3. Operating Experience of RAPSODIE and PHENIX Relating to Sodium Aerosols and Vapours by J.P. DELISLE, M. REBOUL, X. ELIE, France

Abstract : The main difficulties resulting from sodium aerosols and vapours in the cover gas which have been encountered for 10 years in RAPSODIE and for 3 years in PHENIX are reviewed:

- . condensation of sodium in annular spaces
- . plugging in primary gas pipes
- . plugging of filters and vapour traps.

All those problems were easily overcome.

CONTENTS

INTRODUCTION

In spite of the precautions taken in the designing of the components and in spite of the preliminary tests on many equipments, the operating staff of RAPSODIE (since 1967) and of PHENIX (since 1973) has had to cope with difficulties resulting from the existence of sodium aerosols and vapours in the cover gas.

Insomuch as its is possible to avoid, through the acquired experience , the renewing of conception failures which have led to those incidents, it is of major interest to study the causes and the remedes of those incidents.

I - SODIUM DEPOSITS IN ANNULAR SPACES

I.1. RAPSODIE rotating plug

The annular space of the great rotating plug of RAPSODIE is shown on figure 1. When the reactor is operating, temperatures T_1 , T_2, T_3, T_4, are respectively round 250,100, 80 and 40°C.

In the course of reactor shut-down for assembly handling purpose T_1, T_2 and T_3 go down because of the sodium temperature fall, whereas T_4 increases slightly because of the liquefiable seal heating.

The first operating difficulties which occured from the very first year (1967) were easily overcome by a heating process of the plug ($T_2 > 100$°C) followed by a cooling together with frequent rotating mouvements just before handlings.

In 1969, we had to increase the heating temperature until 100°C in T_4 to release the plug, which shows a progression of sodium condensates up to the top of the annular space.

It was then decided to inject continuously a small flow of helium (200 l/h) in the upper part of the annular space. Since then, no more difficulties were encountered by the operating staff for rotating the plug.

This helium injection reduces temperature dissymetries and suppresses free-convection currents and consequently aerosols transfers.

From 1969 to 1974, the main primary gas circuit was still using argon for the control of pressure. Taking into account the helium injection in the rotating plugs, the cover gas of the reactor were in fact a helium-argon mixture , with about 80% hélium.

In 1975, argon was completely removed, and the use of pure hélium did not increase the rotating plug temperatures by more than a few degrees Celsius.

The rotation of the plug is always quite easy.

The small rotating plug of RAPSODIE has a similar design as the great one (annular space 15 mm instead of 16 mm).

This small plug caused no problem to the operating staff. However, to prevent any difficulty, it has been also equipped with a continuous helium injection (helium flow : 100 l/h).

I.2. PHENIX Rotating plug

The rotating plug design of PHENIX (figure 2) is different from that of RAPSODIE since when the reactor is operating the plug lays on a flat support which closes the annular space at the level on this support.

The radial clearance of the annular space is 45 mm.

A checking hole of the vertical annular space was also foreseen. The normal temperature on the top of the annular space is higher than 100°C.

Although, no difficulty was encountered in the rotating of the plug, two endoscopic examinations of the annular space were carried out, one in october 74, the other in august 1975. A thin layer of sodium (estimated to 2 or 3 mm) was noted on the walls. There was no significant change between the two examinations. Thus, these sodium condensations should not trouble the rotation before several years.

I.3. PHENIX control-rod mechanism

One of the two types of control rod-mechanisms of PHENIX is not equipped with a bellow tightness. Thus, there exists a long argon annular space bathing in sodium between the guiding tube and the translation tube (figure 3).

A continuous argon sweeping of that annular space was initially realized to prevent any penetration of sodium inside the mechanism. Argon got out through three holes located under the sodium level.

Following an incomplete fall, a mechanism had to be unloaded in february 1974. A "mesos" deposit was shown in this annular space (mesos : mixture of sodium and oxide or hydride of sodium).

It has been assumed that this deposit came from the continuous sweeping, oxides or hydrides formed from arong impurities which cannot be removed by a clean sodium circulation. This clogging risk was shown during the tests of a prototype mechanism in sodium at CADARACHE. Tests of reactor mechanisms at CADARACHE were realized without sweeping, keeping a static argon pressure in the annular space.

Then sweeping was stopped on the reactor and an examination has shown in august 1975 that there was not any trace of deposit left in the annular space.

I.4. Plug of an experimental channel on PHENIX

The handling of an experimental channel plug was scheduled for august 1975 (figure 4). The lifting strength for unsticking the plug reached 1 000 kg, then stabilized to 200 kg (plug weight) on a 1 800 mm stroke. On an about 30 mm stroke, it suddenly increased to reach 8 000 kg. The strength necessary of get it back into position was of about 600 kg.

It shall be noticed that, when the incident occured, all the temperatures of the rotating plug were lower than 100°C. In the course of the following shut-down, the handling which was carried out before complete cooling of the rotating plug, took place without difficulty, which proves that the plug lifting was really hindered by sodium condensations in the annular space.

II - MAIN PRIMARY GAS CIRCUIT

II.1. RAPSODIE

a) Pipings

During the first years of operating pluggings were observed on "hot" pipings (150 - 250°C) of the primary gas circuit. By releasing into the funnel instead of recycling the gas flow taken from the reactor for analysis purpose, those incidents were on the whole avoided. This action removes the pollution of the circuit by air injected in the analysis apparatus. This air oxidizes and hydridizes aerosols in the pipings, deposits appearing then as solid instead of liquid.

Furthermore a cleaning of the pipings is carried out with sodium at 250°C from time to time (every 2 or 3 years) to remove eventual deposits. this process is very efficient.

No plugging of this type is to be noted since january 1974. The only plugging that happens regularly occurs in a lower point where the normal temperature is too low : but it is here pure sodium that condensates and freezes since unplugging is obtained with a mere periodical heating of that point (every 2 months).

b) filtration equipment

Initially, the primary circuit gas went directly in a vapour trap through NaK bubbling for recycling or release. This bubbler being plugged the circuit was modified (figure 5).

Aerosols trapping now occurs by a mere decantation in the 30 m^3 of the sodium storage tank, cold and empty when the reactor is operating.

The permanent flow is of 150 l/h, maximum flow being 6 m^3/h.

A sintered stainless stell filter is set on the storage outlet. No increase in the pressure drop was observed since its completion (4 years).

II.2. PHENIX

We have noted in the course of the reactor tests in 1973 that the filters located downstream the condenser-separator (figure 6) were subject to fast pluggings (24 h). Those pluggings occured by a recycling argon flow of 50 m^3/h.

These pluggings of filters were partly attributed to an aerosol concentration much higher than that was foreseen and in any case much higher than that of the testing installation on which the condenser-separator was tested at CADARACHE. As it was shown that argon heating before re-injection removed a major source of aerosol production, the return line temperature on the reactor was increased to 300°C.

On the other hand the test carried out at CADARACHE had also proved that the efficiency of the condenser-separator increases with the inlet temperature. Thus the temperature of the coupling line with the condenser-separator was increased until 350°C.

Since those modifications, there was no more large flow (50 m^3/h) recycling tests, but after two years of operating with flows from 4 to 10 m^3/h, we have never noted a change in the pressure drop of filters. If we take into account this period of time, the ratio of flows and the ratio of the efficiencies to those flows we think that the circuit should be able to cope with a large flow recycling of about one week without plugging, for instance in the case of an epuration of the cover gas to remove all fission products before a special intervention. However, that remains to be proved.

III - ANALYSIS GAS CIRCUITS

III.1. RAPSODIE (figure 7)

The gas (150 l/h) is taken from the reactor Vessel. Initially the trap was fitted on the great rotating plug of the reactor and to be removed for every handlings with all the problems resulting from the activity of aerosols deposits, with the risks of pollution of the circuit by inlet of air through removable fitting on hot piping and so on...
Once or twice a week, the trap should be "regenerated" by heating round 300°C in order to get the deposits melted and to return them back into the vessel. But, after a time, this trap plugged.

In june 1975, this trap was replaced by a new model fit within a channel of the small rotating plug. The operating of this new integrated trap is perfect. And still now, no regeneration has been necessary ; this result is probably to ascribe both to the operating with pure helium (which any doubts reduces the aerosol concentration) and to the fact that no accidental pollution from air is possible since there is no more removable fitting between the vessel and the trap.

III.2. PHENIX

The argon taking happens directly in the argon cover of the reactor (with a 250 l/h flow). Two vapour traps, one being in operation and the other being either regenerated or in waiting, clean the argon before it flows towards the detection equipment of fuel failures.

These traps, which have a 10 l volume, are made of stainless steel knit. Their operating time between two regenerations is comprised between 100 and 150 h. After two years of operating, it was not necessary to change these traps.

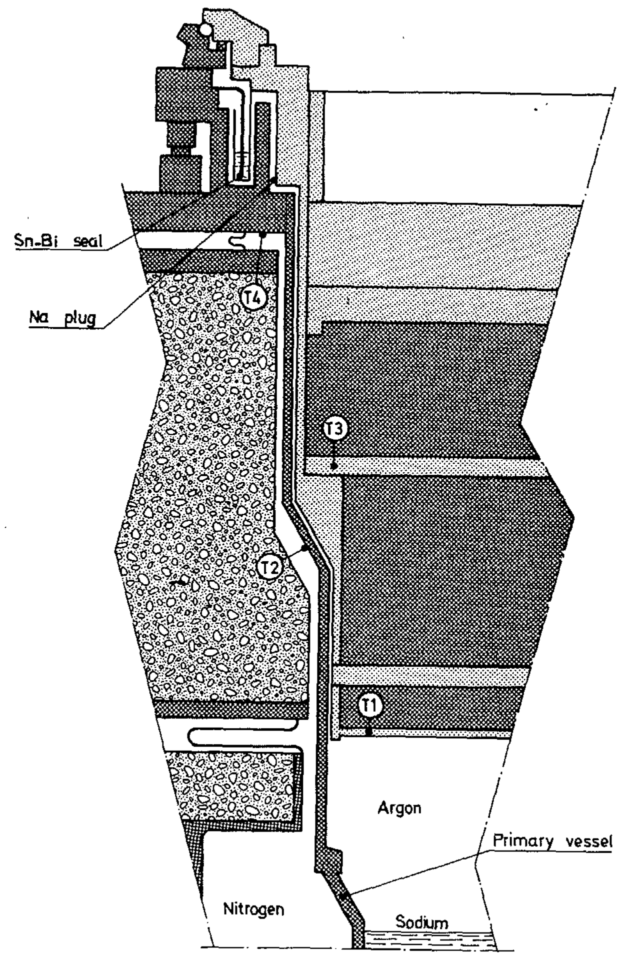
CONCLUSION

The study of the difficulties resulting from sodium aerosols encountered in the operating of RAPSODIE and PHENIX gives rise to the following remarks :

1) no solution was found to the ground problem of annular spaces pluggings, even if the operating staff found how to cope with it or to avoid it. There shall always be a problem as long as we shall not have developed equipments capable of preventing the free convection movements of gas with aerosols in the annular space,

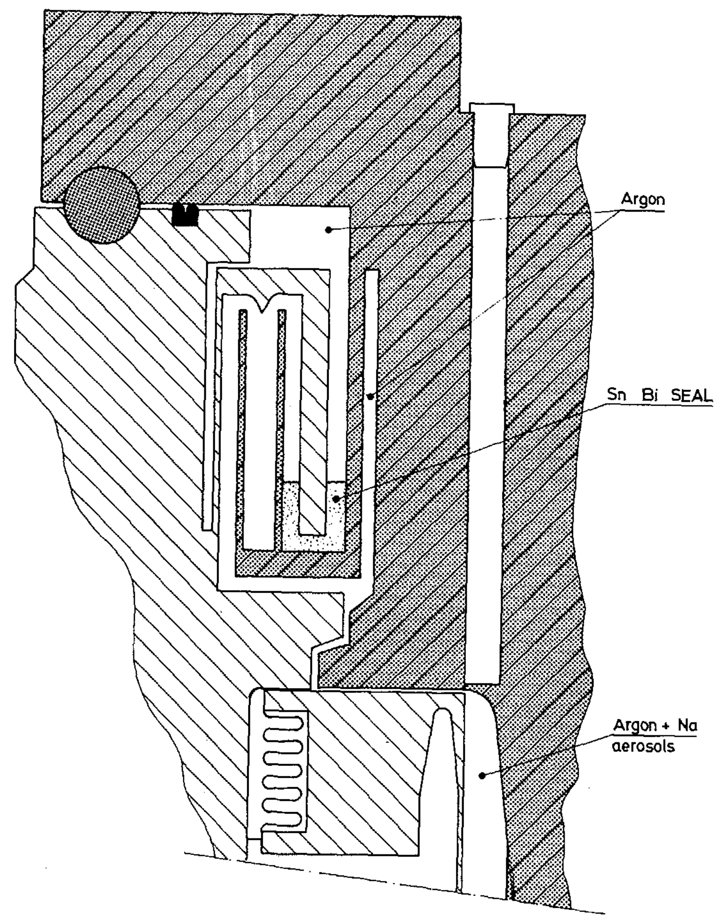
2) without ignoring the improvements that development works on filtration equipments may bring forth it seems necessary to put all our efforts on the initial reducing of aerosol concentration in the gas.

In this respect, as far as we can judge from the experience of RAPSODIE, the use of helium as cover gas seems very promising.



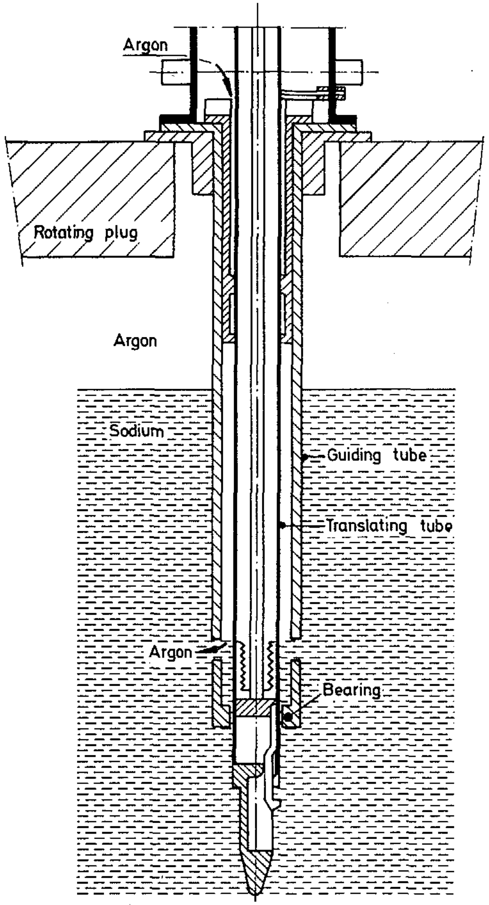
RAPSODIE - ROTATING PLUG

FIG. 1



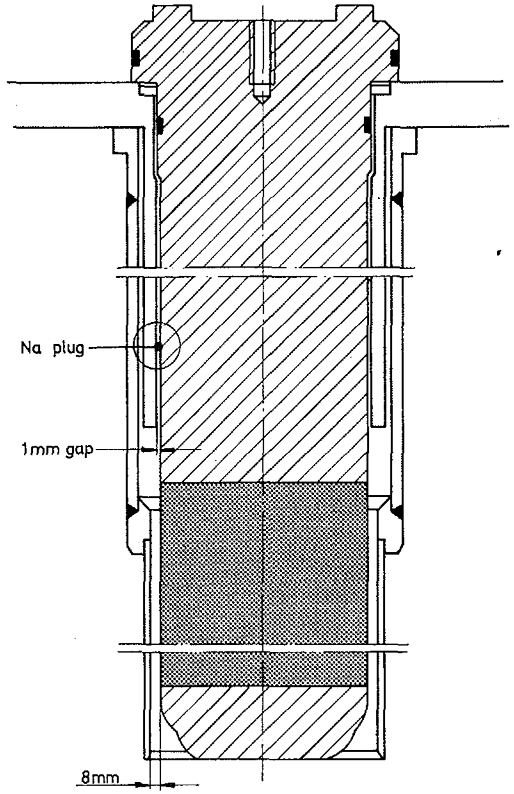
PHENIX - ROTATING PLUG

FIG. 2



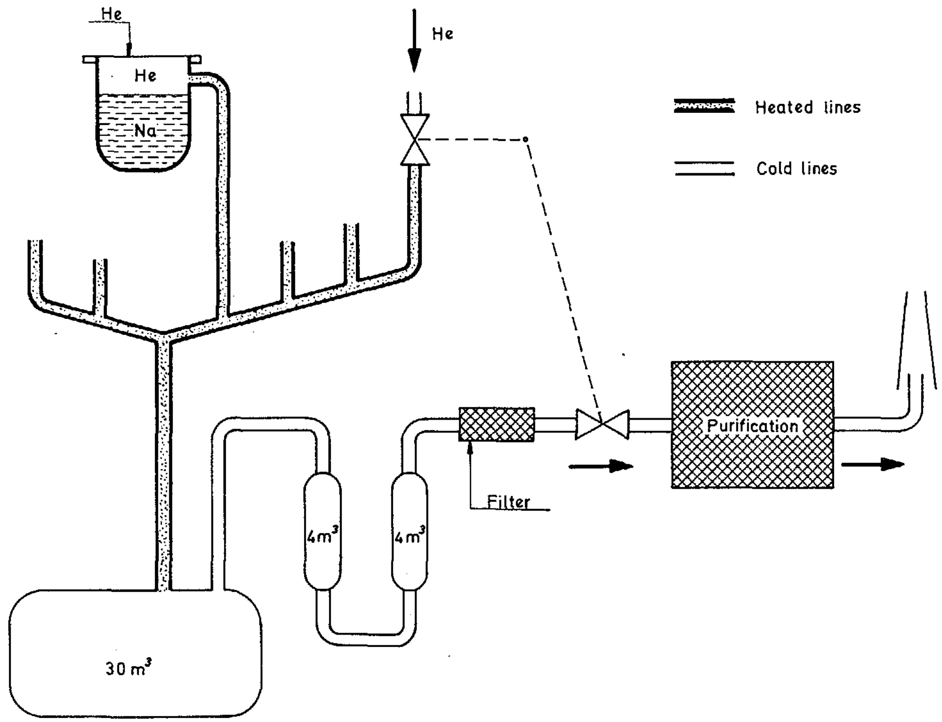
PHENIX – CONTROL ROD MECHANISM

FIG. 3



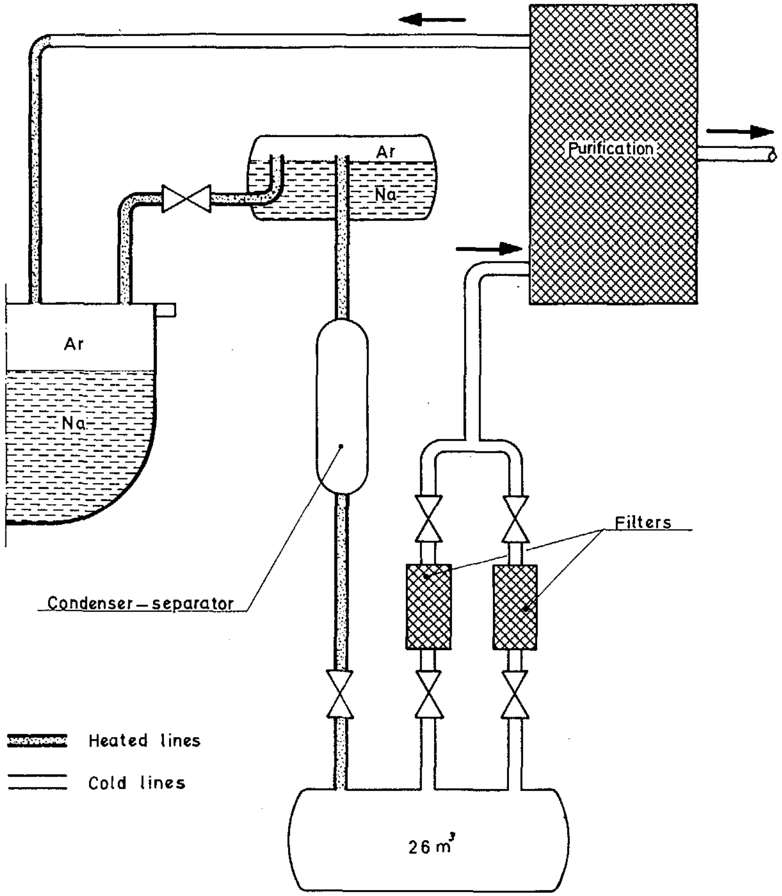
PHENIX – EXPERIMENTAL DEVICE PLUG

FIG. 4



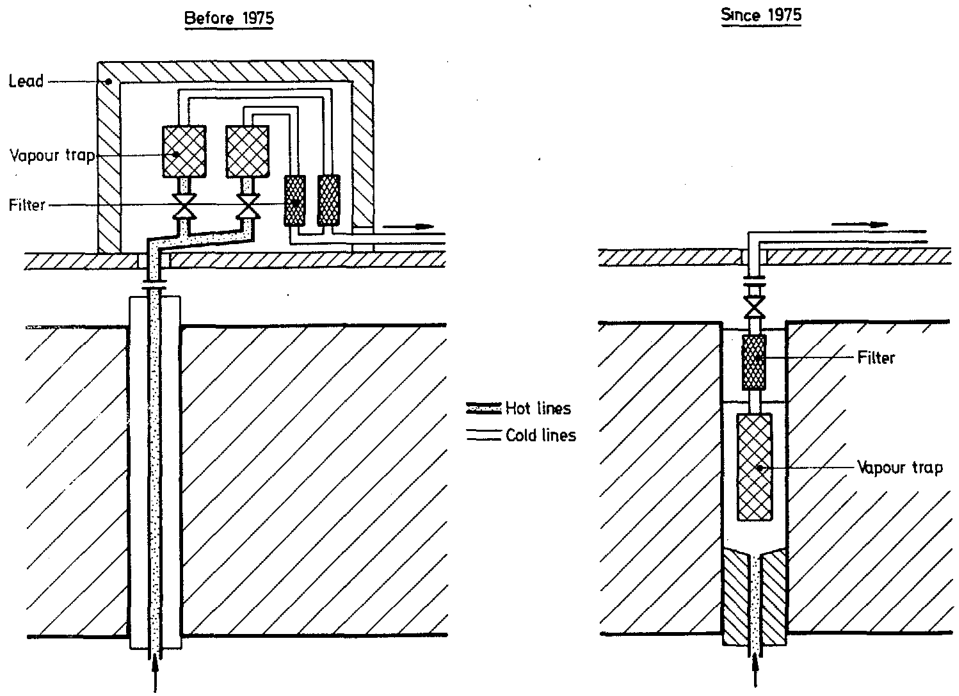
– RAPSODIE – PRIMARY HELIUM CIRCUIT

FIG. 5



\- PHENIX -
PRIMARY ARGON CIRCUIT

Fig. 6



RAPSODIE – SODIUM VAPOUR TRAPS

FIG. 7