# SODIUM FIRE SUPPRESSION

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ABSTRACT :

Ignition and combustion studies have provided valuable data and guidelines for sodium fire suppression research. The primary necessity is to isolate the oxidant from the fuel, rather than to attempt to cool the sodium below its ignition temperature. Work along these lines has led to the development of smothering tank systems and a dry extinguishing powder. Based on the results obtained, the implementation of these techniques is discussed with regard to sodium fire suppression in the Super-Phénix reactor.

## 1 - INTRODUCTION

On the basis of data collected on sodium ignition (1) (ignition temperature for a still surface : 200°C ; ignition of an agitated surface possible upon liquefaction ; ignition possible at standard temperature if the metal is split or presents a granular finish) effective sodium fire suppression will not be obtained by attempting to cool the metal below its "ignition temperature" using systems with a high heat capacity. Sodium combustion studies and the resulting data on combustion mechanisms have opened up new areas in fire-suppression research. The primary requirement is to isolate the oxidant from the fuel ; this constituted the basis for development of the smothering pan system and a new fire extinguishing powder.



## 2 - PASSIVE EXTINGUISHING SYSTEMS : SMOTHERING PANS

Smothering pans are designed to be located beneath the loops to recover any sodium outleakage and to isolate it from oxygen, in order to limit the amount of metal burned and thus the thermodynamic effects on the containment.

Development testing was conducted in a 400 $m^3$ concrete caisson (9m X 6m X 7.6m high) which had been suitably instrumented (thermocouples, gas sampling port for pressure and oxygen consumption measurements) (2). The program included seven tests, each involving approximately one ton of sodium at 550°C at flow rates ranging from 60 kg to 1500 kg per minute .

The pan surface area was $9m^2$ throughout the test program. For the first two tests the system comprised a pan covered by a smothering device consisting of two inclined plates separated by a slot measuring $0.5m^2$. During the first test, sodium was poured directly into the slot at the rate of 96 kg per minute in order to confirm the oxygen starvation principle. One ton of sodium was used in this experiment, of which only 50 kg burned including 12 kg released as aerosols ; this is equivalent to an oxidized sodium release rate of 24 %. (This value is on the order of 40 % for a normal sodium fire (3)).

For the second test, the sodium was poured onto one of the inclined cover plates. Under theses conditions 76 kg of sodium burned, including 30 kg recovered in aerosol form (i.e. 39 %). The temperature and pressure effects of this experiment were equivalent to those resulting from combustion of the same amount of sodium over an area of $5m^2$. Despite the low leakage rate (64kg per minute) the experimental conditions in this experiment were more realistic than during the first test. This smothering device configuration was abandoned because of the excessive thermal effects of combustion.

On the basis of the first two experiments a modified system was designed using hinged shutters to ensure virtually complete isolation of the sodium from the air while simplifying sodium recovery (cf. Figures 1 and 2). The system was designed to withstand the thermal stresses resulting from very high leakage rates (1500kg per minute) of high-temperature sodium. The following results were obtained with this modified smothering pan :

- of 1 metric ton of sodium, only 30 kg burned.
- the initial combustion rate was reduced by a factor of 10
- the sodium oxide release rate was reduced to about 25 %
- the sodium temperature inside the pan dropped immediately.

Figure 3 compares the temperature of a $4m^2$ open sodium mass with that of a $9m^2$ area confined by smothering pans. The temperature after one hour reached 750°C in the first case; whereas it had dropped to only 350°C in the covered pan.

Further tests were conducted by interconnecting a series of smothering pans to increase the system recovery capacity and to cover the entire potential leakage area. When one ton of molten sodium was poured onto four interconnected pans, only 10kg of sodium burned and 4kg of aerosols were generated.



## 3 - POWDER EXTINGUISHMENT

### 3.1 - Fire Transformation

Sodium fire suppression tests showed that it was illusory to attempt to convert the sodium fire into a hydrocarbon fire by spreading an organic compound over the sodium and then extinguishing the hydrocarbon fire. All such tests produced completely negative results.

### 3.2 - Silica and Aluminosilicate Base Powders

Silica reacts with sodium at temperatures above 200°C to form sodium oxides and silicates. The fire is activated on contact with these two products.

Perlite (aluminosilicate) reacts with the sodium because of its high bonded silica content. The molecular chain is broken on contact with the sodium, and a silica-sodium reaction ensues.

Similar reactions occured with products such as cecacite, dry oil and sand.

A 10kg sodium fire was extinguished with 50 liters (4kg) of vermiculite (expanded mica), but only after a violent contact reaction. The resulting residue was very fusible, however ; because of the extensive surface area of the vermiculite particles the product becomes impregnsted with sodium which is thus excessively dispersed. Any subsequent intervention on such residues is therefore extremely difficult.

Three hundred liters (24kg) of vermiculite were spread over 184kg of sodium covering a $2m^2$ area inside the $400m^3$ caisson, with the following results :

- pressure increase from 12mb to 132mb (Figure 4),
- sodium temperature increase (Figure 5);
- gas temperature increase (Figure 6).

Subsequent analysis of the residues confirmed that these effects were attributable to the sodium-silica reaction.

3.3 - Sodium Salt Base Products

. Sodium carbonate - 37 kg of this product were insufficient to extinguish 10 kg of burning sodium.

. ANSUL Na - X (a powder mixture of sodium carbonate and organic compounds). The organic compounds contained in the powder ignited, and the sodium carbonate was not sufficient. It was not possible to estimate the amount of product necessary to extinguish a 10 kg sodium fire.

. TOTALIT-M ( a powder containing sodium chloride and organic compouds). The organic compounds decomposed with the sodium to form volatile cyanide-containing products. A 10kg sodium fire was extinguished with 23kg of Totalit, which is nevertheless highly corrosive because of its chlorine content.

. MARCALINA

After these relatively umpromising results, the CEA developed an alkaline carbonate and graphite base powder, containing neither mineral products capable of reacting with sodium nor organic compounds.



It has been tested with 200 kg of sodium poured at 550ºC into a $2m^2$ combustion pan inside the $400m^3$ caisson ; 100 kg of powder were used for this test (i.e. enough for a layer 8cm thick).

When the powder was spread over the fire, simultaneous drops were recorded for sodium temperature (Fig. 7); gas temperature (Fig. 8), pressure (Fig. 9) and oxygen consumption (Fig. 10) indicating that the fire was extinguished. No reaction occured on contact with the sodium (any reaction would have been registered on one of the parameter curves).

This powder is based on alkaline carbonates and graphite. The carbonate proportions are such that eutectic properties are achieved, so that at high temperatures the powder forms a doughy air-tight film on the surface of the sodium. At lower temperatures the mechanism is not the same : one of the features of this product is that one of its components contains a small amount of crystallization water which serves two purposes. First, it reacts with the sodium and sodium oxides on the sodium/powder interface, forming a thin film of sodium hydroxide which is a powerfull extinguishing agent ; the amount of water that reacts with the sodium in this way is nevertheless quite limited, since no traces of hydrogen were detected. Moreover, as it is eliminated the water results in the agglomeration of the compounds to form a compact insulating layer on the surface of the metal. For this reason, the powder is equally effective at low and high temperatures, as shown by testing at Cadarache and at CNRS facilities. The graphite not only increases the fluidity of the powder compound but is also a fire extinguishing agent.

This powder is capable of extinguishing fires irrespective of the sodium temperature. In use it presents the significant advantage of clinging to vertical and horizontal surfaces, and thus permits fire suppression not only on the floor but also of burning sodium on piping - which is much more probable. Aerosol generation is checked immediately, a significant factor for fire-fighting intervention. Moreover, the powder gave excellent results when tested on heavy oil and electrical wiring fires. For plant operators, Marcalina powder thus constitutes an effective means of suppressing the two possible types of fire hazards.

## 4 - APPLICATION TO SUPER-PHENIX

Sodium fire hazards in Super-Phénix will be localized in certain areas of the reactor building, in the secondary loop galleries and in the steam generator building.

Smothering pan systems will be installed in the galleries beneath the secondary sodium loops.

Powder extinguishing systems are planned for the reactor and steam generator buildings. Therefore, after developing the powder the CEA began research to assess the product behavior in time, to design the transport system and spreading devices and to determine their installation position around specific Super-Phénix vessela. The experimental program currently in progress ia intended to determine the minimum powder thickness required for fire suppression (after which any minor flare-ups may easily be controlled by covering the exposed sodium with a small amount of powder) and to define intervention procedures compatible with the poor visibility inside the containment volume due to aerosol release.

## REFERENCES



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(3) CHALOT A. - FOUREST B. - COLOME J. - DUCO J. - MALET J.C. -
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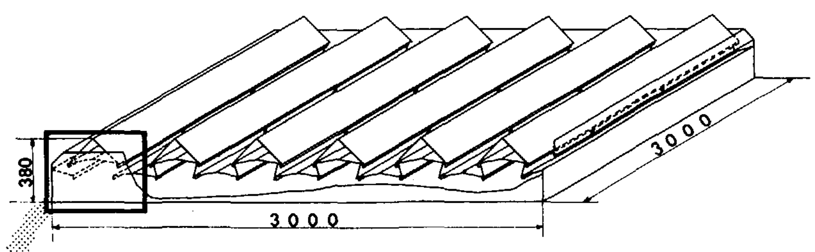
VII Congrès International de la Société Française de Radioprotection Versailles 28-31 Mai 1974 - p 315 - 340

**FIG. 1 - BAC ETOUFFOIR.** (*smothering pan*)



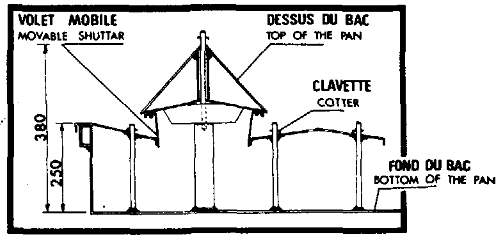
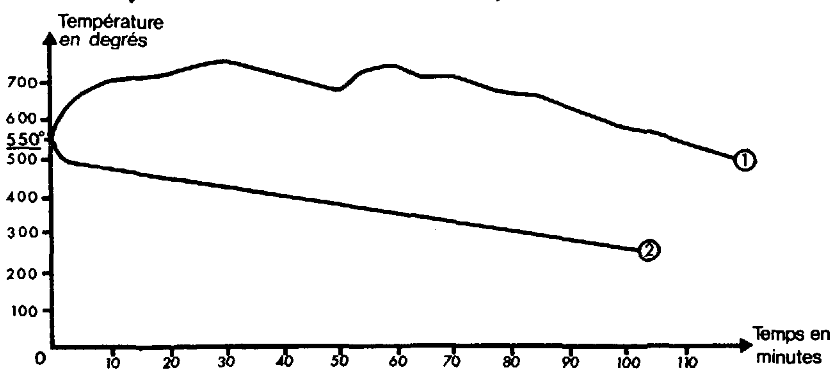



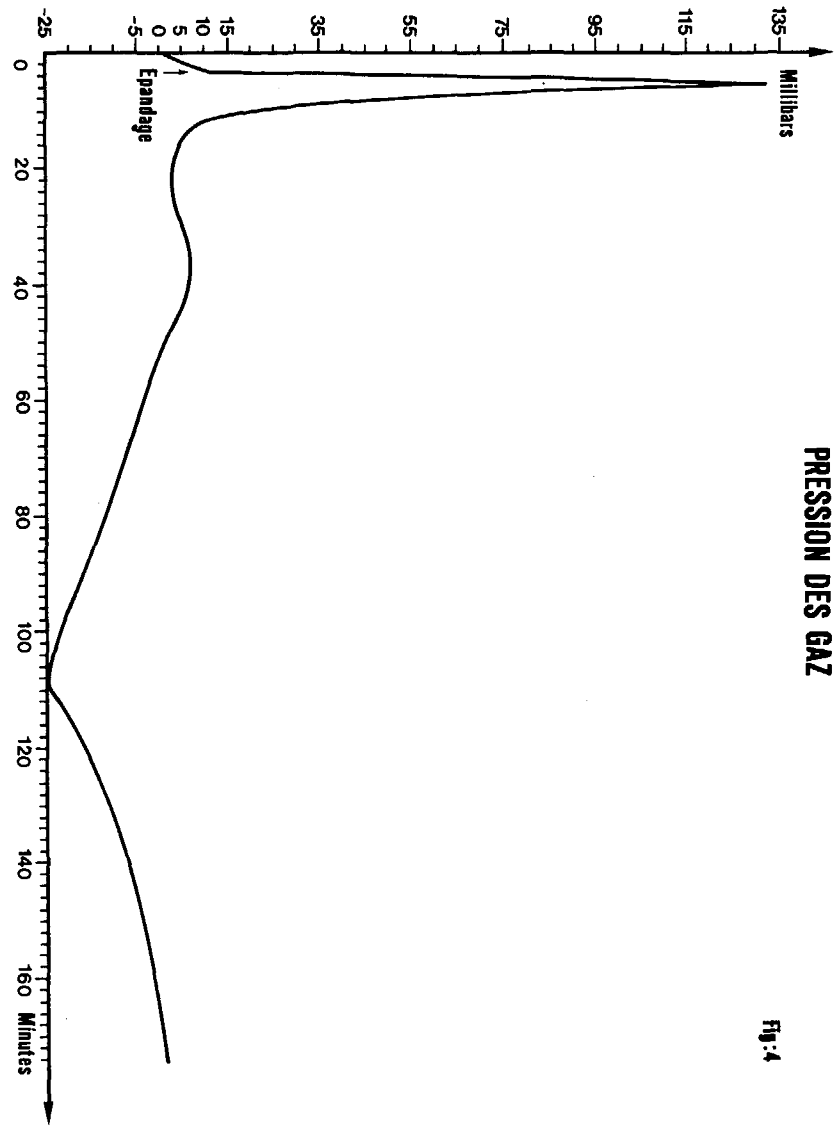

**FIG. 2** - DETAIL D'ASSEMBLAGE DES ELEMENTS

**FIG. 3 - TEMPERATURE MOYENNE DU SODIUM EN FONCTION DU TEMPS.** (*mean temperature of sodium versus time*)




① { **FEU EN NAPPE DE 300 KG A 550°C SUR 4m$^2$ SANS COUVERTURE**
Pool fire without cover(mass 300kg; initial temperature: 550°C ; area: 4 m$^2$ )

② { **FEU EN NAPPE DE 1000KG A 550°C SUR 9 m$^2$ AVEC COUVERTURE**
Pool fire with cover (mass 1000 kg; initial temperature: 550°C; area: 9m$^2$)




**PRESSION DES GAZ**

Fig:4

## TEMPÉRATURE MOYENNE DU SODIUM

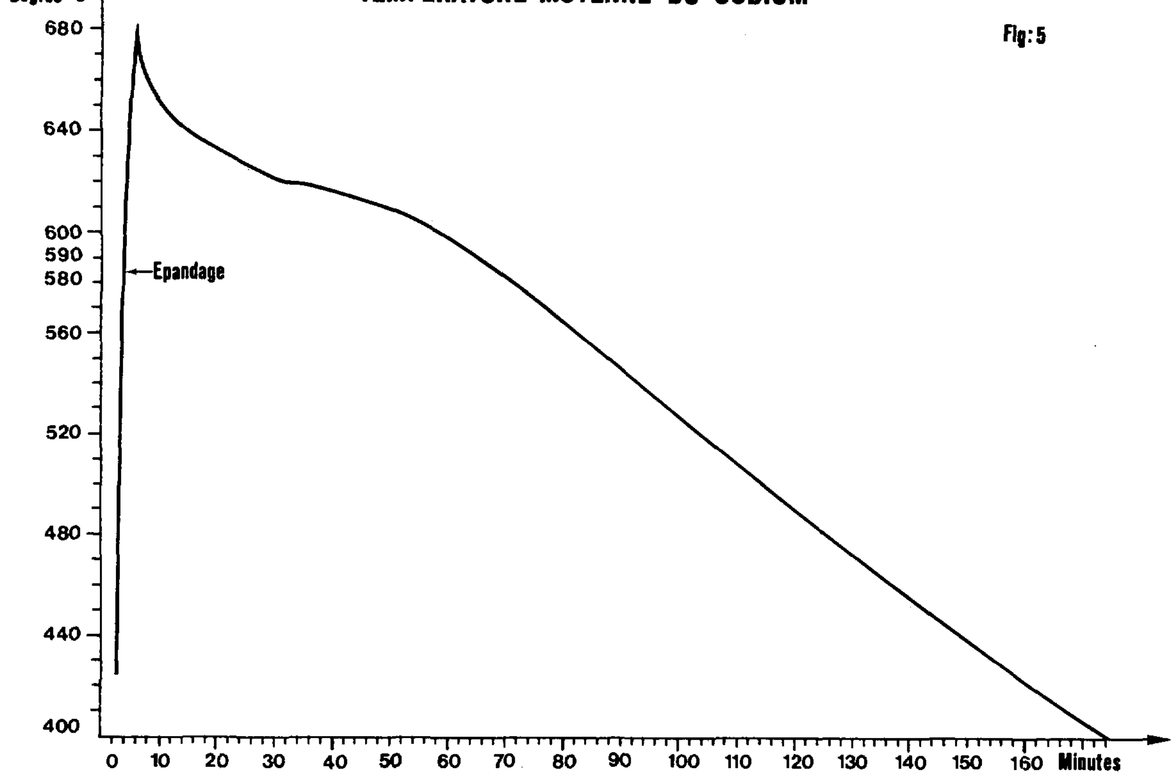



Fig : 5

## TEMPÉRATURE MOYENNE DES GAZ

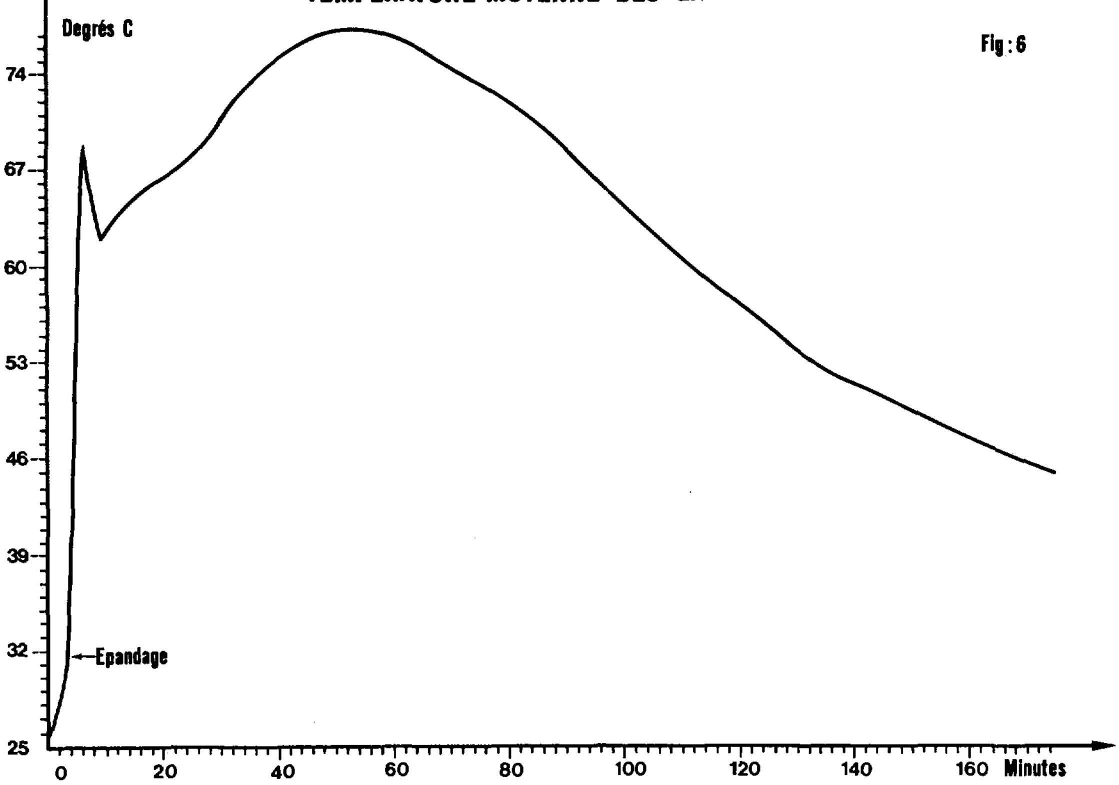



Fig : 6

Fig:7

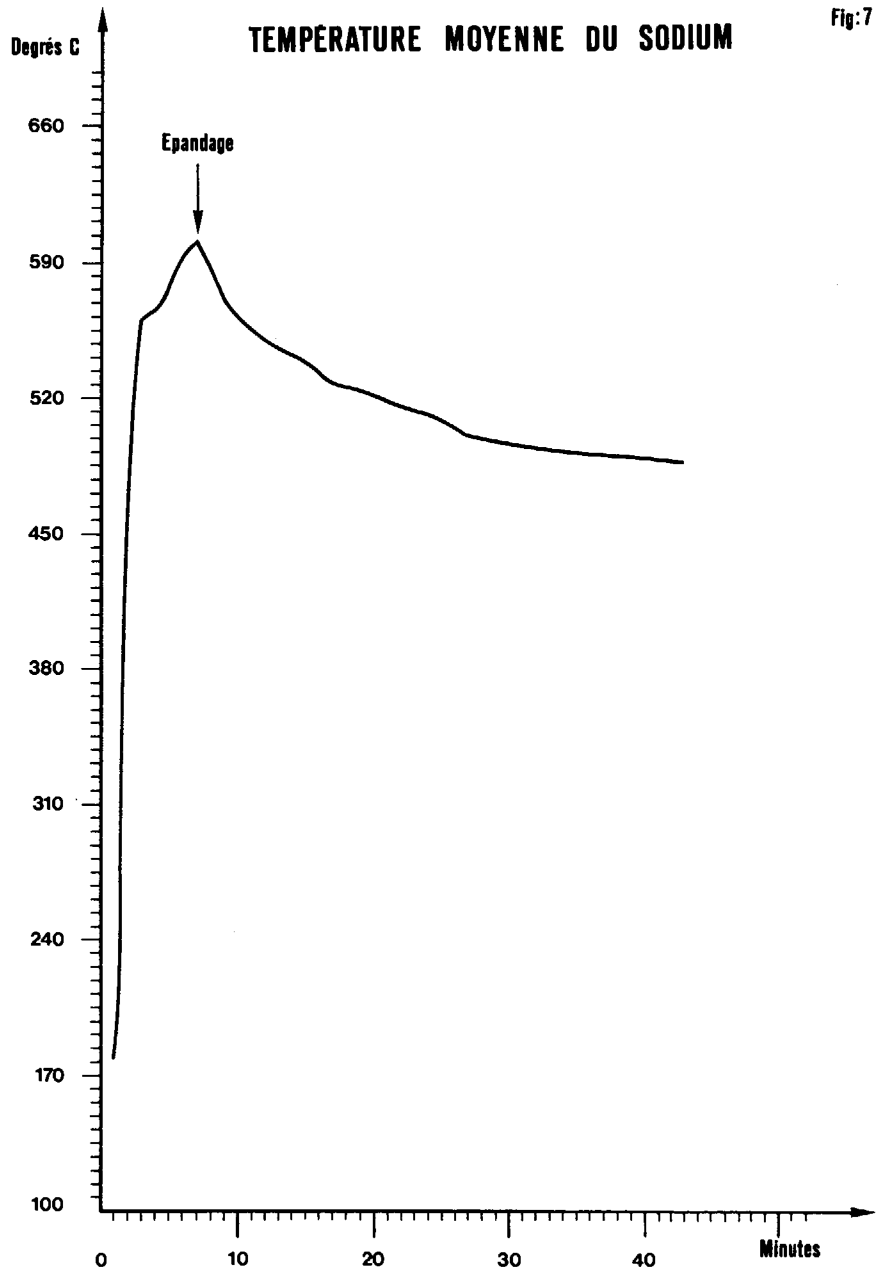

TEMPÉRATURE MOYENNE DU SODIUM
Degrés C
660
590
520
450
380
310
240
170
100
Epandage
0
10
20
30
40
Minutes

Fig:8

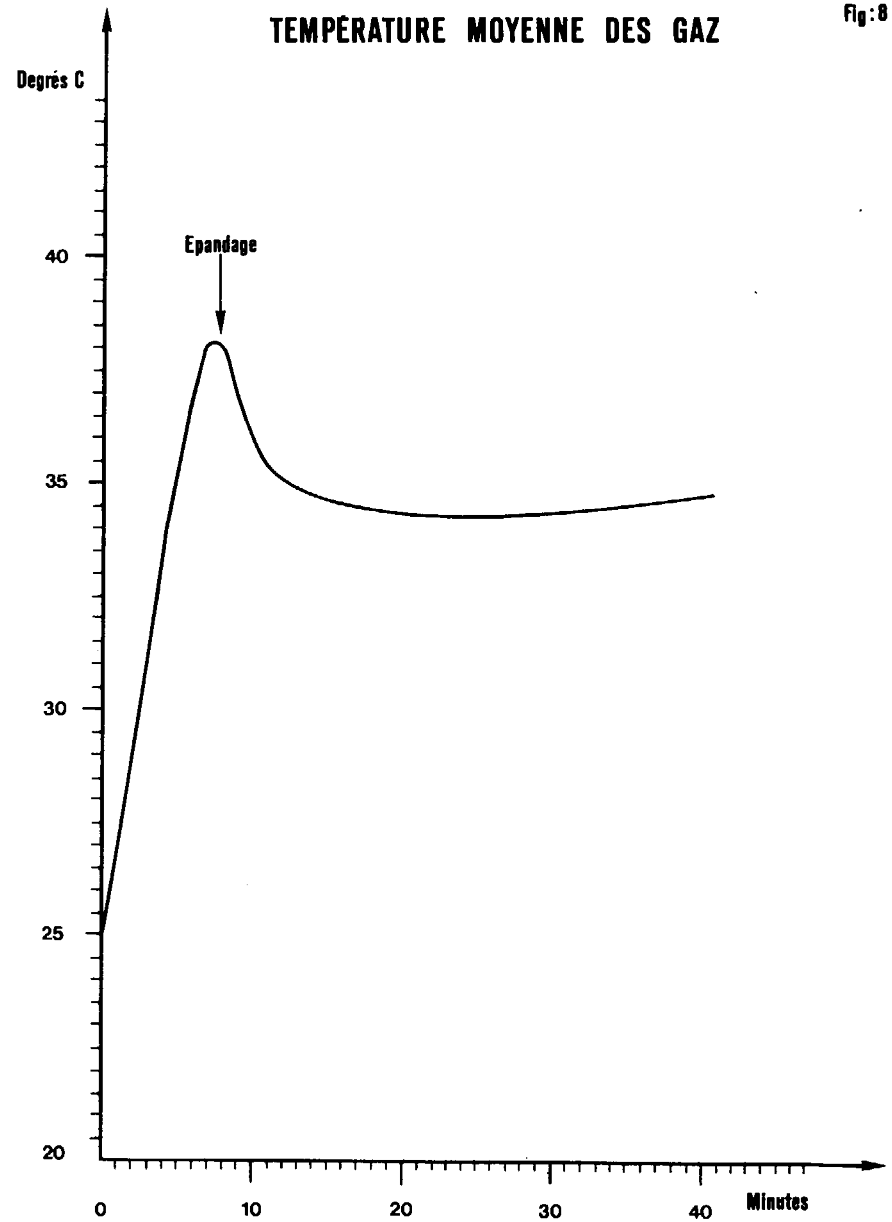
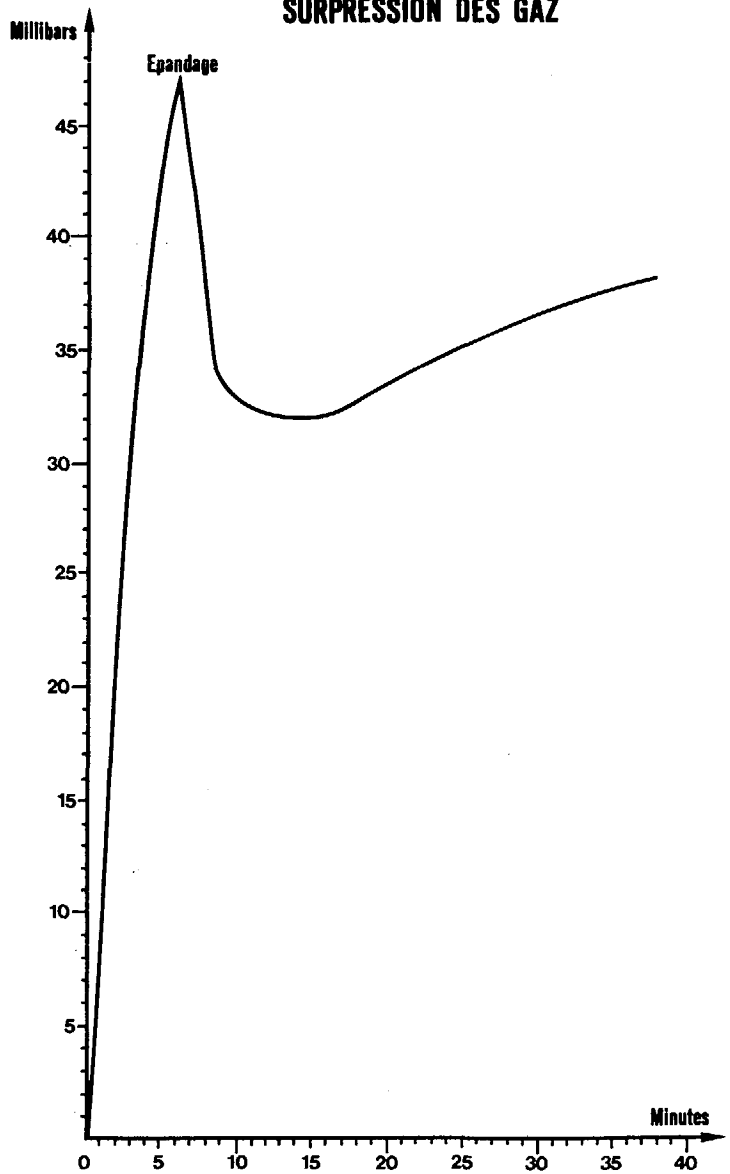

TEMPÉRATURE MOYENNE DES GAZ
Degrés C
40
35
30
25
20
Epandage
0
10
20
30
40
Minutes

Fig:9

SURPRESSION DES GAZ






# PROTECTIVE CLOTHING

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## ABSTRACT

The present operational and intervention suits are described. Research work is currently in progress to improve the performance of the existing suits and to develop more resistant protective clothing.

## 1 - INTRODUCTION

The increasing number of sodium test loops and the development of the fast neutron reactor program have increased personnel safety hazard levels. Adequate protection requires both standard operational clothing and special intervention suits. The former are intended to be worn at all times by the personnel working on the loops to ensure protection in the event of sodium leakage, while the latter - more cumbersome in use - are designed for intervention during and after a contained sodium fire.

## 2 - OPERATIONAL SUIT

Ordinary fabrics ignit spontaneously on contact with a very small quantity of sodium at 150°C, and the combustion quickly spreads over the entire garment. This