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on
Maintenance and Repair
of
LMFBR Steam Generators

Session 3

R and D work in Maintenance and Repair in DeBeNe

by

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1. INTRODUCTION

The research and development work on Maintenance and Repair of steam generators in DeBeNe, specifically in The Netherlands, covers three different fields:

a. Inspection techniques
b. Cleaning
c. Repair

In this paper we will discuss each field and, where applicable, give references to more detailed papers in each topic.

2. INSPECTION TECHNIQUES

Inspection tools for the steam generators constructed in ferritic steels, used in DeBeNe are:

a. Visual test
b. Pressure test
c. Helium test
d. Dye-penetrant/magnetic crackdetection
e. X-ray
f. Ultrasonic testing

All tools are used during fabrication, but for in-service inspection a, b, c and f are foreseen. A lot of R and D work has been done in The Netherlands on the development of the microfocus X-ray rod and on the development of the Nerason in-bore ultrasonic probe and data processing system.

2.1 The 150 kV microfocus X-ray rod

This tool was developed by Technisch Physische Dienst TNO-TH in Delft. It allows X-ray inspection of Internal Bore welds and accessible tube-tube welds for rather small diameters. It is in use now in several countries all over the world.
Previous publications are listed as references [1], [2].

2.2 The Nerason System

The Nerason in-bore ultrasonic inspection system has been developed for use in straight and coiled tubes of internal diameters over 10 mm to measure their wall thickness. In this measuring no influence is felt from layers covering the metal, such as magnetite, paint or deposits or of outside remnants of sodium. Beside the wall thickness, indications are obtained on spots where the outside of the tube is damaged. Further more detailed information see references [3], [4].

3. CLEANING

In Kalkar SNR300 two methodes will be available:

- Wet - gas
- Vacuum cleaning

The vacuum cleaning was developed in The Netherlands for the large components of the 50 MW sodium component Test Facility at Hengelo, operated by TNO. It has been extensively reported elsewhere. Reference [5], [6].
In Neratoom's opinion vacuum cleaning is superior for cases with low amounts of hydroxide, for other applications wet gas is the method to be used.

4. REPAIR METHOD

On the bases of our experience in the 50 MW SCTF and the small-leak tests at Interatom and TNO-laboratories we have decided that leaks in steam generators can be very hard to find and that no operating time must be wasted by looking for small leaks. Once a leak situation is firmly established, it should be decided to replace the affected unit if it cannot be guaranteed that repair will take, say, two weeks.

In case of replacement of a steam generator component the operator has two options. The first one is immediate removal and replacement. The second one is isolation of the faulted unit and continued operation with somewhat reduced power in one loop. Isolation will be achieved by cutting and capping of the main piping. In the following an overview is presented of the actions and procedures that will be followed in case of a leak signal.

Let us assume a leak develops and that the leak is sufficiently small to prevent actuation of the rupture disks.
After shut down the faulted unit will eventually be removed and the sodium side cleaned. The cleaned component will be filled with nitrogen.

The next step is: to establish which tube is the faulted one. To do this the following steps will be taken:

1. Chemical examiniation
2. Acoustical testing
3. Helium leak test

The chemical method is the one that was developed in Great Britain. Felt bungs will be pushed through each heat transfer tube by means of nitrogen pressure. After this each bung will be chemically analysed to find out whether there are sodium traces. Notwithstanding the fact that there is a pressure differential of approximately 160 bars, experience shows that sodium traces can be found at the steamside of the tube wall.

If this step is not succesful in determining the leak, acoustical testing will be used. For this the nitrogen pressure at the shell side will be increased to 2 bars and microphones will be inserted in the tubes. This method is only succesful in case of a fairly large leak.

The most accurate method is the helium leak test. It should be mentioned that after cleaning the sodium side an overall leak test will be executed. In order to be sure that no helium traces are left in the component, the component will be flushed with clean nitrogen. After this the sodium side is evacuated to 0,1 bar. The actual leak testing is carried out by filling the sodium side with a helium (20%) nitrogen mixture at 1,2 - 2 bars.

The tubes are initially examined in layers. For this operation it is necessary to seal the ends of the tubes. For the straight tube design local vacuum is applied in the IB-weld area. A simple tool was designed for this purpose; fig. 5.
For helium leak testing of the helical coil design a movable seal will be employed; fig. 6.
The seal has to be inserted in the top steam header. The lower steam header will receive a temporary seal in the shape of a balloon of synthetic material. After determining which layer houses the faulted tube every tube in this layer will be individually leak tested.

The next part of the procedure is to determine whether the adjacent tubes are damaged. For both steam generators this can be done by means of an ultrasonic wall thickness measurement. For the helicoil steam generator this is not so simple because one has to check at what height in the bundle the leak is located. This will be done by a bubble technique. By this is meant an acoustical method. In this operation the shell side is slightly pressurised and the faulted tube slowly filled with alcohol. The alcohol level and the change in noise level will yield information on the leak position. If the leak position is known it can be established which are the 8 adjacent tubes.
The repair method is in fact a capping operation of the damaged tubes.

Let us assume a leak in straight tube steam generator. The straight tube steam generator can only be repaired after removal of the steam headers. After this the next steps take place:

1. Cleaning of the bores with alcohol.
2. Visual examination by means of boroscopes.
3. Dye penetrant test.
4. Cutting of IB-welds of the faulted tube.
5. Determining of the flaw position in order to facilitate action 7.
6. Removal of the faulted tube.
7. Assesment of damage to the adjacent tubes by means of boroscopes and UT.
8. Installing of a dummy tube with vent holes at either side.
9. Installing of an elastic bung as chip collector.
10. Welding a heavy gauge extension stud to the tube sheet bore; fig. 7-1.
11. Removal of the rootweld by drilling.
12. Radiography by means of the microfocus rod anode X-ray system; fig. 7-2.
13. Welding of a cap on the extension stud after removal of the chip collector; fig. 7-3.
14. Radiography of the seal weld.
15. Helium leak test of the repair weld; helium at the sodium side and local vacuum outside the repair weld.
16. Dye penetrant test.
17. Rewelding of the steam headers.
18. Testing of step 17 by NDT after heat treatment.

The dummy tube will have vent holes so that sodium can enter during operation of the steam generator. A circulation device, fig. 8, could be installed; this to assure a optimal hydrogen detection for this steam generator.

In step 12 single wall radiography is employed. The rather complicated weld geometry makes it most desirable to use a "single wall" radiographic method. This is possible due to the unique qualities of the micro focus X-ray equipment, which can be used with extremely short film-focal distances.

Plugging of peripherical bores differs somewhat from the above mentioned method due to the tube sheet shape. For this local milling of the tube sheet is necessary; fig. 7. The weldstud differs also, fig. 8., in this case however the same steps apply.

On account of the chosen IB-weld shape a tube replacement can be executed. However this can only be executed in the workshop of the manufacturer of the steam generator. The comparative ease by which a tube can be replaced is a great asset for the straight tube steam generator.

Although we propose to execute the repair welding after removing the steam generator from the system, it is not a necessity. In the 50 MW test facility we removed a tube, for metallographic investigations, with the component still connected to the sodium system. Cutting, repairing, welding and heattreatment was succesfully carried out on site.

The helical coiled steam generator will be plugged in a different manner due to the thermal sleeves. If a leak occurs this means: cutting of the external tube lengths and capping of the thermal sleeves and welding caps at the steam header side, fig. 9.
In order to avoid stagnant sodium the sleeves will receive vent holes so that sodium can flow via this way. The radiographic examinations will be of the double wall type. This is acceptable because of the wall thickness and the rather simple weld geometry [7].

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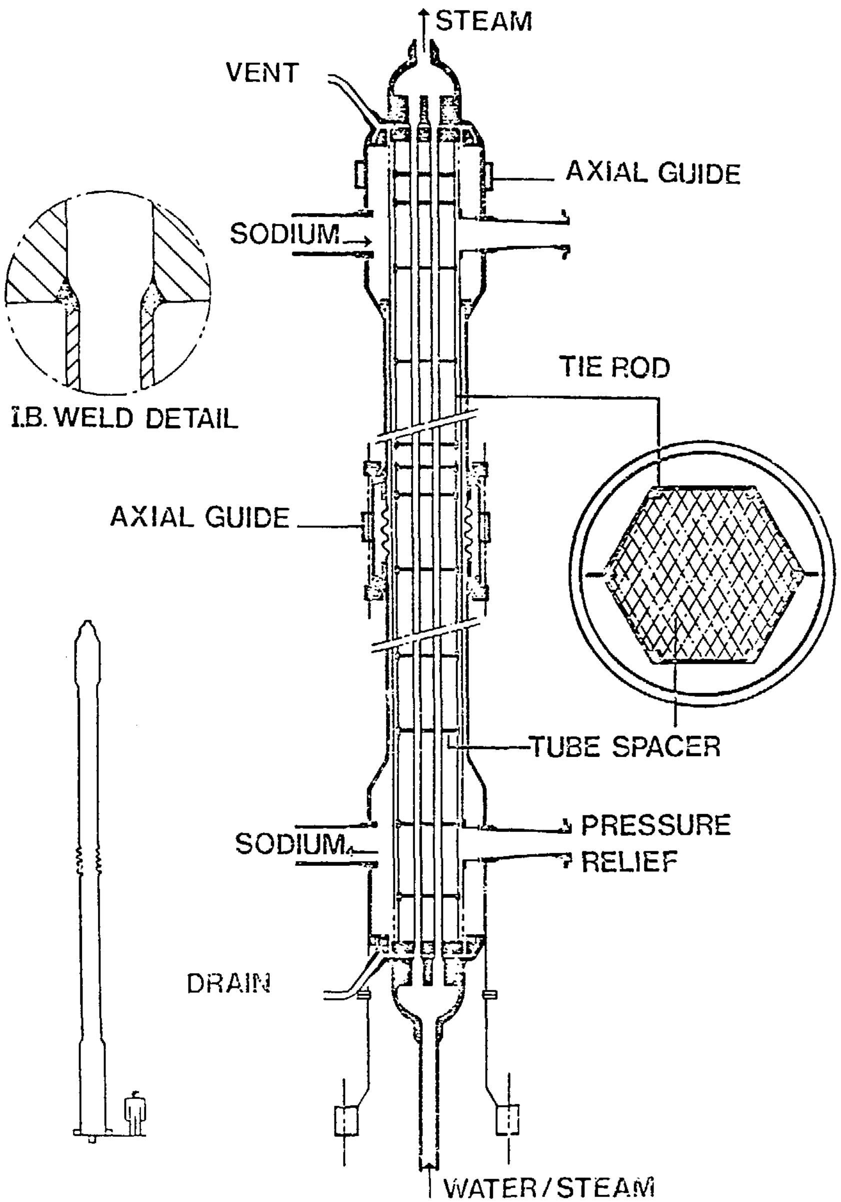

Fig. 1.
Straight tube s.g. SNR-300

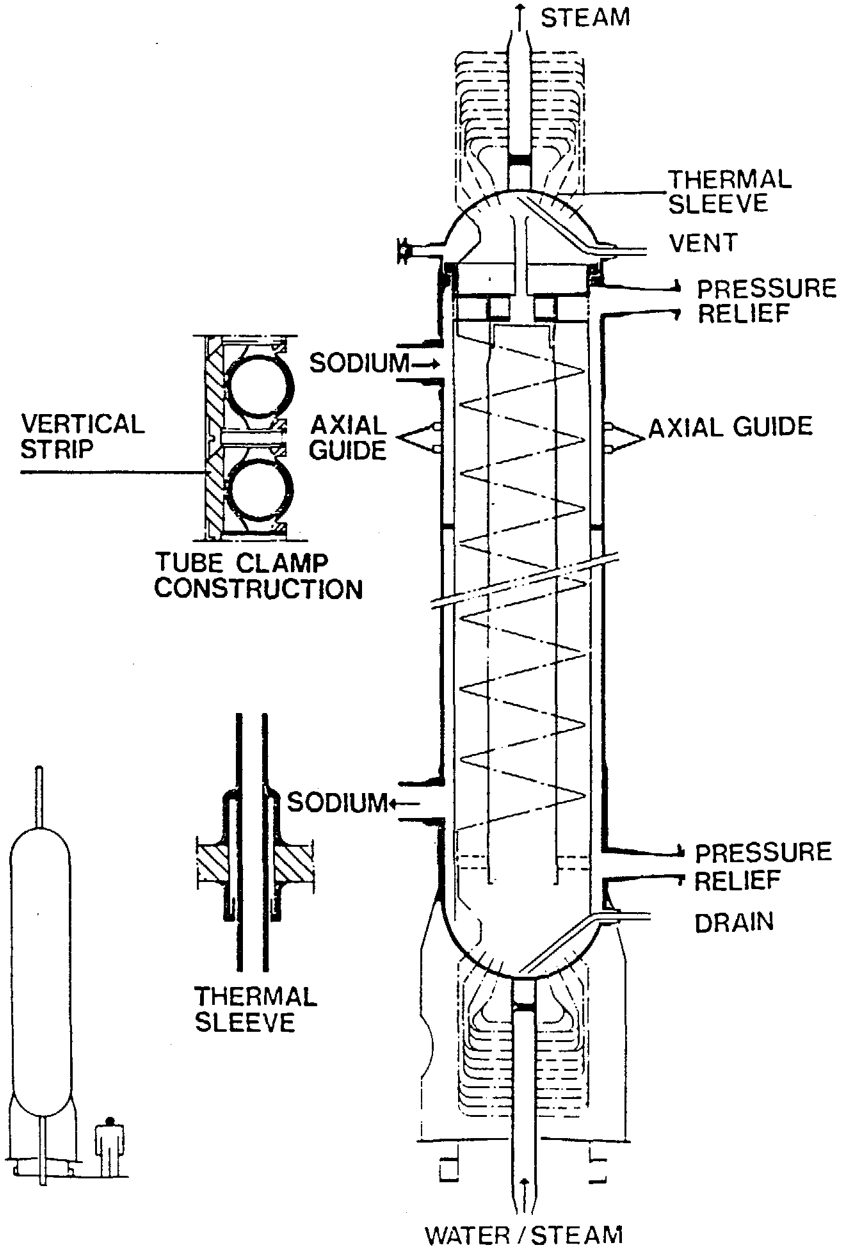

Fig. 2.
Helical tube s.g. SNR-300

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CREVICE FREE TUBE_TUBE SHEET JOINT

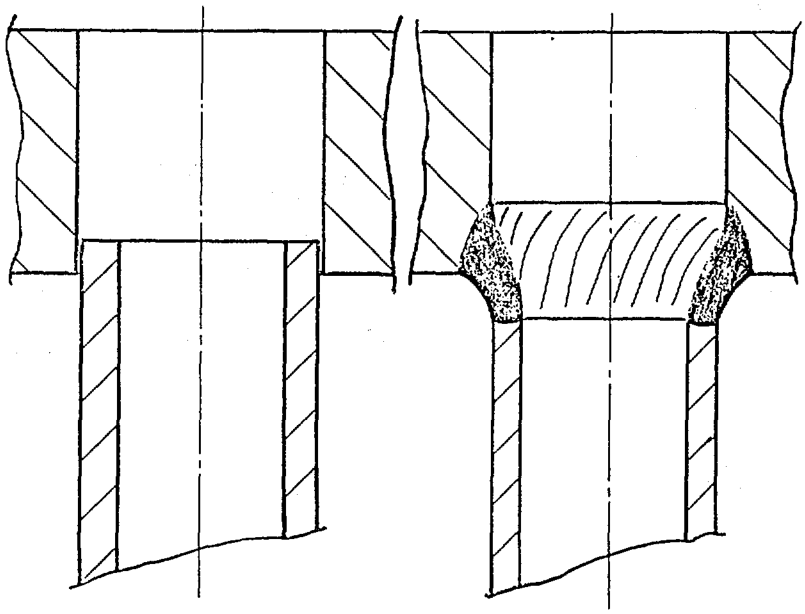

Fig. 3.

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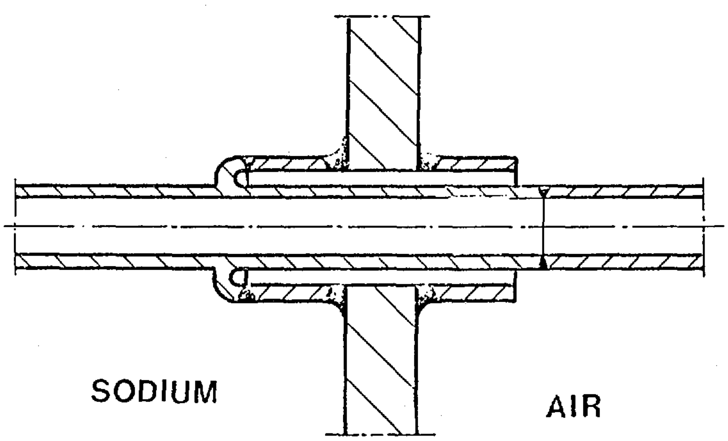

Fig. 4.

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THERMAL SLEEVE

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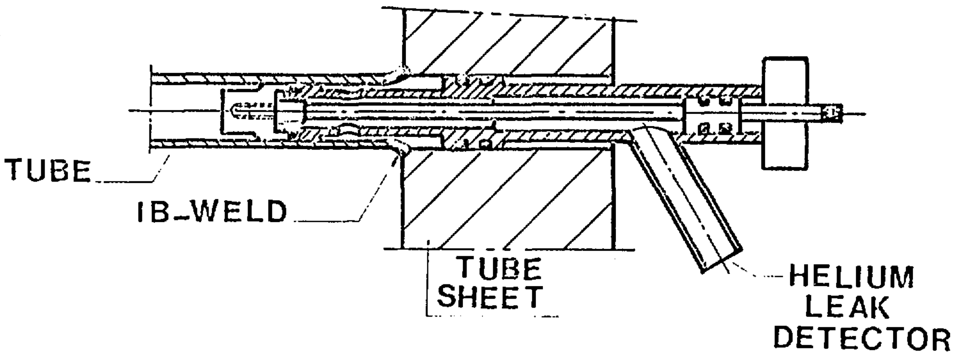

Fig. 5. TOOL FOR HE LEAKTESTING

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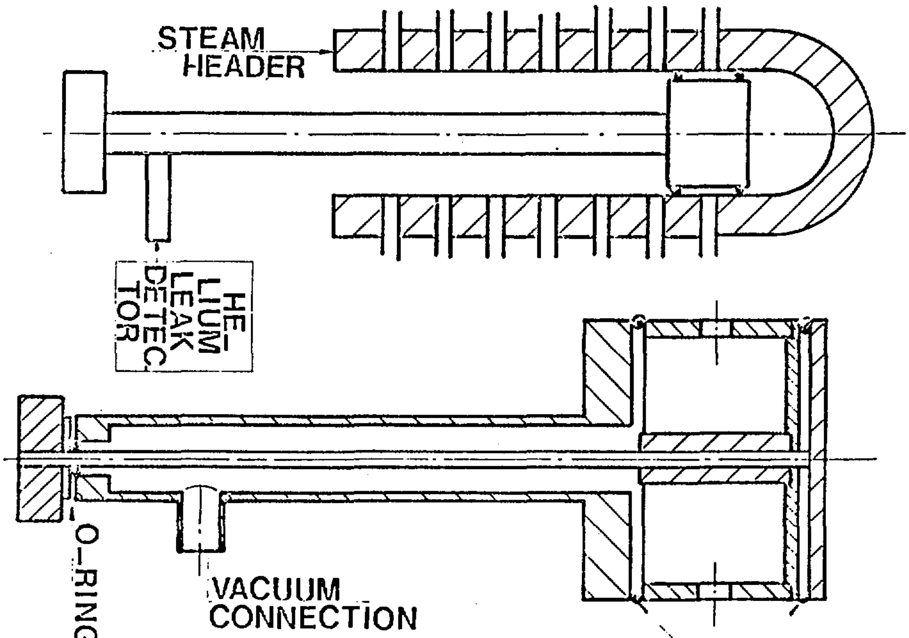
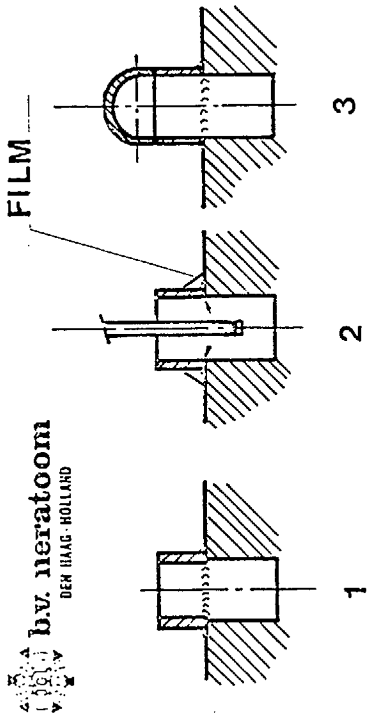


Fig. 6. MOVABLE SEAL



CAPPING OF A TUBE

Fig. 7.

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SODIUM CIRCULATION DEVICE

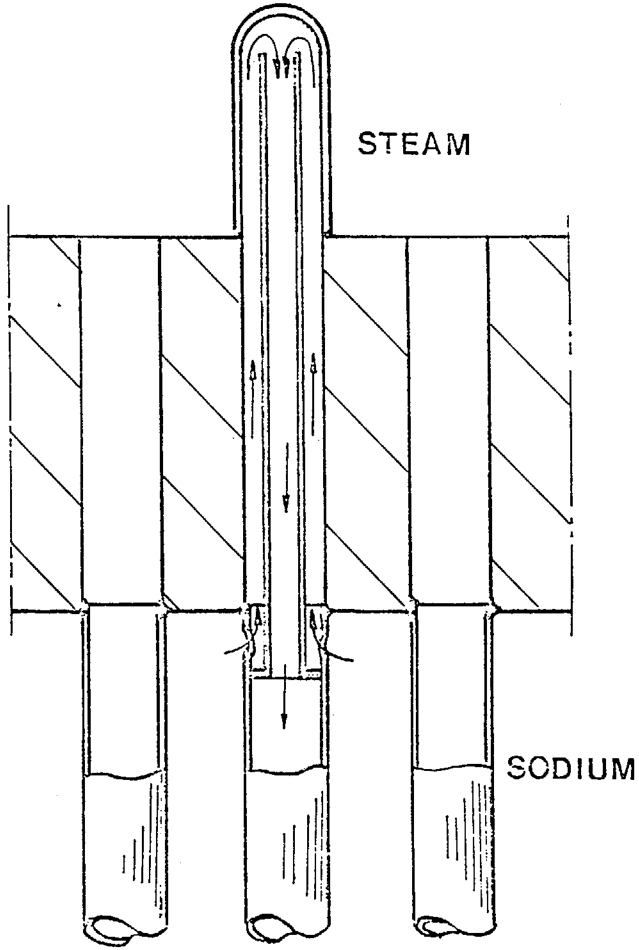

Fig. 8.

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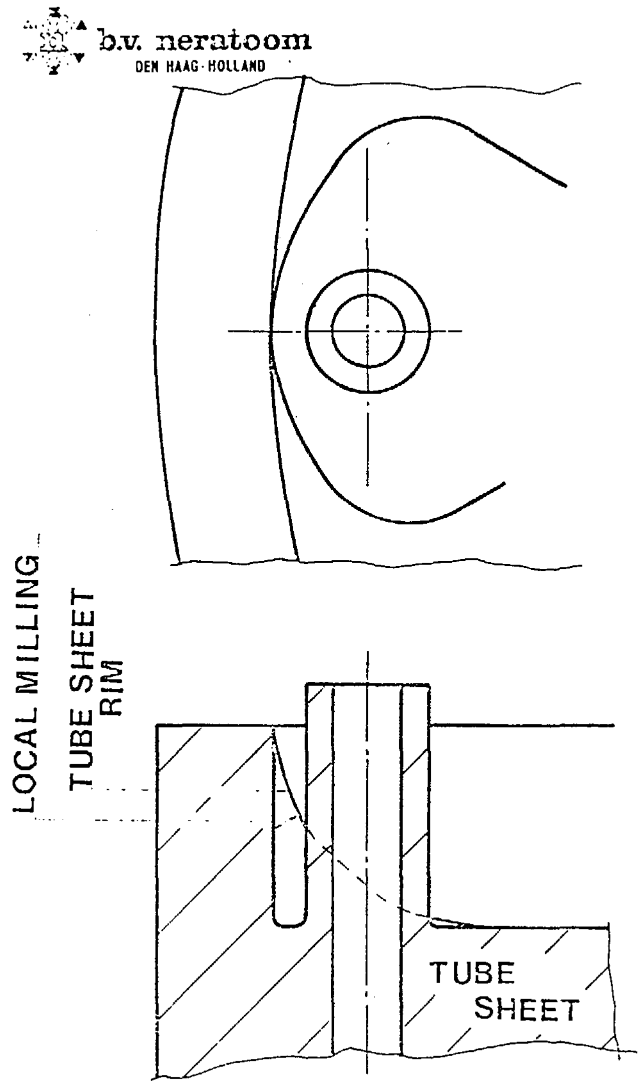
b.v. neratoom
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LOCAL MILLING
TUBE SHEET
RIM
TUBE
SHEET

Fig. 9.

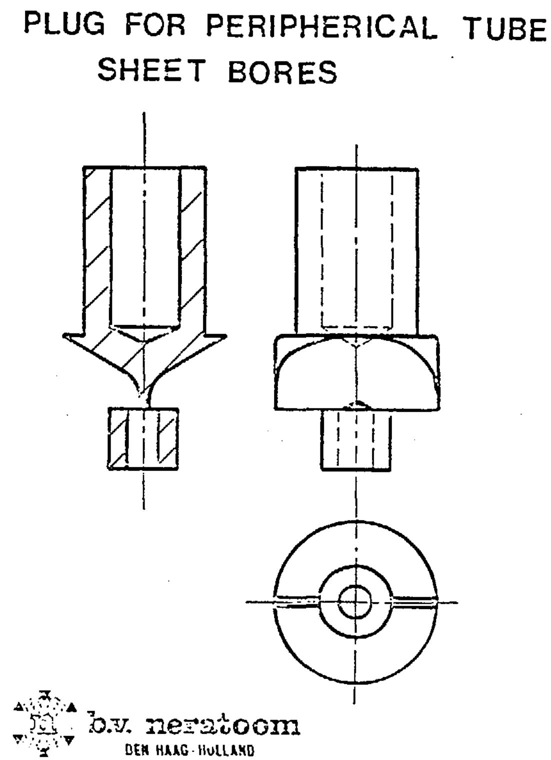
PLUG FOR PERIPHERICAL TUBE
SHEET BORES
b.v. neratoom
DEN HAAG-HOLLAND

Fig. 10.

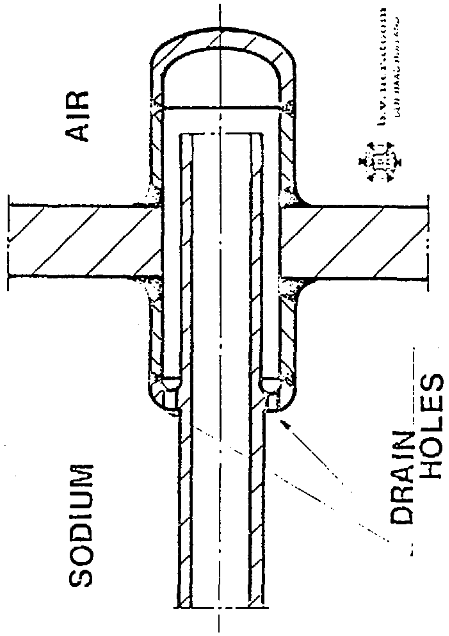

Fig. 11.

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Session 4

Experience in DeBeNe

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