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# NaK HANDLING AND REMOVAL

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**Abstract**

Sodium-potassium alloy is used in specific application in French Fast Breeder Reactors as:

- cold traps,
- NaK bubbler for argon purification,
- valves

and also in experimental irradiation devices.It has been preferred to sodium because it is liquid from + 7 °C for the most common peritectic alloy.After its use, NaK is considered as a hazardous waste (nuclear or not) due to its high reactivity with air and water.

The most important risk remains in handling NaK systems which have not been operated for some time.The NaK will be covered with a crust of the superoxide K02 which is a strong oxidising agent.

Thermodynamically, K02 will react with most organic material or metallic dust or swarfs and can also react with additional NaK to give sufficient heat to boil part of the NaK, resulting in a sudden increase in pressure and small explosions.

We describe the formation given to experimenters in our Sodium School and the CEA's experience in treating specific devices for transportation, decanting of tanks, tank opening and NaK removal.

## 1. INTRODUCTION

Amongst the liquid metals used in fast reactors, sodium-potassium alloy (NaK) is used in specific applications such as the cooling of cold traps, valves or bubble chambers to purify argon. NaK is also used in special irradiation devices.

The most commonly used mixture is the peritectic alloy which has a 52 % K mass composition (40% atomic) which has a fusion temperature of 6.9 °C, and is liquid up to 810 °C under normal pressure.

After use, NaK is considered as a dangerous waste (whether active or not) due to its high reactivity with air and water.

The purpose of this paper is to present the CEA at Cadarache's experiments in relation to the handling and destruction of components' inactive NaK.

## 2. NAK SAFETY

When the NaK is not oxidised, the safety procedure is identical to that of liquid sodium in relation to air and water, with a reaction a bit more important for the NaK. However, precautions have to be taken for oxidised NaK handling, even more so when in contact with large quantities of oxides.

In fact, when in contact with air oxygen, sodium oxides are formed ($Na_20$ and $Na_20_2$) and potassium oxides ($K_20$ potassium oxide, $K_20_2$ potassium peroxide, $K0_2$ potassium superoxide).

It is the formation of the superoxide which is the main source of danger. This formation occurs when the NaK is covered by an atmosphere containing oxygen, for example, in tanks of NaK which are not completely sealed, one finds a superoxide crust on the NaK surface.

$K0_2$ is a highly oxidising agent which reacts with most organic material and with NaK, by causing small explosions and a rapid increase in pressure due to the increase in temperature and the generation of gas.

The reactions are promoted by the presence of metal filings or by impacts on the container.

When we need to handle or displace NaK drums, we set a safety valve on the drum to control pressure and often we freeze NaK at low temperature in order to solidify it to avoid reactions.

## 3. OPERATOR TRAINING

A safety training session in connection with NaK was implemented for CEA operators at the end of 1996. This session, provided by the Ecole du Sodium (Sodium School) at Cadarache, is now open to all operators wishing to be trained.

It is spread over 3 days and includes the following courses:

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|---|---|
| *1st day*: | Sodium derivatives, the chemical properties of NaK, safe intervention in a NaK environment, washing and destruction of NaK and its derivatives. |
| *2nd day*: | NaK sampling procedures with practical work, destruction of NaK in the laboratory, operation on reactors (Quality Assurance and experience feedback). |
| *3rd day*: | Presentation of the Madenak destruction procedure, destruction of NaK, case study and evaluation of session and participants. |

## 4. EXPERIENCE FEEDBACK ON THE DESTRUCTION OF NAK

### 4.1. Surboum containment:

Destruction of sodium or NaK is carried out in the Surboum containment.

The facility is mainly composed of:

- a destruction cell,
- a Peabody aerosol washer,
- a soda treatment assembly.

This facility was made for the destruction, by hydrolysis, of 50 kg quantities of sodium per hour. Each kg of sodium destroyed requires approximately 7 kg of water.

*4.1.1. Destruction cell:*

This is a concrete construction with a blowing roof, with a ground surface area of 4 m x 8 m and a 150 $m^3$ volume. The bottom and the lower section of the cell are covered with stainless steel plates.

Three manually controlled water hoses make it possible to spray the parts stored in the cell. These hoses are operated from the adjoining monitoring-control room.

Windows (one per hose) make it possible to follow the progress of the operations.

A suction duct evacuates the fumes towards a Peabody aerosol washer.
An opening bored in the cell door provides a sufficient air passage for this suction.

The soda collected in a sump located at the cell's low point is evacuated by pumping towards a tank located outside.

*4.1.2. Peabody aerosol washer:*

A fan providing an output of 10,000 $m^3/h$ sucks the aerosols which are in the destruction cell. These aerosols, before being released into the atmosphere, pass through sprayed water curtains. This sprayed water circulates in a closed system inside the washer through a pump.The main body of aerosols are trapped in the aerosol washer.

*4.1.3. Soda treatment assembly:*

The soda or potash formed in the cell at the time of destruction of the sodium is transferred and stored in a storage tank situated outside the building.

This soda storage tank is a horizontal cylinder made of A42 steel, with a sensitive volume of 12 $m^3$. Its service temperature is 80 °C.

When it is filled, the tank is drained into the chemical water collector of the Centre after pH and contamination checkings.

### 4.2. Madenak:

The liquid character of NaK at an ambient temperature made it necessary to construct a machine for the destruction of NaK called "Madenak".

The principle diagram for this equipment is shown in Fig. 1.

This machine is designed to destroy non active NaK which is relatively "clean" (with few oxides).

It is implemented in the Surboum containment which is used as a protection in relation to risks of explosion or NaK fire.

The principle of the Madenak procedure is based on the constant destruction of NaK. The current destruction rate is 9 kg/h, a performance which we hope to increase to reach 15 kg/h.

The transfer of NaK towards the Madenak equipment is achieved by pushing by gas pressure on the tank situated outside the Surboum premises.

All these operations are controlled from outside the containment, in protected premises.

The advantage of this equipment is its simplicity of use and implementation, and the possibility which it provides for the daily destruction of sizeable volumes of NaK, using a machine of reduced bulk (approximately 1.5 $m^3$).

The main difficulties relate to start-up periods, after a long halt.
It is then necessary to ensure the total cleanliness of the equipment by an adequate cleaning (hydrolysis then drying). This makes it possible to avoid reactions between any remaining oxidised NaK with the NaK to be destroyed (sometimes violent heating, sudden increase in the pressure).

### 4.3. Tank opening:

When a tank has been drained, it must be opened in order to destroy the remaining NaK (< 10 kg).

The technique used is that of an explosive string wound around a tank situated in the Surboum premises previously mentioned. During the explosion, the string cuts the drum's plate (2 mm thickness) on its entire periphery. If it does not catch fire, the NaK is destroyed by atomised water hoses.

Several drums containing 250 kg of NaK (630 mm diameter, 1,300 mm height) were opened after draining, in accordance with this principle, from 1989 to 1996 [drum diagram in Fig.2].

## 5. EXPERIENCE FEEDBACK ON THE HANDLING OF NAK

### 5.1. Transfer of NaK at CREYS-MALVILLE, FRANCE:

Within the framework of change of the four SUPERPHENIX secondary loops' sodium cold traps, it was necessary to ensure in turn the sequences of both draining of the NaK contained in old traps (approximately 870 litres) and the filling of new model cold traps with NaK (approximately 530 litres) [Fig.3].

Prior to each draining, a sample of NaK was taken in order to confirm the mass concentration of both elements, as well as a radiological analysis. A device was developed in order to take rapid and reliable samples [Fig. 4].

The new cavities concerned (storage tanks and dual cold trap enclosure) were the subject of operations aimed at ensuring their cleanliness: primary vacuum or oven loading sequences.

For the transfer operations, all valves were fitted with PERBUNAN membranes.Account was taken of tests mentioned in various bibliographies, particularly data distributed by the NaK manufacturer (Callery compagny). In addition, a series of soaking in cold, then hot NaK, on several types of membranes was carried out within the department, in order to validate them. The membrane matters tested were neoprene, butyl rubber and perbunan.

The butyl rubber and perbunan behaved satisfactorily.

### 5.2. Transport of a large size NaK bubble chamber:
(425 litres of NaK, 3 $m^3$ total volume)

In March 1996, the Service de Technologie des Métaux Liquides (Liquid Metal Technology Service) transported a large size NaK bubble chamber from the Phenix reactor located in Marcoule, in the Gard department in France, to Cadarache. The distance between the two sites is approximately 130 Km [Fig. 5].

This device was used for the purification of argon supplied to the reactor. It had become obsolete following the installation of a better large capacity argon storage. It is due to be destroyed.

The operation therefore concerns a particularly reactive NaK, taking into account the presence of a large quantity of oxides and sodium and potassium peroxides, as well as carbonaceous compounds arising from treated argon impurities.

Prior to any handling or displacement, the NaK was solidified at a temperature of -18 °C and the bubble chamber was fitted with a safety valve. The NaK solidification was performed using an isotherm box and an industrial refrigeration unit (emergency equipment was kept available at the hirer's, with an operation time of less than four hours).

This temperature appeared to us to be the best possible compromise between:

– A temperature which was sufficiently low as to allow adequate action times in the case of stopping of the refrigerating device.

– A temperature which was sufficiently high in order to avoid weakening of the carbon steel which constitutes the device.

The internal pressure in the bubble chamber, as well as its temperature at several points, were monitored and recorded during the whole of the NaK solidification and transport periods, and at the time of its return to the room temperature.

Due to the bubble chamber's thermal inertia of the bubble chamber, the pressure was the sole parameter which allowed us to follow the internal phenomena which occurred.

Destruction of the bubble chamber and NaK should be carried out in 1998.

## 6. CONCLUSION

Handling and destruction of non active NaK waste are highly delicate operations, particularly when oxides are present.

These operations require well trained specialised personnel.

The STML has developped processes and constructed the Madenak machine in order to perform these operations itself, particularly for the destruction of its own stock. This stock is currently estimated at 90 tanks, that is to say, in the order of 4 $m^3$ of NaK.

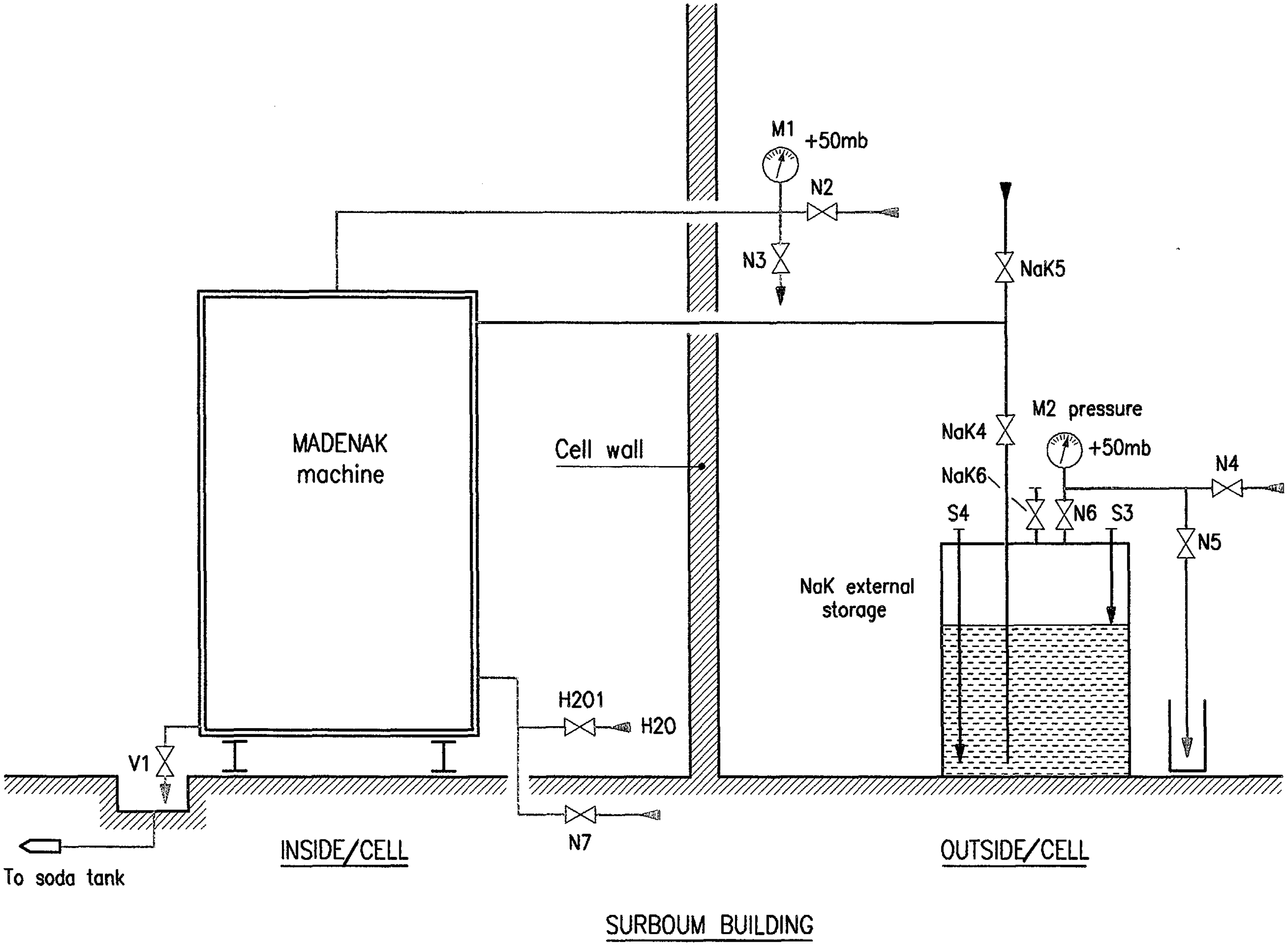


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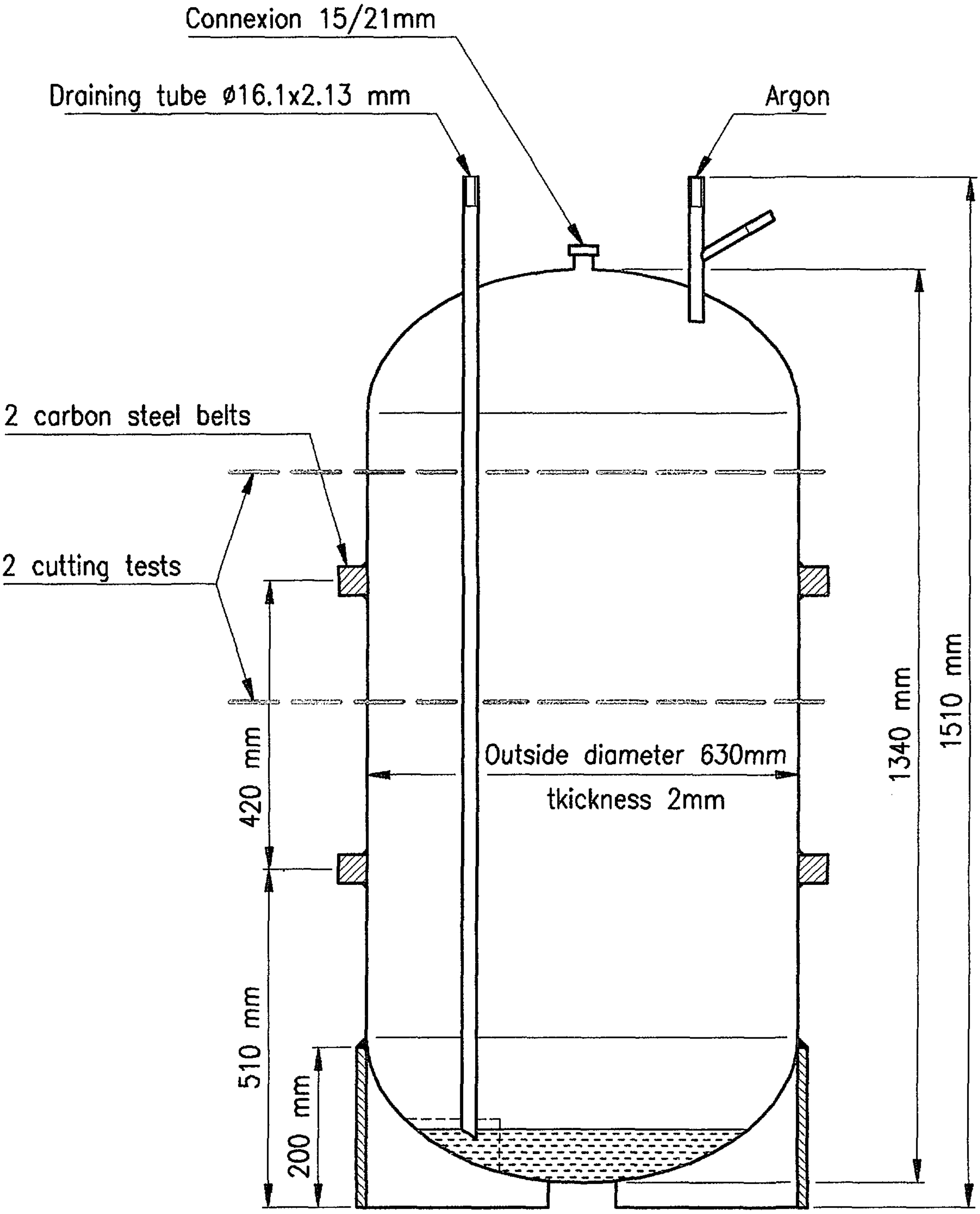
Figure 1

MADENAK flow diagram

Figure 2

# NaK storage tank




Storage tank weight : 325 kg
NaK weight : 250 kg
Material : tank body 304L

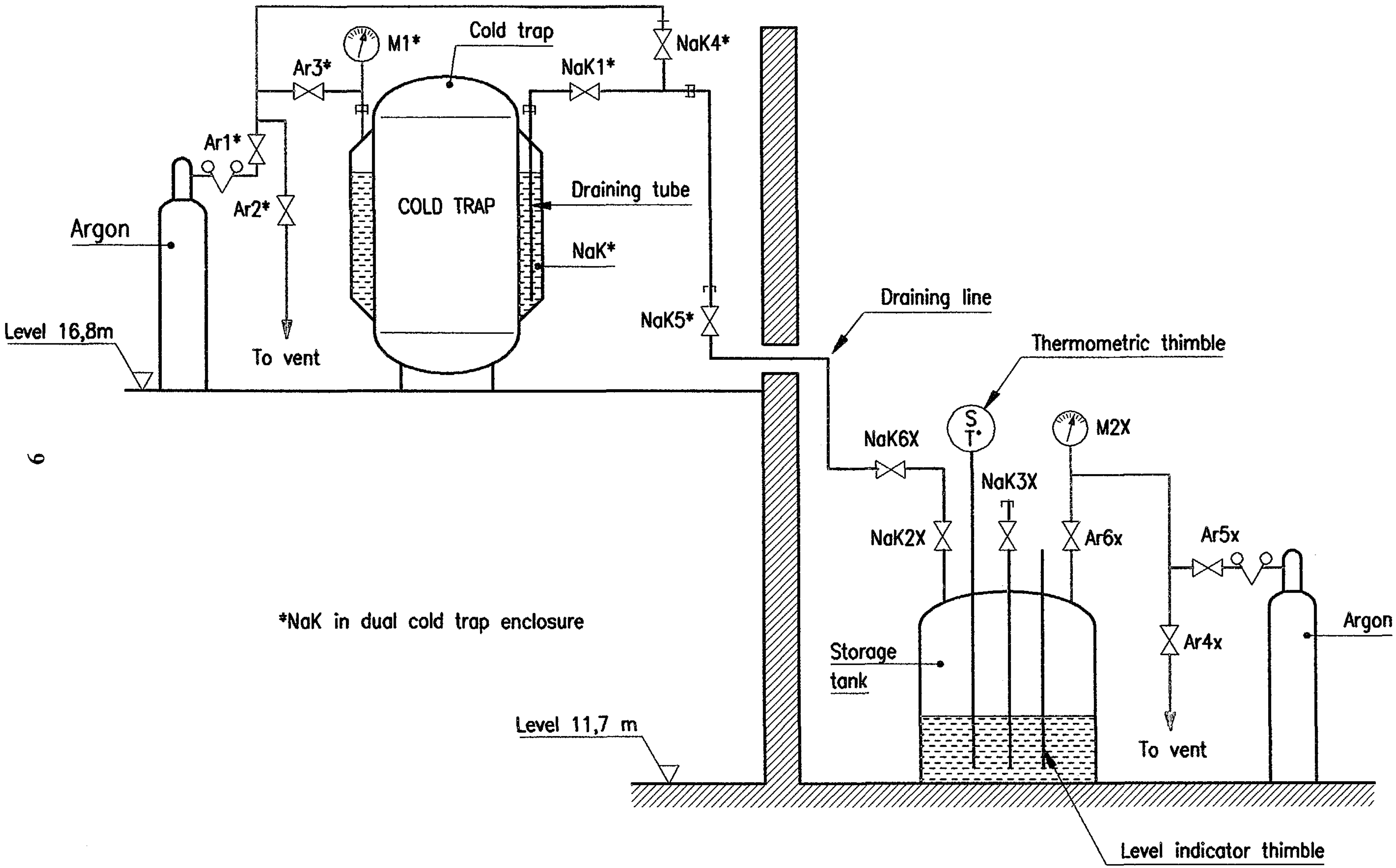



Figure 3

Schematic flow diagram for old pattern cold traps draining

Figure 4

# Sampling-device for NaK

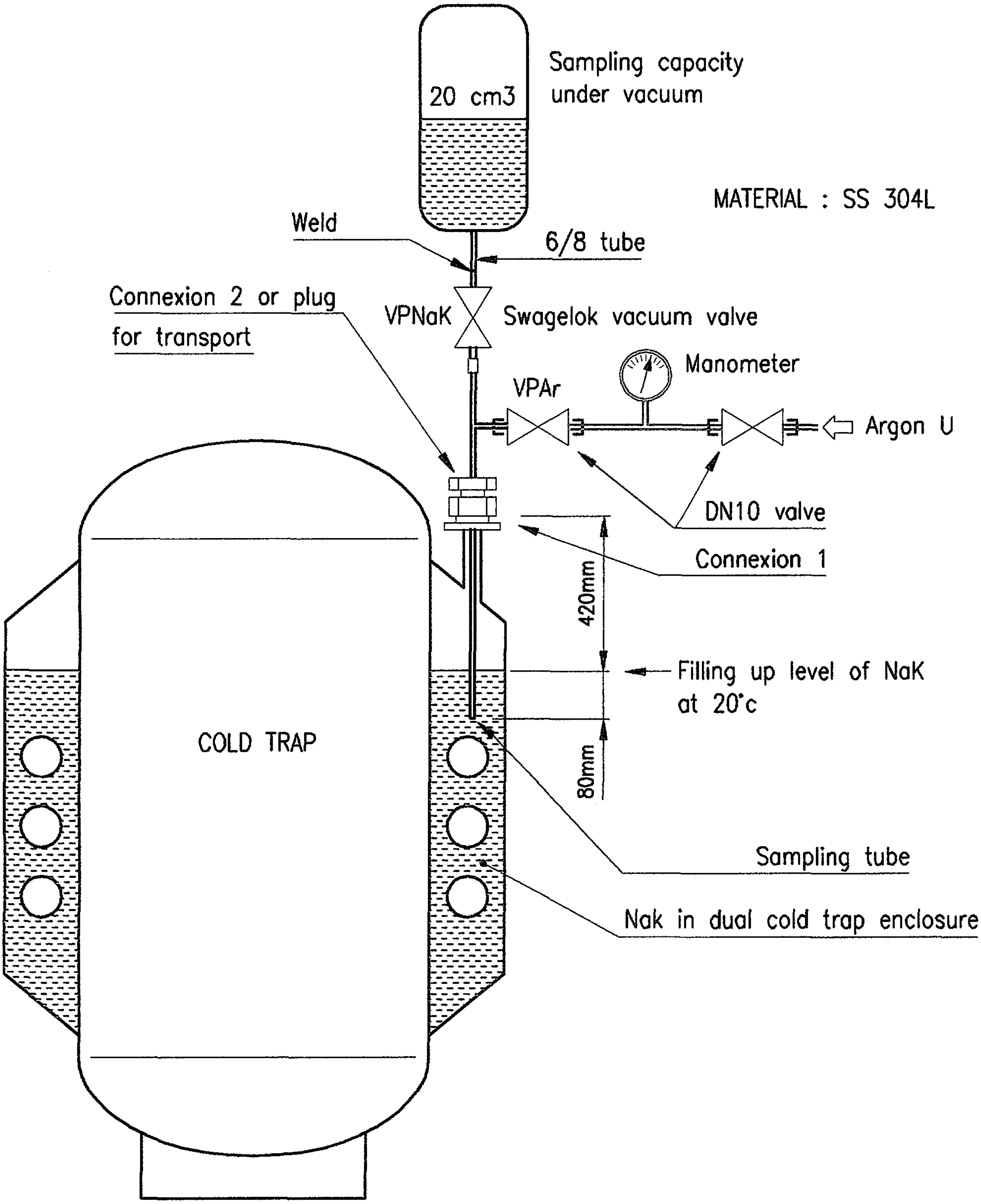
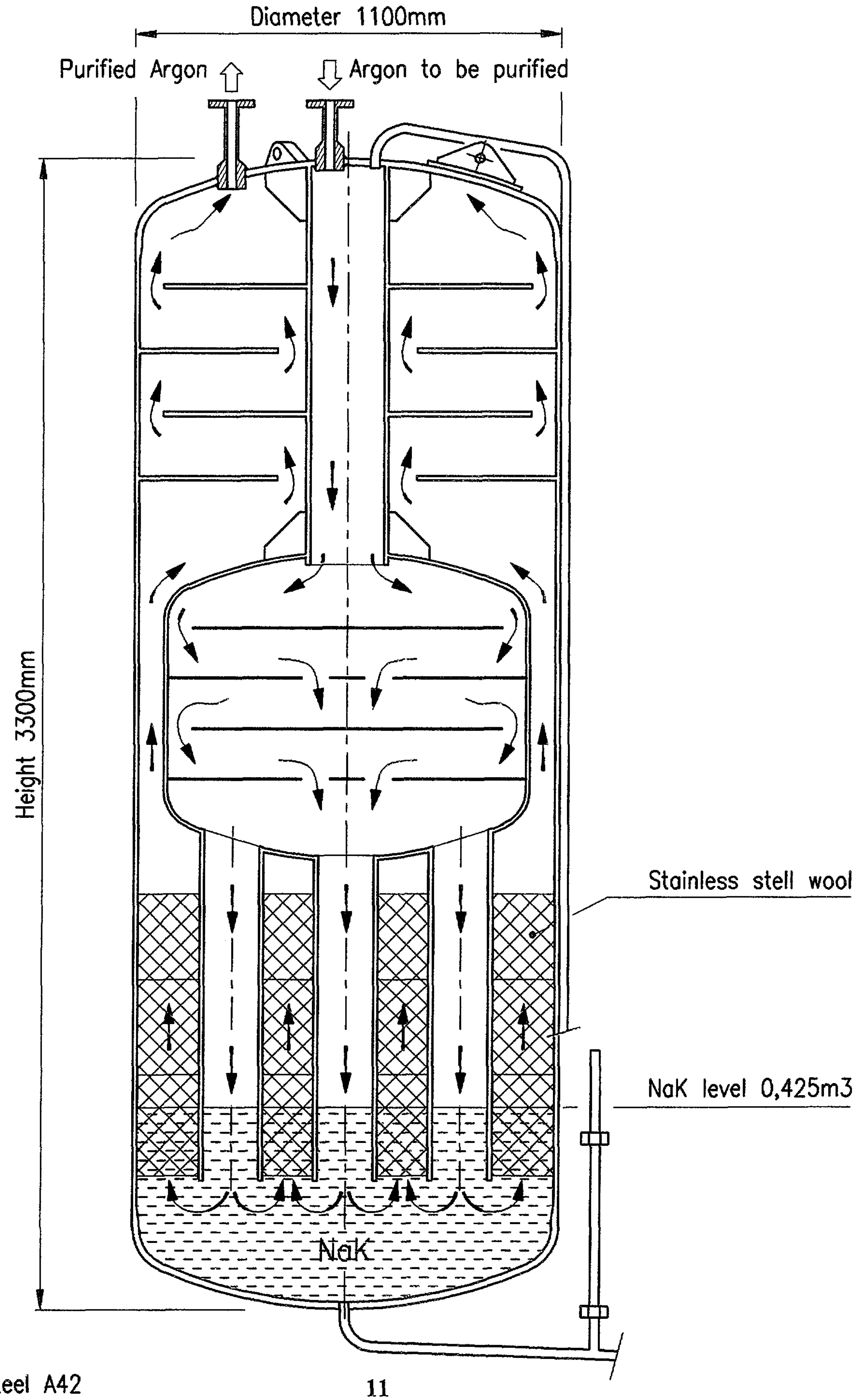


Figure 5

# NaK bubbler for argon purification




Material : Carbon steel A42