KERNFORSCHUNGSZENTRUM

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The Karlsruhe Sodium Tank Test Facility

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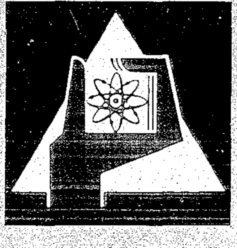

GESELLSCHAFT FUR KERNFORSCHUNG M.B.H.

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F. Huber
R.A. Müller

Gesellschaft für Kernforschung m.b.H., Karlsruhe

Abstract

The Sodium Tank Test Facility operated by the Institute of Reactor Development of the Karlsruhe Nuclear Research Center is described. This facility offers universal application allowing full scale and semi-technical scale studies of the manifold questions in the field of sodium technology. It consists of two vertical installed experimental tanks of 1 and 2 m diameter, respectively, the associated supply systems for sodium and cover gas, and a cover gas circulating system. The two experimental tanks are licensed for operating temperatures of 700 °C and 600 °C, respectively. For experiments conducted at higher temperature insert tanks, which can be heated separately, are installed into the experimental tanks; in this case, the experimental tanks serve as protective vessels only. The cover gas circulating system allows to study the behavior of sodium aerosols in the cover gas and, if necessary, to provide purified and cooled cover gas for flushing and cooling.

Kurzfassung

In diesem Bericht ist die Natrium-Behälter-Versuchsanlage, die vom Institut für Reaktorentwicklung der Gesellschaft für Kernforschung in Karlsruhe betrieben wird, beschrieben. Bei dieser Anlage handelt es sich um eine universell verwendbare Forschungseinrichtung, mit der die vielfältigen Fragen auf dem Gebiet der Natrium-Technologie im Original-und im halbtechnischen Maßstab untersucht werden können. Sie besteht aus zwei senkrecht angeordneten Versuchsbehältern mit 1 bzw. 2 m Durchmesser, den dazugehörigen Versorgungseinrichtungen für Natrium und Schutzgas und einer Schutzgas-Umwälzanlage. Die beiden Versuchsbehälter sind für Betriebstemperaturen von 700 °C bzw. 600 °C zugelassen. Für Versuche bei höheren Temperaturen werden in die Versuchsbehälter getrennt beheizbare Innenbehälter eingesetzt, so daß die Versuchsbehälter in diesem Fall lediglich als Schutzbehälter dienen. Mit der Schutzgas-Umwälzanlage kann das Verhalten von Natrium-Aerosolen im Schutzgas untersucht werden sowie bei Bedarf gereinigtes und gekühltes Schutzgas für Spül- und Kühlzwecke zur Verfügung gestellt werden.

1. Introduction

The use of sodium as a reactor coolant introduces a completely new technology to industry. This innovation process calls for a number of test facilities and, in many fields, very extensive experimental investigations as well as new developments and tests.

In Germany, this scope is pursued mainly by private industry (INTERATOM, in particular). In addition, some sodium test facilities, mostly small ones, are installed at the Karlsruhe Nuclear Research Center. These facilities allow the performance of manifold and mostly fundamental investigations and thus supplement industrial facilities. Moreover, experts working in this central federal research center are provided with the possibility of direct contact to the practical problems of operation. The Sodium Tank Test Facility described below is one of these facilities.

The experiments performed in this facility so far covered specific tasks within the development of the German-Belgian-Dutch Breeder Reactor SNR. They are related mainly to the behavior of contact surfaces under static and dynamic loads in sodium. The test program started will be continued under general aspects and extended to typical components of the reactor, refueling devices and control rod drives.

2. Description of the Facility

A simplified flow sheet of the whole installation is shown in fig. 1. The two vertical installed experimental tanks (1 and 2), diameter 1000 and 2000 mm, respectively, are both connected to the two headers (3) of the sodium supply system by a filling and a draining line each. The sodium supply system consists of two storage tanks (4 and 5) with a total capacity of about 12 m^3, installed at a lower level, an electro-magnetic pump (6), a sodium purification circuit and the piping system, interconnecting the individual components, including the headers already mentioned. The electro-magnetic pump is connected to the two headers, thus, the sodium can be transferred from each tank into each other and circulated through the purification circuit. The pump capacity is 15 m^3/h at a total head of 3 at. Two nozzles equipped with shut-off valves permit to connect further test facilities to the two headers and in this manner, to the sodium supply system.

The purification circuit consists of a cold-trap (7), a heat exchanger (8), a pluggingmeter (9) and a heater (10). This circuit is operated as a bypass. Its maximum throughput is 2 m^3/h, being measured by an electro-magnetic flowmeter (12) and controlled by a valve (13). The temperature of the sodium flowing into the cold-trap is controlled by a bypass to the heat exchanger. The oxide content of about 10 to 20 ppm required for the experiments can be easily attained by purification in the cold-trap. The heater installed in the purification circuit reheats the sodium which returns to the experimental tanks to its initial temperature, so that the test temperatures can be maintained also in the course of purification. The capacity of the heater is 48 kW. Sodium samples are taken at regular intervals and subjected to a chemical analysis.

The cover gas supply system has two main functions:
to provide the gas blankets in the two experimental tanks (1 and 2), the two storage tanks (4 and 5) and the overflow tank (14) with the required argon atmosphere and to establish a controlled pressure difference between different tanks for the filling procedure of the piping system and the transfer of sodium from one tank to one other without the use of the electro-magnetic pump. To satisfy these requirements, the gas spaces, which exist above the sodium levels are connected to the cover gas supply system via vapor traps (15) and manually operated stop valves. The cover gas supply system is formed by a battery of argon cylinders (16), its maximum capacity is 100 STD m^3.The argon used is welding argon 99.95. By means of pressure reducing valves the pressure is reduced to the required working pressure which is about .1 at at normal operation. A stationary vacuum pump (17) of 45 m^3/h suction allows to evacuate the whole installation before the

cover gas is fed in. Due to the pressure drop of the check valves installed in the vacuum lines the pressure attained is limited to 20 Torr. During operation the vacuum line serves as bleed line for the cover gas system, too.

The design temperature for the piping system and the large experimental tank is 600 °C in conformity with the presently usual reactor outlet temperatures. In order to be able to carry out experiments at even higher temperatures also, the smaller one of the two experimental tanks is designed for an operating temperature of 700 °C. This is of particular advantage because it allows to strengthen the test conditions so that the duration of experiments can be reduced in some cases. The storage tanks which stay at a relatively low temperature, were designed for 450 °C only.

Contrary to temperature, the operating pressure did not play a decisive role in the design. The essential factors were the pressures built up during the filling and draining procedures with the pump or with increased differential gas pressures. Moreover, the requirement had to be fulfilled that the tanks can be evacuated at a temperature of some 150 °C without collapsing under atmospheric pressure. Taking into account these requirements, the experimental tanks were designed for a pressure of 2 atm. and the storage tanks for 4 atm. These pressures allow also to use common foil safety valves.

Except to the storage tanks all components which are in contact with sodium are made of the high-temperature austenitic steel X8CrNiNb 16 13 (denomination according to the German industrial standard DIN). This material is Nb-stabilized and has chromium and nickel contents of 16 % and 13 %, respectively. The rupture strength for 10^5 h is 11 kp/mm^2 at 600 °C and 4 kp/mm^2 at 700 °C. This material shows the tendency to form transverse cracks when being welded. Therefore, the welding process has to be carried out with the utmost care. For the storage tanks the Nb-stabilized material X10CrNiNb 189 was used due to the lower temperature. The chromium and nickel contents of this material are 18 % and 9 %,respectively. Until recently, this material had been licensed in Germany only up to a temperature of 400 °C. If certain conditions are fulfilled, the material can now be used up to 600 °C.

To avoid sodium leakages only welding joints had been used in the entire sodium area of the installation. All welding joints were radiographed, if technically practicable. Spindle sealing of the sodium valves used is ensured by a bellows and backed up by a safety gland. In addition, the valves are provided with an electric leak sensor. All main components as well as the entire installation were checked by a helium leak test after completion.

The tanks and pipings are supported by a steel framework of about 8 x 8 m floor space and about 10 m height. Fig. 2 shows the whole installation with the two experimental tanks in the foreground. On the left, the control panel is shown. The total area below the installation is designed as a collecting basin, so that sodium which might leak out of the system cannot spread over the floor. The collecting basin is divided into four sections and can take up the maximum possible amount of sodium of the installation. The basin is covered with plates, alternating bent to the angle of a roof and provided with holes at the lower edges. This helps to avoid, as far as possible, an area conflagration in the basin in case of a major leak. The pipings are routed in a manner which makes a complete draining into the storage tanks possible. By contrast, the two experimental tanks can be drained only by the pump or by increased gas pressure, because the draining pipes enter above the maximum sodium level. The nominal size of pipings and valves are 50 mm diameter.

Fig. 2 shows the general design of the experimental tanks, in specially, the small tank is shown. The upper cover permits access to the tanks over their total diameter which, however, is required only when large-sized test assemblies are being installed. For the introduction of smaller-sized test assemblies several nozzles are provided both at the cover and the cylindrical part of the tank enabling to install several test assemblies at the same time. The sodium level can be set at any height. Measurements are made by the determination of the differential pressure with the help of Barton cells filled with a sodium-potassium mixture for transmission. To avoid excessive filling, the experimental tanks are equipped with one overflow line each at the point of maximum level, leading into the large storage tank.

Heating of the sodium in the experimental tanks is ensured by horizontal heaters, Ø 16 mm and heated length 450 mm, which are installed directly over the bottom of the tanks. The heating capacity is 27 kW in the small experimental tank and 90 kW in the large one. Electricity is supplied by one infinitely variable regulating transformer each. A base plate placed above the heaters serves as a protection. Outside the tanks the electrical supply lines of the individual heaters are made sodium-tight up to the height of the maximum level of sodium to prevent leakage of the sodium as a consequence of a defective heater. This precaution is justified by an incidence in the continuous flow heater of the purification circuit in which a burn out occurred during the initial start up phase. As result some holes were burnt into the sheath of some heaters allowing the sodium to penetrate and leave the system throuth the magnesium oxide. The lower parts of the experimental tanks were provided with cooling jackets which are supplied with air from a blower (18) and allows to dissipate heat from the tanks. Besides, these jackets together with the coolant air pipes serve as sodium collectors in case of a leak occurring in the tanks.

The experimental tanks rest with their flange rings on a special circular support structure (cf. Fig. 2). As a result of this design it was not necessary to reinforce locally the tank wall, being an advantage in particular with respect to thermal stresses. For a first series of experiments with small test assemblies an insert consisting of 4 separate tanks of about 50 l each was placed into the smaller experimental tank, so that filling the whole tank with sodium was not necessary. Each of the four tanks is provided with a heating of its own, so that 4 experiments can be carried out simultaneously at different temperatures. The access to these tanks is through the nozzles provided at the cover, which have an inside diameter of 200 mm. The heaters of the individual tanks are introduced also through these nozzles. This proved to be very useful since at higher temperatures the life of the heaters is very limited and frequent replacements must take place. The four tanks are connected directly to the headers of the sodium supply system by a common pipe of 25 mm diameter. A gage to determine the level is installed in one of the tanks. By using this insert system, the experimental tank serves only as a safety tank. This arrangement provides the possibility to carry out experiments at temperatures above the design value of 700 °C for the small experimental tank. The temperature is limited in this case only by the boiling temperature of the sodium and the maximum permissible heater temperature, respectively.

Instead of installing the four-tank-insert one larger insert tank can be used, of course. This is presently the case in the large experimental tank. The insert tank installed has a diameter of 600 mm and a height of approximately 7300 mm. It is used for studying the behavior of a full sized fuel element under extreme load conditions. Sodium temperatures above 900 °C are reached in this experiment. For this experiment the large experimental tank was supplemented with two extensions of 1 and 3.5 m height, respectively, offering a total inert gas space of 2 m diameter and some 8 m height. Fig. 4 shows the large experimental tank equipped with the 1 m extension and the insert tank during assembly.

The cover gas spaces in the experimental tanks allow also to study the behavior of sodium aerosols in the cover gas. The cover gas circulating system which had been integrated into the installation, serves this purpose. It consists of a blower for cooling air (18), a blower for cover gas (19), a heat exchanger (20), and a test section (21). With special sodium vapor traps and filter systems installed in the test section, the purification of the cover gas can be studied. A second purpose of the cover gas circulating system is the supply of purified and cooled cover gas for flushing and cooling, if necessary.

All pipings and components were equipped with a preheating system. The total power consumption is about 200 kW. The system is split up into 40 control circuits. Each control circuit includes a defined heating section equipped with one resistance thermometer, serving as a temperature probe. The range of control extends from 100 to 400 °C. The time required to heat up 200 °C is about 8 hours.

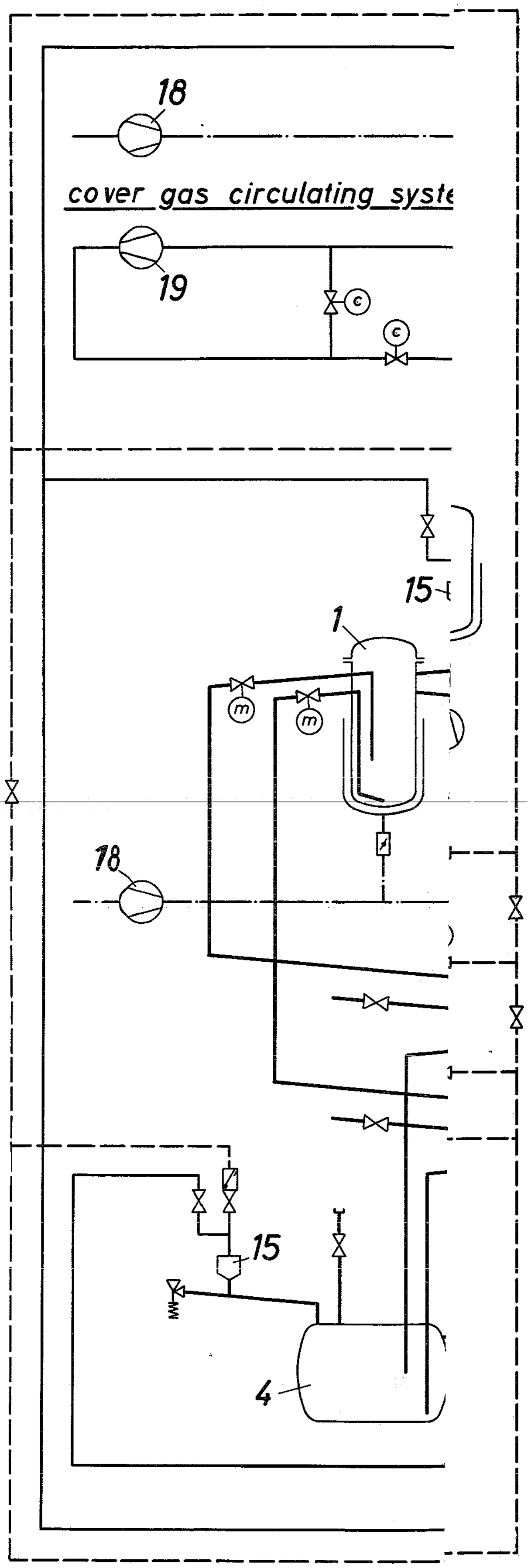
The entire instrumentation is centralized in one control panel adjacent to the test facility. The control panel consists of several sections which contain the instruments pertaining to a determined subsystem of the facility. The respective subsystems are represented as flow charts on the control panel. The main features of the instrumentation correspond to the usual instrumentation for sodium facilities. For flow measurements both permanent magnetic and electromagnetic flowmeters are used. For level measurements induction probes of INTERATOM are used in the storage tanks, while the already mentioned Barton cells serve this purpose at the experimental tanks. Both methods of measuring yield satisfactory results. However, the measurement of the differential pressure with the Barton cells requires that both pressure sensors are at the same temperature and that the sodium temperature deviation stays within a certain range, otherwise considerable measuring errors are encountered.

These conditions are not fulfilled by an experimental facility of this type. Therefore additional corrective circuits in the electronic system were provided which adjust the measuring signal in accordance with the temperature difference between the two pressure sensors and the deviation of the sodium temperature. An additional heating system prevents the freezing of the sodium in the two pressure sensors if the experimental tanks are operated at a low temperature.

The indicators of important measuring data, e.g. intolerable exceeding of temperature or level, are equipped with adjustable limit detectors which actuate an alarm when this limit is exceeded. Some limits are used also for interlocking. Thus, for instance, the pump is stopped automatically when the temperature of the pump duct exceede the preset rated value. Another example is that the heaters of the experimental tanks and of the continuous flow heater can be switched on only when they are submerged in sodium.

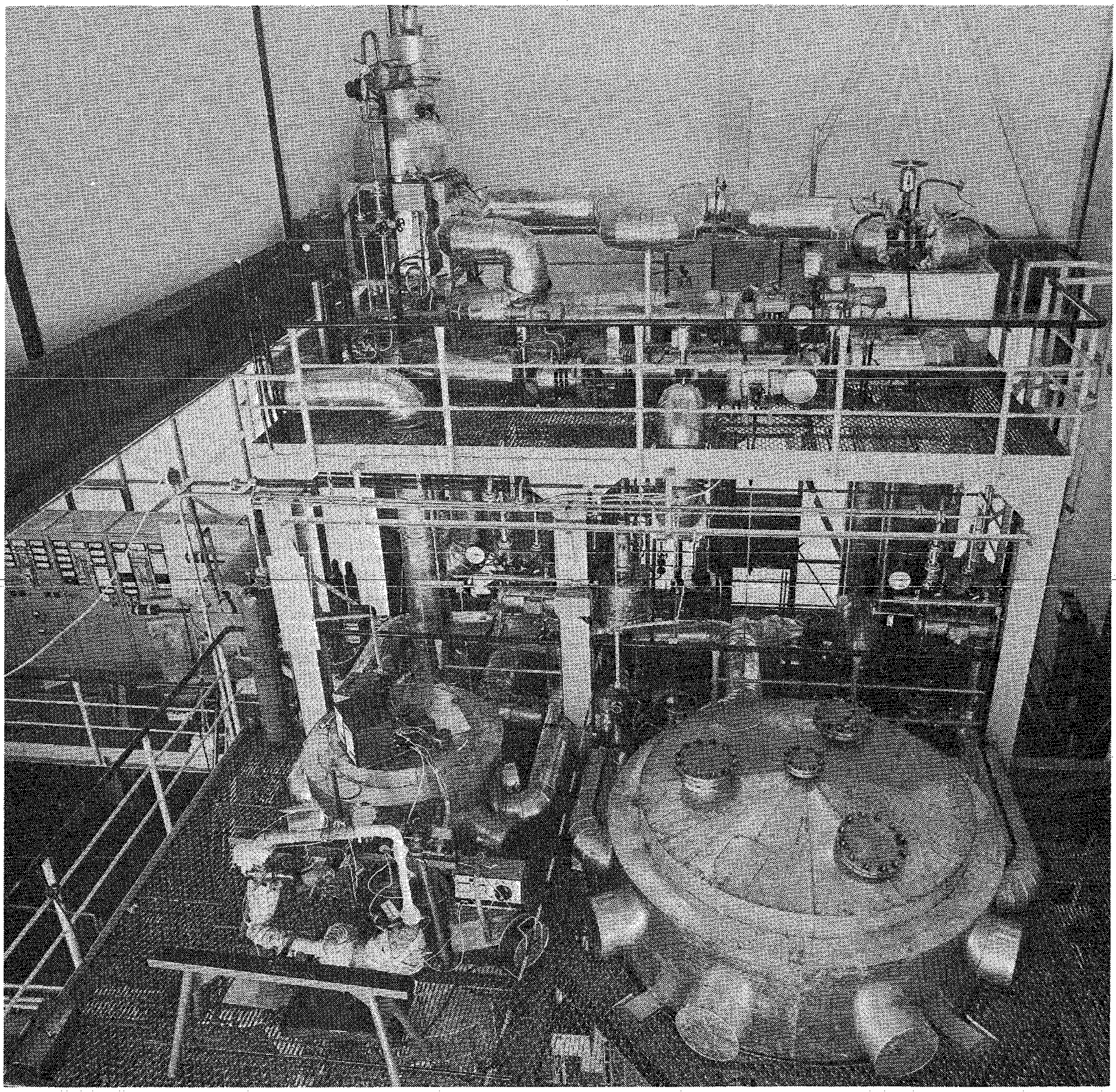
The experiments so far mainly included investigations into the behavior of contact surfaces under static and dynamic loads in sodium at a temperature range of 700 °C. All of these experiments were carried out in the four-tank-insert of the small experimental tank. Due to the installation of some additional control and alarm systems it was possible to conduct these experiments without permanent supervision by the operating staff. However, in this case all sodium - except the sodium present in the four-tank-insert - had been drained into the storage tanks.

As a rule, the withdrawal of the test assemblies at the end of the experiments takes place after draining the sodium and cooling down the experimental tank. The components contaminated with sodium are wrapped into plastic envelopes upon withdrawal and transported to a cleaning system. Cleaning is achieved with slightly superheated steam. This has proved to be the most convenient method for the components concerned.

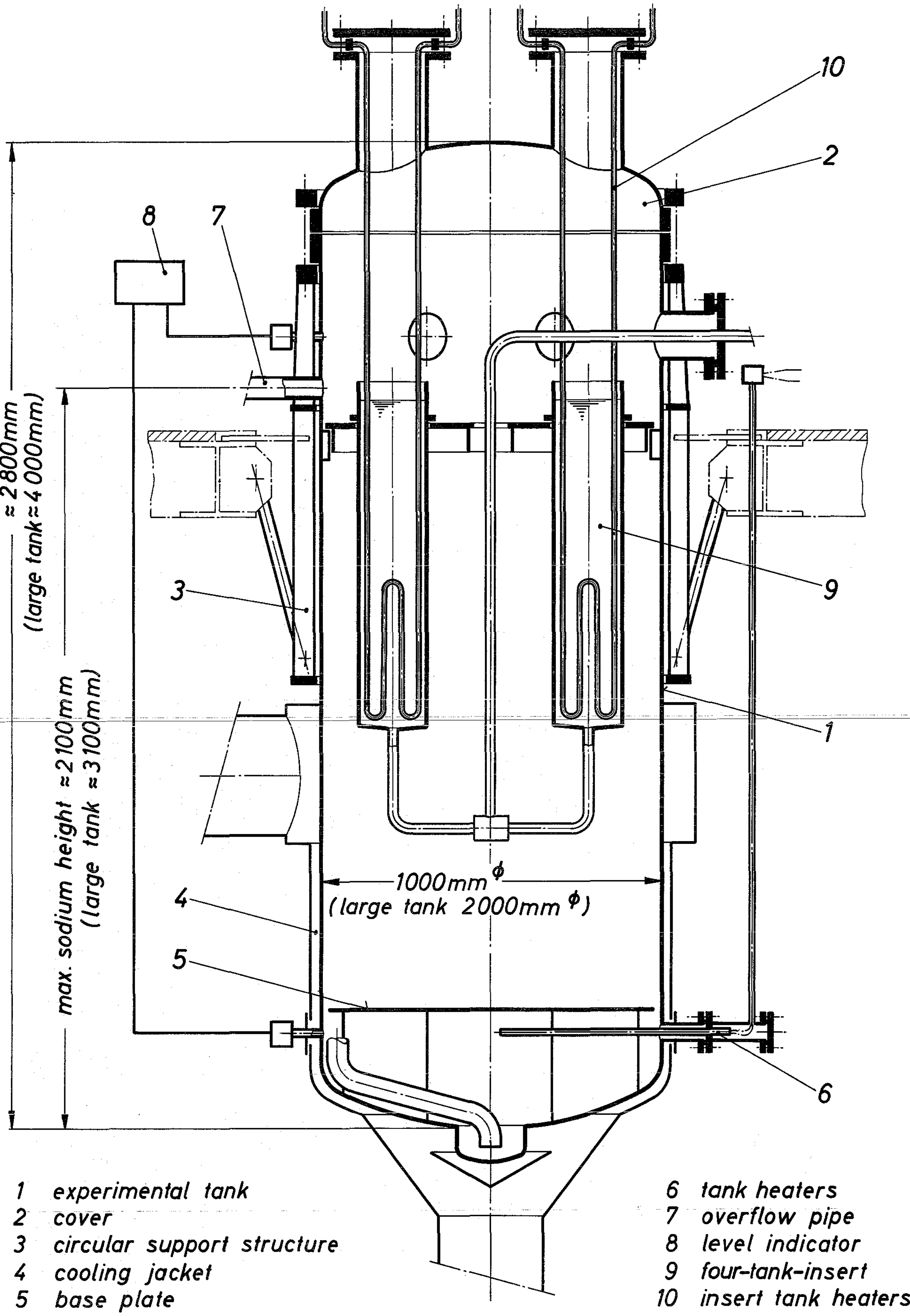


——— sodium
——— cover gas
------ vacuum and bleed
—·— cooling air

1 small experimental tank
2 large experimental tank
3 header
4 small storage tank
5 large storage tank
6 elektromagnetic pump
7 cold trap
8 heat exchanger sodium/sodium
9 pluggingmeter
10 continuous flow heater
11 permanentmagnetic flowmeter
12 elektromagnetic flowmeter
13 control valve
14 overflow tank
15 vapour trap
16 cover gas supply system
17 vacuum pump
18 cooling air blower
19 cover gas blower
20 heat exchanger argon/air
21 test section



<u>Fig. 2</u> The sodium tank test facility with the two experimental tanks in the foreground



1	experimental tank	6	tank heaters
2	cover	7	overflow pipe
3	circular support structure	8	level indicator
4	cooling jacket	9	four-tank-insert
5	base plate	10	insert tank heaters

Fig. 3 1m - diameter experimental tank temporarily equipped with four insert tanks

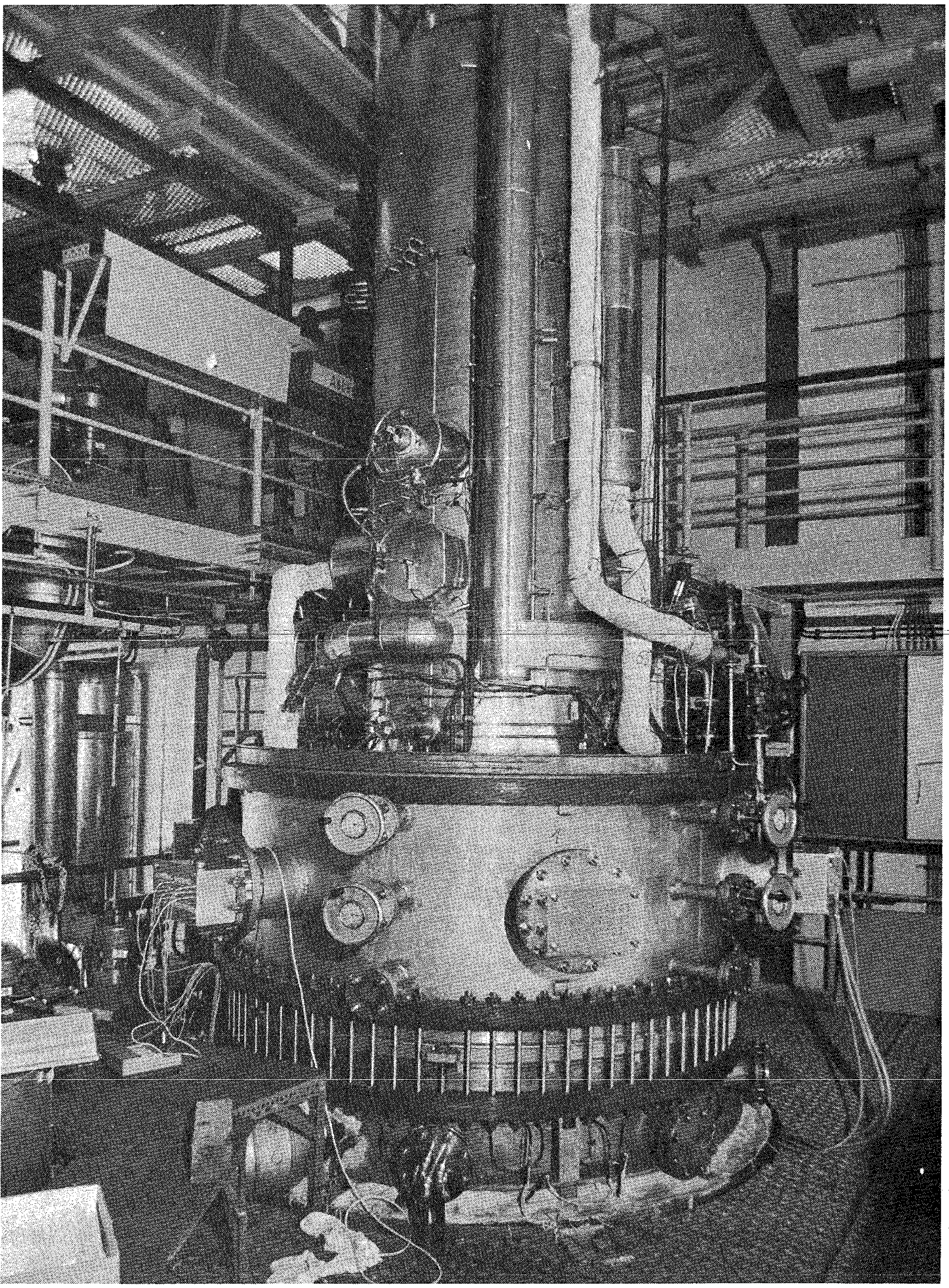


Fig. 4 2 m-diameter experimental tank equipped with the 1 m extension and the insert tank during assembly