THE EDAC SYSTEM AND NEW DEVELOPMENTS UNDER CONSIDERATION AT THE COMMISSARIAT A L'ENERGIE ATOMIQUE FOR CRITICALITY ACCIDENT DETECTION

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As a result of the Commissariat à l'Energie Atomique CRAC experimental program, which studied the phenomenology and the radiological consequences of a criticality excursion in fissile solution, the EDAC system has been developed. This system detects a criticality accident and warns personnel as early as possible by triggering the necessary audio-visual alarm. The main features of this equipment are its ability to cover all types of accidental kinetics and to use sensors giving a total dose response in neutron and gamma radiation.

According to new results acquired with the SILENE reactor in the field of criticality accidents, an evolution is taking place in France. An improved EDAC system is being designed not only to trigger a criticality alarm but also to provide information on the accident, to assist in accident diagnosis, and to contribute to being better equipped to cope with an accident situation, for example, il intervention is needed or if reoccupation of evacuated areas is desired.

INTRODUCTION

In spite of precautions taken to prevent criticality accidents from occuring in fuel cycle installations, a low probability of risk remains. In this eventuality, and because the Commissariat à l'Energie Atomique (CEA) is involved in the vast French electronuclear program which includes reprocessing, safety authorities have devoted a sustained effort to accident study and, in particular to criticality accidents, to be able to give optimum warning time to operators, order evacuation of personnel, and institute an intervention strategy in the shortest time possible. In the 1970s, the CRAC and SILENE experimental facilities provided design guidance for a new generation of criticality accident detection systems known as EDAC (Ensemble de Détection et d'Alarmes de Criticité, manufactured and sold by the Intertechnique Company, France, and patented and licensed by the CEA - see Fig. 1).

DETECTION PHILOSOPHY RESULTING FROM THE CRAC AND SILENE PROGRAMS

New data appeared during the 1970s, following the implementation of the CRAC program (radiological consequences of criticality accidents). Since 1974, those data have been enhanced by the SILENE program. These programs have already been described,[1-3] however, it is appropriate to recapitulate their objectives and the resources employed. The objectives were to carry out a systematic experimental study of deliberately produced accidents in order to obtain realistic elements to define a nuclear safety philosophy for the installations. This safety philosophy was previously based on theoretical evaluations of accident consequences. The experimental studies involved criticality excursions with uranyl nitrate solutions in 0.3-, 0.36-, and 0.8-m-diam vessels.

In our area of concern, namely, accident characteristics and consequences, the most important conclusions drawn from the obtained experimental results are as follows :

1. During all performed divergences, the chain reaction is self-sustained after the initial peak, resulting in a slowly decreasing power level, following a transitory stage (or not), characterized by a series of variable amplitude oscillations, which can sometimes exceed the initial peak amplitude. Basically, therefore, there is no major difference with respect to the previously selected model ; however, the number of integrated fissions in the initial peak is extremely variable. For the 0.3-m-diam vessel, this value falls between 10^{14} and 10^{17}, while the figure for the 0.8-m-diam vessel is between 10^{17} and 10^{18}. Demonstration of this range of values is extremely important, because an accident must be detected at the instant of the first peak in order to achieve maximum benefit.

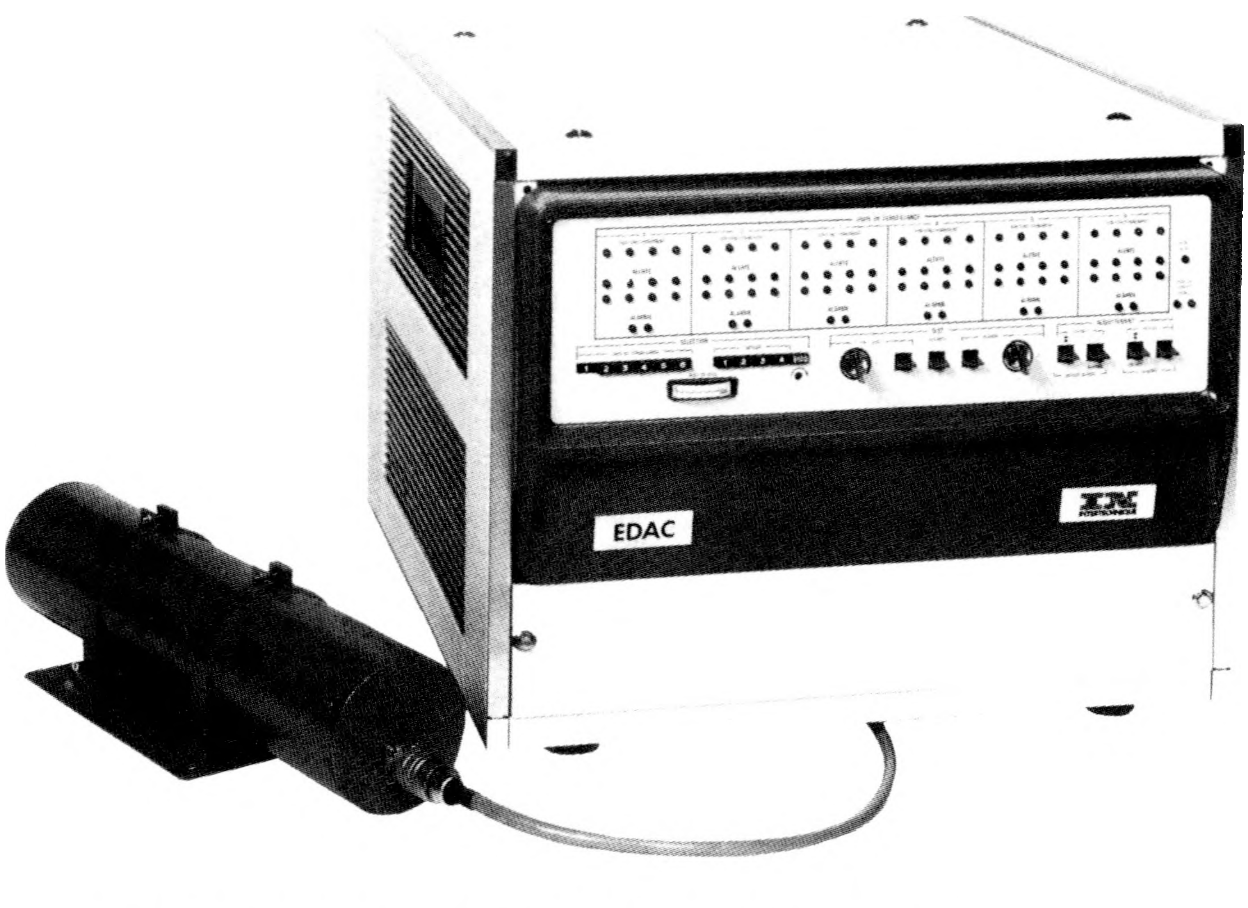

Fig. 1 - The EDAC criticality accident detection system

2. The second conclusion concerns the results of dosimetric measurements made in the vicinity of the source of the divergence. In the absence of any shield, we observe that there is no approximately constant ratio between the number of fissions and the absorbed dose in the air for the several vessel sizes. This is particularly sensitive between the measurements made on the 0.3- and 0.8-m-diam vessels. The fission dose is approximately half as large with the larger diameter vessel. As expected, divergence source geometry and solution volume, in particular, with modification of the leakage neutron spectrum, lead to highly variable dose levels.

3. A third major conclusion relates to initial excursion kinetics. This excursion is not always "instantaneous", as assumed in the past, but develops more or less quickly in time (Fig. 2). This effect has been clearly demonstrated by measuring the power doubling time (T_2) from time zero, namely, from the moment of reaching delayed critical solution height to the maximum of the initial peak. During the CRAC program, the lowest value recorded was 1 ms ; the highest value was a few seconds. The French criticality accident detection system was developed from these experimental data. During recent experimental work on SILENE, it was demonstrated that the possibility of a very slow kinetics excursion (period of a few minutes) could not be totally excluded and that, under those considerations, it was inadequate to accept the concept of "minimum accident of reference."[4]

Now, due to the two main conclusions resulting from these test programs, i.e., the difficulty of defining a standard accident and the fact that it is impossible to establish a dose/fission number ratio, the detection system in operation at the present time corresponds to the following essential physical criteria :

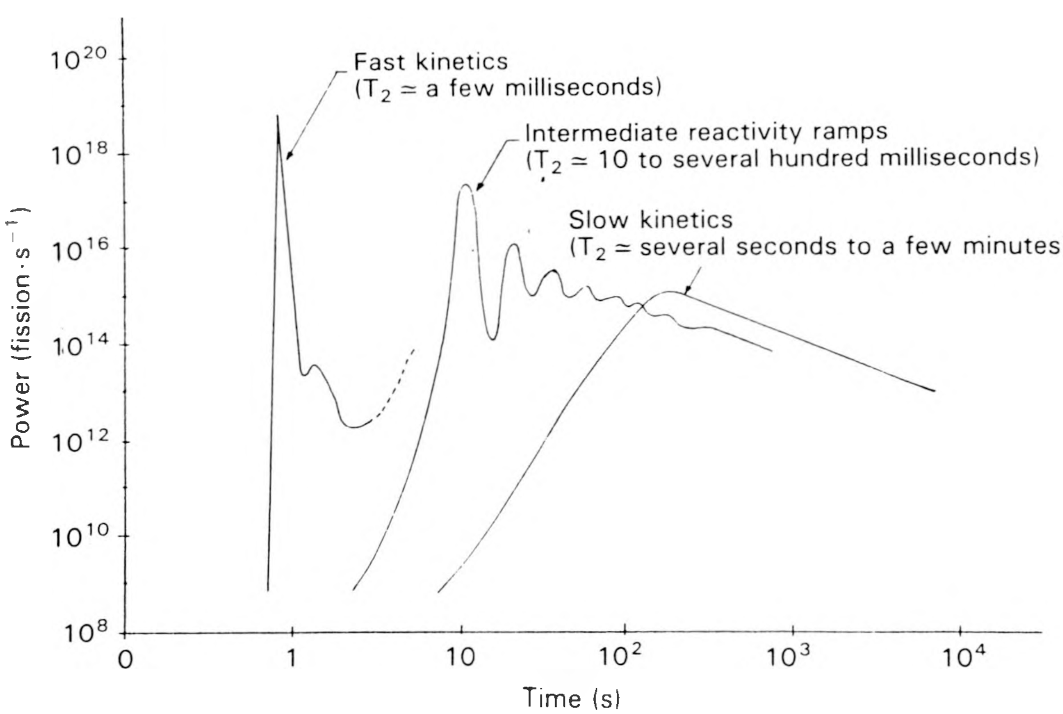

Fig. 2. Various types of power excursions in fissile solutions.

1. It is capable of covering all the accident kinetics.
2. The sensors used give a total dose response in neutrons and gammas.

CHARACTERISTICS OF THE FRENCH CRITICALITY ACCIDENT DETECTION SYSTEM (EDAC)

The detailed characteristics of the French criticality accident detection system (EDAC) are given in Refs. 5 and 6. The EDAC system is designed to warn personnel of a criticality excursion occurring in an installation by triggering the necessary audiovisual alarms when the selected dose thresholds at the location of the detectors have been over-ranged.

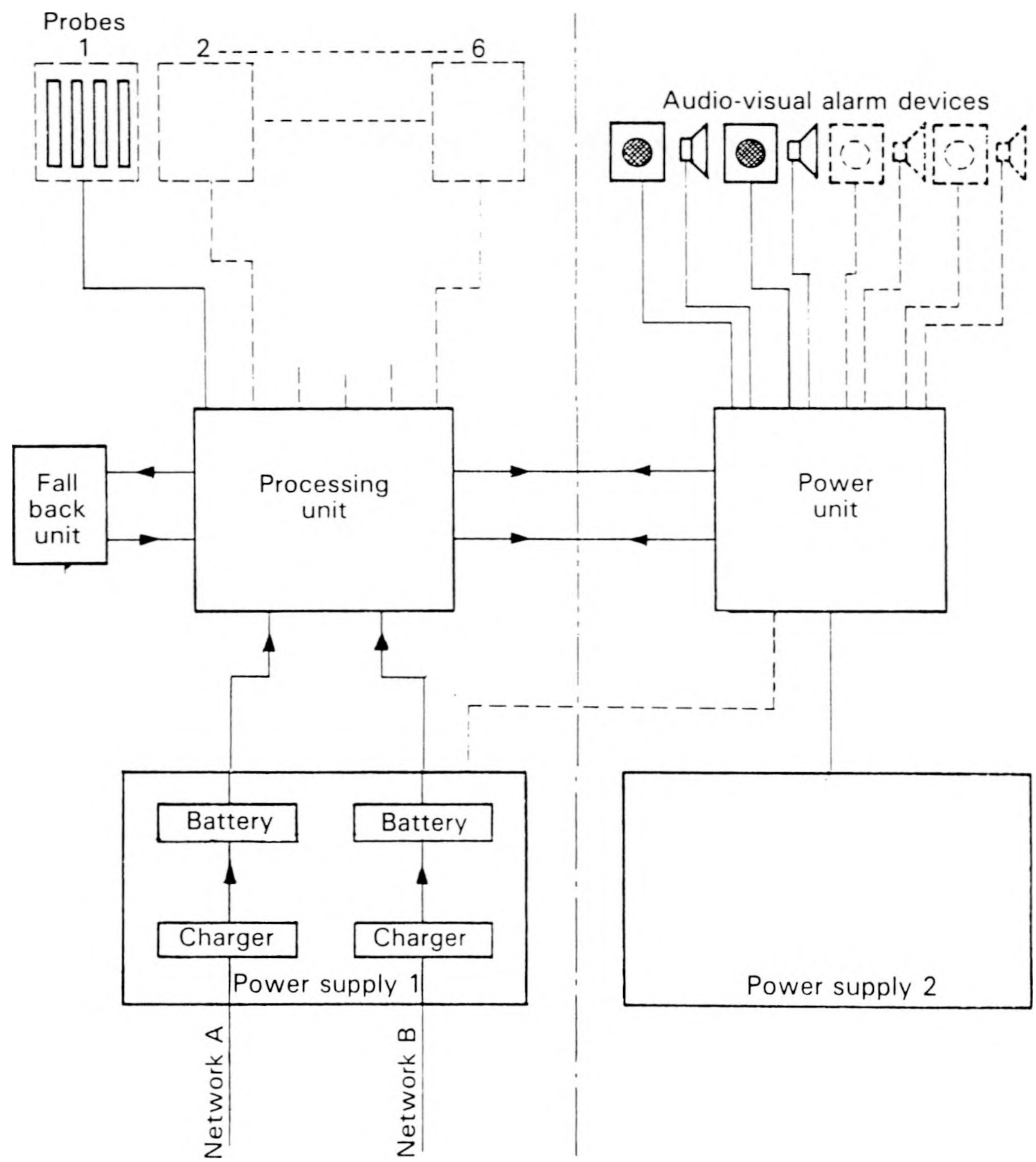

Fig. 3. Criticality accident detection installation—block diagram.

The general organization of the EDAC system, illustrated in Fig. 3, consists of a processing unit that handles the information from one to six monitoring units, each of which includes four detectors. The information analysis system of one monitoring unit is of the 2/n ($n \geqslant 3$) majority logic type.

A warning signal to evacuate personnel, for example, is only generated when two probes indicate an alert state. This alert level is delivered by a probe when the preselected dose and dose rate thresholds for triggering are over-ranged (values generally used are 2.5×10^{-5} Gy and 1×10^{-2} $Gy.h^{-1}$).

The device must provide an absorbed dose measurement. The detection probe has been studied to give a roughly balanced dose response in the mixed neutron and gamma radiation field produced by a criticality excursion in the free environment and also behind shielding. A balanced response for the detector is obtained by optically coupling two scintillators to a photocell, namely, a plastic scintillator principally sensitive to the gamma radiation and a boron scintillator sensitive to thermal neutrons. The whole unit is placed in a polyethylene sleeve. Tests have shown that during the first peak the probes can be saturated but never blinded. The probes remain in service after sending a warning signal and are therefore able to deliver information about the dose rate ar their locations. Moreover, the EDAC is designed to achieve maximum simplicity, while providing its radiation protection function with an adequate degree of certainty. Redundancy is deliberately limited to a reasonable level, and the reliability of the unit is excellent so that the probability of false alarms in particular is practivally nil.

SOME REMARKS ABOUT THE CEA APPROACH TO THE CRITICALITY ALARM DETECTION SYSTEM

It is interesting to note the French approach to the criticality alarm detection system and its present state.

The results obtained during the CEAC and SILENE programs have shown the necessity for improving existing equipment and developing a new system, namely, the EDAC system, which must be able to respond to a total dose in the widest possible range of criticality excursions.

The old system used in France was unable to correctly detect an accident in the case of slow excursions or of an accident occuring behind a gamma protection.

The EDAC system currently covers most situations in any complex environment. It is also worthwhile to note that we have confirmed these performance levels by testing the system in the more severe possible experimental conditions with various kinetics and behind protection by using the SILENE reactor.[6-7]

Technical progress and improved knowledge of the physical phenomena to be detected have been possible because the CEA is conducting an important program to study the criticality accident and uses for that purpose the flexible and original SILENE testing facility. About 400 probes are currently in service in France, and all the EDAC systems have been tested before delivery with the SILENE reactor under representative accidental situations to check that the industrial equipment meets defined specifications.

NEW DEVELOPMENTS UNDER CONSIDERATION

There is a new evolution of the criticality accident detection system taking place at the CEA, due to information acquired at the Valduc study programs currently being conducted with the SILENE reactor in the postaccident and intervention fields, in the case of a criticality accident. No changes are contemplated in the equipment design to attempt to obtain additional information following the initial activation of the warning signal. However, different types of situations can be encountered after the first peak, and these are described schematically in Fig. 4.

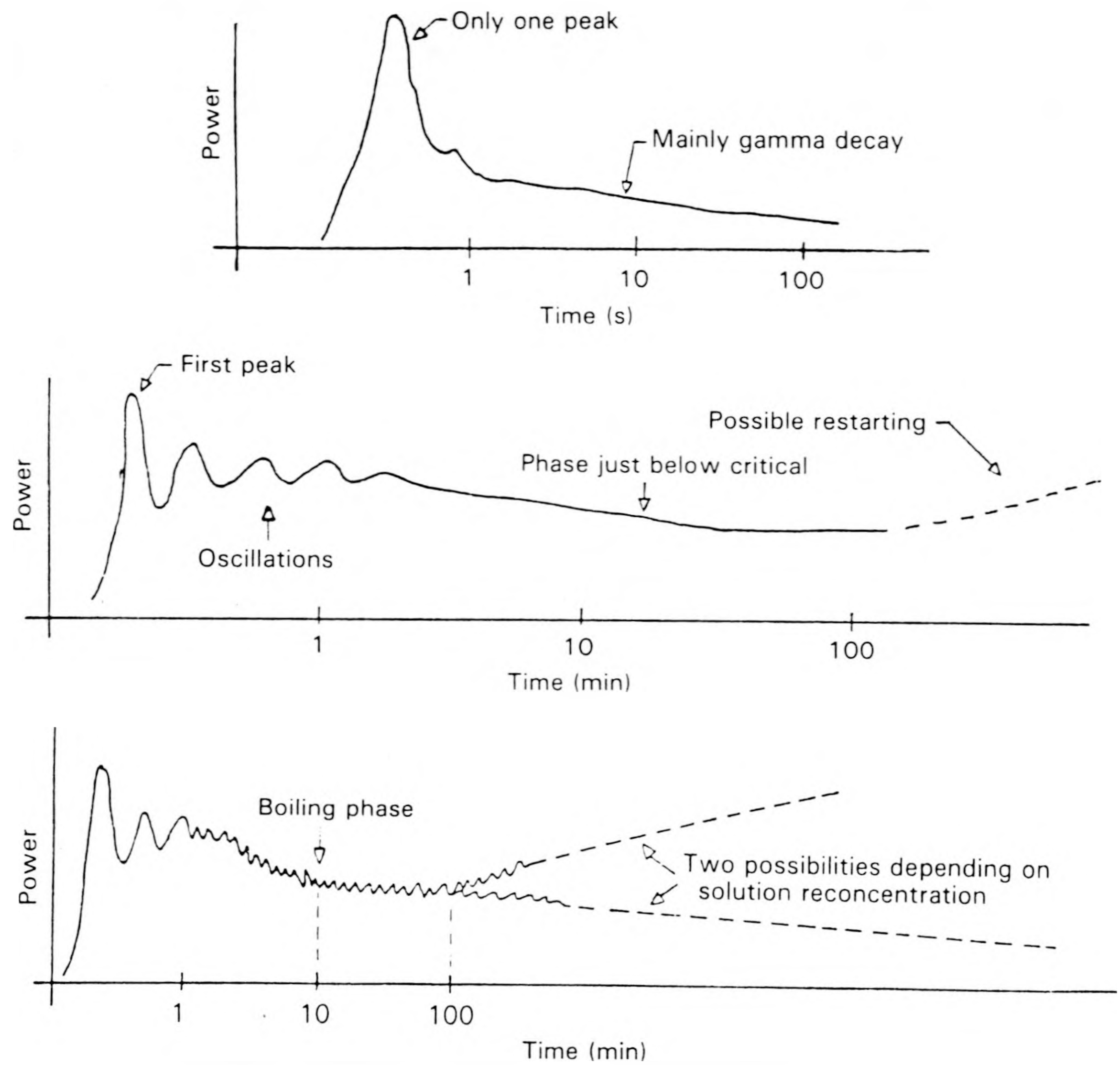

Fig. 4. Criticality excursions in solution—some possible typical postaccident phases.

One of the original characteristics of the French equipment is the possibility of confirming of locating an accident from a remote point by using the dose rates delivered by the probes in the concerned installation. This possibility in no way modifies the essential detection and alarm functions of the accident detection system as defined by the Criticality Safety Commission.

The objective of the new developments under consideration (Fig.5) at the CEA relates to the processing of information gathered from the criticality detectors to supply the installation authorities, using only the existing detection network, with the greatest possible amount of information about the accident (evolution, integrated dose, etc.). This proposed improvement would assist in accident diagnosis and make a very effective contribution to decision making in the event of intervention or reoccupation of evacuated areas. For example, a rescue operation in the event of an accident could be attempted, knowing that intervention of this type is possible or not, without needlessly exposing a rescue team. The planned improvements in the EDAC system would undoubtely contribute to a system better equipped to cope with an accident situation.

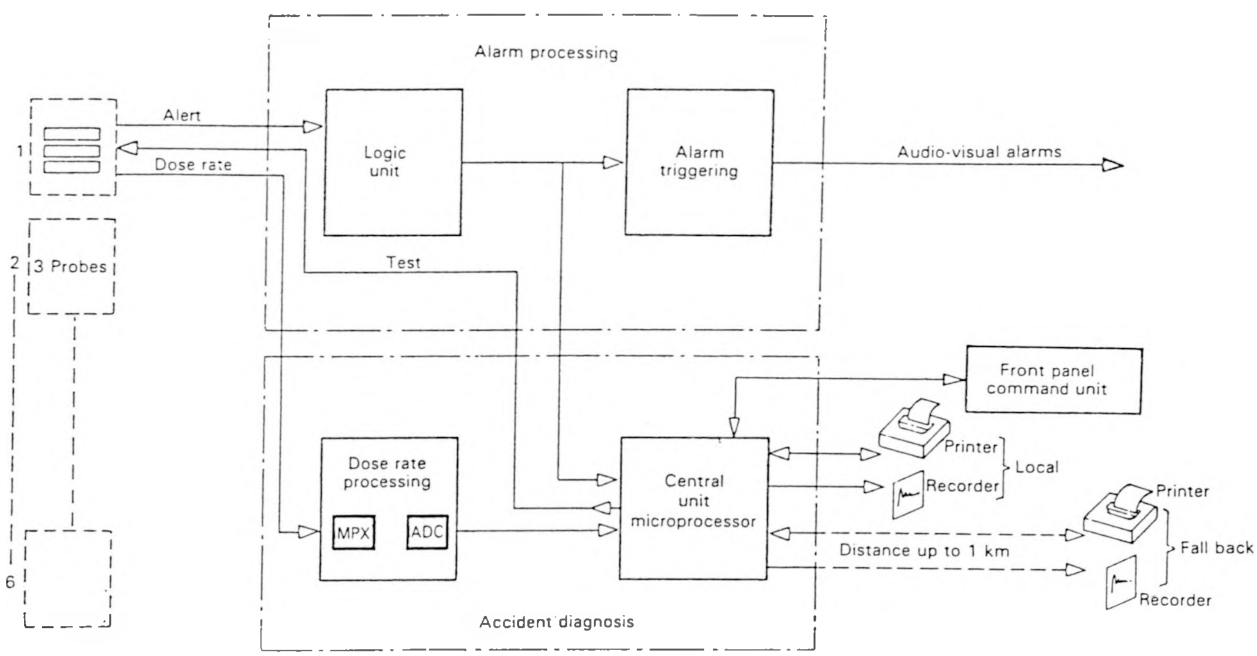

Fig.5 - New EDAC processing unit

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