		
Isotope correlations	B					2				
	C						3			
	D					4		5		
	E							6		
Bench-mark experiments	F							7 9	10 8	
	G									
Non-destructive assay of fissile isotopes	H	11				12				
	I				16	14	13	15		
	J			19			17	20	18	
	K			22				21 23		
	L									
Destructive assay of fissile isotopes	M			24						
	N							25		
	O					27		26 28		
Surveillance	P							29		
	Q	30					32	31		

A Study of control systems for various nuclear plants
- 1 Completion of the design of control systems for HEU and Pu fabrication plants and for LWR reactors

B Theoretical investigations
- 2 Report on fission products correlations

C Establishment and operation of data banks
- 3 Start-up of the operation of the data bank at Ispra

D Experiments in reprocessing plants
- 4 Execution of the experiment in WAK
- 5 Completion of the data analysis for the experiment

E Organization of a Symposium sponsored by ESARDA
- 6 Date of the Symposium

F Experimental analysis of the irradiated fuels
- 7, 8 Start-up and completion of the analysis on the TRINO 3 fuel
- 9 Completion of the analysis on the Obrigheim fuel
- 10 Start-up of the analysis on other reactor fuels

G Data analysis in terms of cross-section ratios

H Assessment of the standardization problem and preparation of procedures
- 11 Compilation of a list of reference materials available in EEC and IAEA
- 12 Report on the international activities

I Preparation of reference materials
- 13 Report on the characterization of LEU fuel pins
- 14, 15 Start-up and completion of the characterization of UO_2 powders
- 16 Start-up of characterization of Pu fuels

J Development and application of neutron techniques (active and passive)
- 17 Completion of the project design of the new version of PHONID (Sb/Be)
- 18 Completion of the fabrication and test of PHONID
- 19 Proposal for the improvement of the random driver
- 20 Completion of test, calibration and preparation of procedures for various passive neutron counting heads

K Development and application of gamma techniques
- 21 Report on the determination of the isotopic composition of Pu
- 22, 23 Start-up and completion of intercomparison of gamma and neutron techniques for Pu fuel pins

L Automation of NDA instruments

M Automation of mass spectrometry
- 24 Completion of the on-line automatic analysis evaluation

N Setting-up of transportable mass spectrometer
- 25 Completion of the development of the sources (surface ionization and plasma)

O Input measures in reprocessing plants
- 26 Review paper on the problems connected with the input measures
- 27, 28 Experiments in plants for the input tank calibration

P Development of ultrasonic apparatus and seals
- 29 Completion of the industrialization of the US apparatus

Q Applications of sealing and identification techniques to LWR, MTR, FBR, CANDU reactors
- 30 Completion of the 1st part of the work on CANDU fuel trays
- 31 Completion of the 2nd part of the work on the same subject
- 32 Demonstration at Savannah River on the application to MTR fuel elements

4. JRC PUBLICATIONS

[1] U. MIRANDA, M. BRESESTI, P. DE BIEVRE, L. KOCH, "Development and Application of Safeguards Techniques in the Nuclear Fuel Cycle", paper presented at the Intern. Conference on Nuclear Power and its Fuel Cycle, IAEA, Salzburg, Austria, May 1977

[2] P. BARBERO et al., "Post-Irradiation Examination of the Fuel Discharged from the Trino Vercellese Reactor after the 2nd Irradiation Cycle", report EUR-5605e (1976)

[3] G. GUZZI, P. PERONI, "Comparison between Experimental and Theoretical Data for Am and Cm Build-up in the Trino Vercellese PWR", paper presented at the First Technical Meeting on the Nuclear Transmutation of Actinides, Ispra, March 1977

[4] L. KOCH, B. BRANDALISE, "On-Line Data Evaluation Used in Automatic Mass Spectrometric Isotope Dilution Analysis of Nuclear Fuels", paper to be presented to the 4th National Mass Spectrometry Conference, Catania, September 1977.

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