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BACKFITTING OF THE FRG REACTORS

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1 The FRG-research reactors

The GKSS-research centre is operating two research reactors of the swimming pool type fueled with MTR-type type elements. The research reactors FRG-1 and FRG-2 having power levels of 5 MW and 15 MW are in operation since 31 a (FRG-1) and 27 a (FRG-2). They are comparable old like others, too. The reactors are operated at present at approximalety 180 d (FRG-1) and between 210 d and 250 d (FRG-2) per year. Both reactors are located in the same reactor hall in a connecting pool system (fig. 1).

2 Backfitting reasons

Backfitting measures are needed for our and other research reactors to ensure a high level of safety and availability.

Generally reasons for backfitting in our case have been:

1. operating experience;
2. main modifications related to e.g. power increase, changes in utilization or lack of spare parts;
3. changes in safety philosophy;
4. updated risk analyses, recent research results and political impacts;
5. necessary repairs.

3 Summary of the main backfitting activities within the last ten years

Midth of the seventeeth there were plans to increase the power of the FRG-2 from 15 MW to 21 MW. This was the reason for the following activities e.g.:

1. comparison of the existing design with today demands (criterias, guidelines, standards etc.).

2. probability approach for events from outside like aeroplane crashes and earthquakes.

   It should be mentioned, that the FRG-reactors are located in an area where aeroplanes flights are restricted as this location is close to the boarder of the German Democratic Republic and that this location is an extreme quiet region for earthquakes, too.

   Therefore: the risk coming from events from outside is acceptable for the operation of FRG-1 and FRG-2.

3. The main accidents had to be rediscussed like startup from low and full power, loss of coolant flow, loss of heat sink, loss of coolant and fuel plate melting.

4. We were forced to install a new reactor protection system following today demands on redundancy (2 out of 3), diversity etc. from the relevant power reactor standard. Fig. 2 gives a general overview of the design of the reactor protection system. The design principle can be seen in the table. It should be known that there are comparators between each channel of the redundant analog signals.

probable accident	diverse chain 1	diverse chain 2
startup from low power	startup chambers (1 out of 2) safety chambers (2 out of 3)	linear chambers (2 out of 3)
startup from high power	safety chambers (2 out of 3) N^{16}-chambers (2 out of 3) primary temperature (2 out of 3)	linear chambers (2 out of 3)
fuel plate melting	N^{16}-chambers (2 out of 3)	γ-chambers on ceiling of reactor hall (2 out of 3)
loss of primary coolant flow	primary flow rate (2 out of 3)	pressure primary circuit (2 out of 3 in max. and min.)
loss of coolant	water height in pool (2 out of 3)	water height in basement (2 out of 3) γ-chambers on ceiling (2 out of 3)
loss of secondary coolant flow	primary coolant temperature (2 out of 3)	slow time response therefore only standard actions
experiments (FRG-2)	2 out of 3	2 out of 3

5. In the reactor hall a new crane has been installed (fig. 3). Before designing and installing the new crane a risk estimation has to be made giving the demands on the design coming up from power reactor standards. The crane load has been increased at that time, too.

6. An operation manual and inspection manual has to be written in the meantime not only for the research reactors FRG-1 and FRG-2. We have such manuals now for the cold neutron source and for the hot cells. A lot of work and a lot of paper but if these manuals are on hand they are very useful.

4 Backfitting activities within the last two years

Especially within the last two years larger backfitting and modernization activities have been made to enable reactor operation for the following ten and more years.

4.1 Installation of a cold neutron source

A cold neutron source has been installed to increase the flux of cold (5 Å) neutrons by a factor of 14. The source is in operation since June 1989. A report will be given next week at the workshop in Los Alamos.

4.2 Enrichment reduction to LEU fuel for FRG-1

The FRG-1 is being converted from 93 % enriched U with UAl_x fuel to 20 % enriched U with U_3Si_2 fuel. We have the license and the fuel elements on hand. This has been reported already, too, at an earlier meeting and present results will be presented this year at the RERTR meeting.

4.3 Measures for fire protection

The gap between an old building and new standards on fire protection has to be closed

1. all three stairways have to be separated from the floors
2. the fire resistance for some walls and doors has to be increased
3. not used cables from cable channels must be removed
4. smoke flaps and smoke ventilators have to be installed
5. cable penetrations must be fire protected
6. a fire detection monitoring system in all technical rooms and a fire alarm control panel was installed (fig. 4).

4.4 Installation of a double tubing for parts of the primary piping of the FRG-1

The piping, valves, pumps etc. of the FRG-1 are located in the cellar below the FRG-1 reactor pool. Between ceiling and the first valve there was nothing to stop leaking water. For this reason between the ceiling and the first automatic operated valve a double tube has been installed for the water inlet and water outlet pipings.

In fig. 5 the double tubing and an auxiliary construction can be seen. This auxiliary construction is necessary to fix the double tubing in place in case of a leak in the first piping. Then the double tubing has to withstand the pressure of 10 m water above. In the space between the tubes 3 water detectors (heated thermocouples) have been installed giving an alarm in 2 out of 3 mode.

4.5 Repair of both cooling towers

The internals of both cooling towers consisted of wooden materials for the distribution and spraying of the cooling water. The following actions were taken

1. In the FRG-1 cooling tower all wooden internals have been replaced by polystyrol and the coolant capacity has been slightly increased

2. In the FRG-2 cooling tower the water distribution system has been renewed totally.

4.6 Modernization of the ventilation system

Old flaps were partially removed and hose flaps were installed. Within the exhaust air channels the conventional filtering system has been replaced totally. Now all inspections can be made leaving the filters in place and the main flaps can be operated automatically.

4.7 Measures against water leakages

As I know that water leakage is a problem for some other older research reactors, too, I will describe these repairs in more details.

Two kind of damages were known before starting the repair action: Water leakage from the ceiling in the cellar below the reactor pools and some defect tiles (fig. 6) at the walls of the FRG-1 pool.

The licensing authorities demand to present a repair program for the pool and for avoiding water leakage into the cellar in the future.

To understand the considerations and the proposed repair program a brief design description of the biological shield must be taken from fig. 7.It is clear that there were rised the following questions:

1. quality of the internal part of the 60 cm concrete (ρ = 2.3 g/cm³)
2. quality and γ-resistance of the epoxy resin layer
3. status of the steel liner (5 mm!)
4. status of the thiokol waterproofing between steel liner and Al beam tubes.

Steps of the repair program were the following:

1. The reactor bridge of FRG-1 including core and grid plate was moved to an other pool.

2. Radioactive components like the inpile parts of the beam tubes, etc. were removed by three divers. A maximum whole body dose of 0,9 mSv

was achieved by the divers. It should be mentioned that at the front part of the beam tubes the dose level was between 100 and 600 mSv/h around 8 weeks after shutdown.

3. After removing parts of the tiles, of the epoxy resin and the internal concrete the situation looks like it can be seen in the fig. 8.

   This shall demonstrate that after removing all radioactive components we were able to stay there. At most places the dose level was below 10 µSv/h after shielding the flanges of the beam tubes.

4. Inspection of the internal concrete was done by the consultants of the licensing authority. This includes optical inspection, compression measurements on selected samples and hardness measurements. The result of all these inspections were that the concrete is in good condition.

5. The steel liner has been inspected at two different positions: In both cases the liner was found to be in an excellent condition (fig. 9).

6. The polyurethan has been injected with high pressure to tighten the thiokol seal between steel liner and Al beam tubes. For this purpose holes have been drilled through the concrete near to the thiokol. In these holes polyurethane was pressed. There are 20 of such penetrations of the liner and concrete and per penetration as a minimum 2 holes must be drilled to get a high confidency in this work.

7. After repairing the concrete, sealing the concrete with - at this time - unsaturated polyester (as this polyester is better γ-resistant than epoxy resin), the tiles have been placed and the pool cleaned up.

The next fig. 10 shows the repaired pool:
- the beam tubes in place
- a Be block reflector installed
- and the inpile part of the cold neutron source.

Now I am coming to an absolutely different kind of damage and repair: In a separate part of the cellar (3 x 12.5 m^2) which is below pool 3 and 4 there were a few small cracks within the concrete of the ceiling. This looks not dangerous but it may become a severe problem.

Removing these damaged parts in a small region and to a depth of ca. 2 cm we checked the pH of the concrete which gives good information about the quality of the concrete. With a great surprise to the involved parties a carbonization depth of ca. 12 cm was found. This carbonized conrete must be removed totally and new concrete has to be placed there as otherwise the whole structure may loose its stability.

Finally on these repairs: All repair actions were fully accepted by the licensing authorities and their consultants and til today the status of the repaired parts is excellent and no water leakage into the cellar was seen again. You may believe, we are happy about this.

5 Ongoing and planned backfitting activities

5.1 Replacement of instrumentation etc.

As it could be seen that there will be within the next future increasing difficulties for maintaining and repairing the process control system and for getting new spare parts it was decided to renew the instrumentation, the process control system and the alarm system. The order was placed end of 1988. Fig. 11 shows the principal design of the instrumentation and monitoring system. The system is being implemented. We are hoping to go into operation again in March 1990.

5.2 Renewal of the emergency power supply

At present we have since approximately 25 years in operation a flying wheel diesel generator and a diesel generator for the emergency power supply (1 out of 2). The capacity of these generators is large so that they are not only used for the needs of an emergency power supply. Probable faults can be caused by other reasons.

Considering this situation the decision was made to build a new station for (1 out of 2) diesel generators to be used only for the emergency power supply for our two reactors. The principal design work is being finished and we are going to ask for inquiries from competent suppliers. The principal design can be taken from fig. 12.

5.3 Lightning protection

The standard conventional lightning protection is present and inspected annually by consultants. Due to research results taking into account damages in modern electronics (IC) arising from induced voltages and currents a by far more increased lightning protection is necessary. A report is being made by consultants we hired ourselfes.

6 Resumee

The GKSS research centre intends to operate their research reactors safe to prevent undue risks from the public and the operational staff. Therefore many actions have been made

- to follow present safety philosophies
- to replace old equipment to have an installation which is near the state of the art
- to learn from operation experience got in our and other facilities.

These efforts will continue to allow safe operation of our research reactors over their whole operational life.

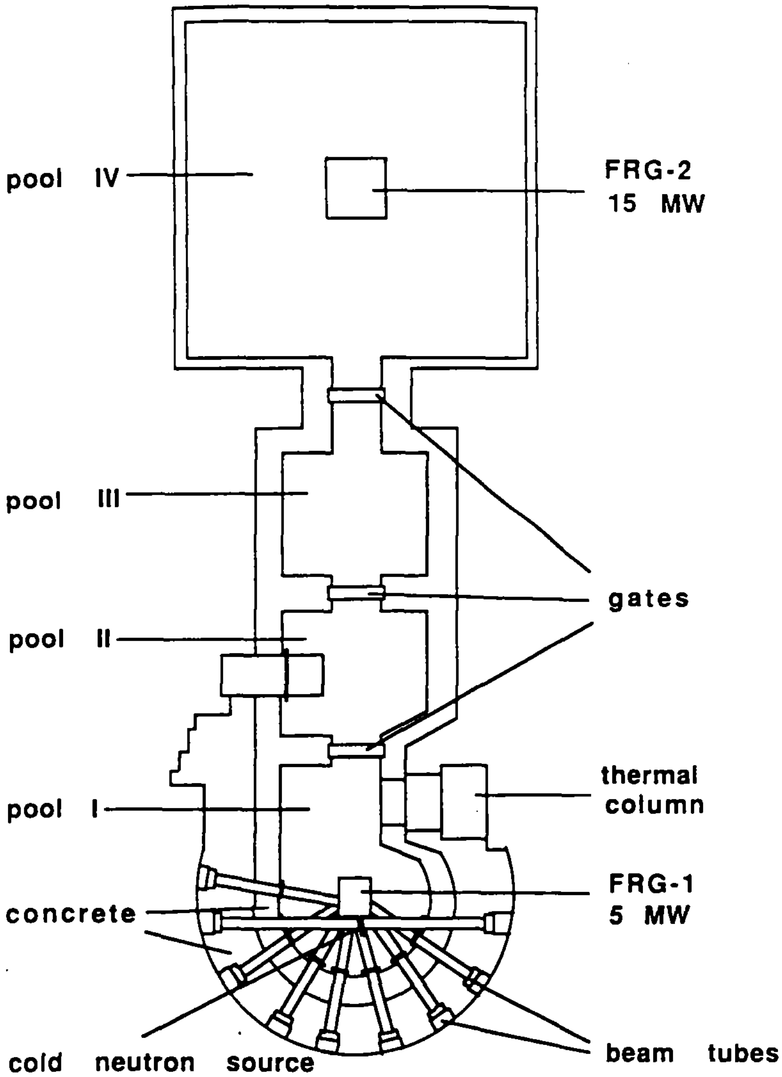
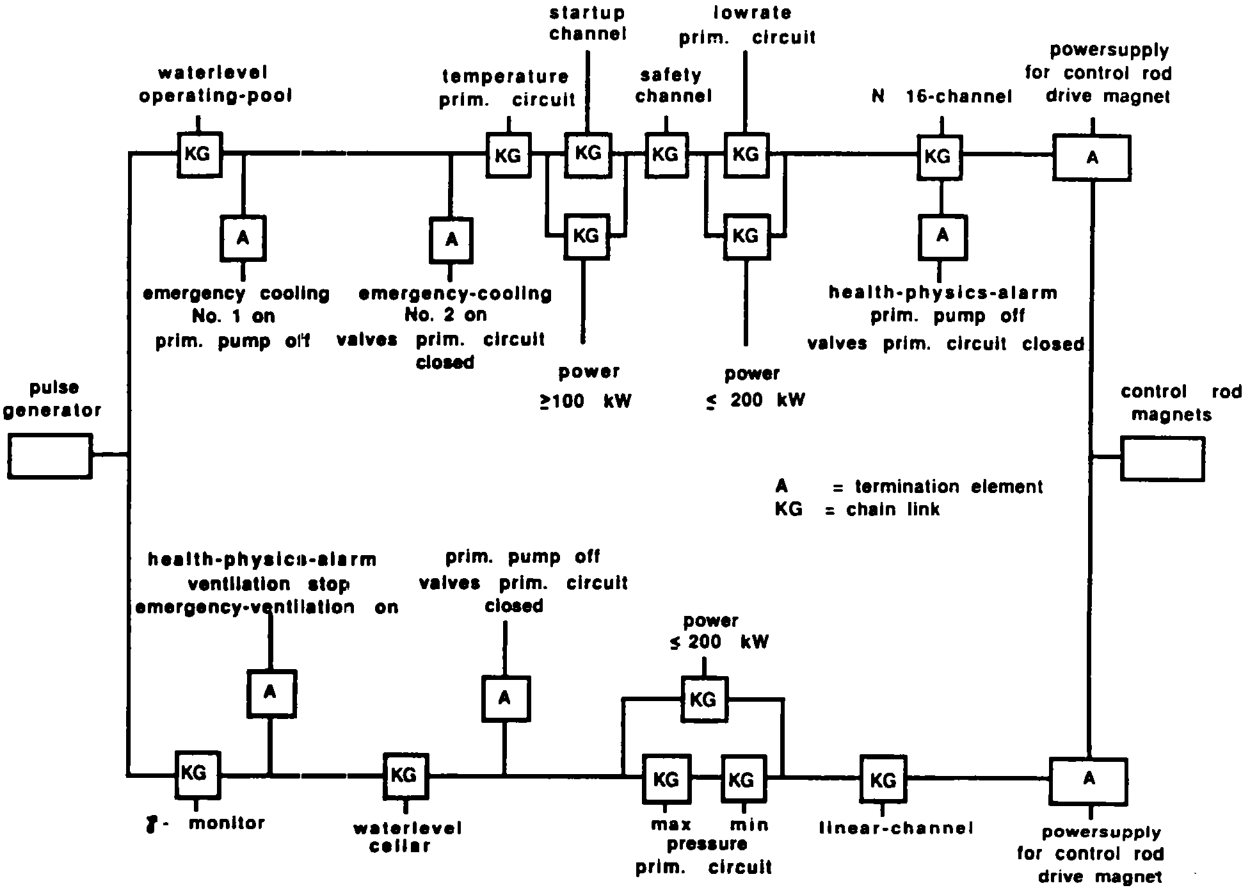

pool IV
FRG-2
15 MW
pool III
gates
pool II
thermal
column
pool I
FRG-1
5 MW
concrete
cold neutron source
beam tubes

Fig. 1



startup channel
lowrate prim. circuit
waterlevel operating-pool
temperature prim. circuit
safety channel
N 16-channel
powersupply for control rod drive magnet
KG
A
emergency cooling No. 1 on prim. pump off
emergency-cooling No. 2 on valves prim. circuit closed
power ≥100 kW
power ≤ 200 kW
health-physics-alarm prim. pump off valves prim. circuit closed
pulse generator
control rod magnets
A = termination element
KG = chain link
health-physics-alarm ventilation stop emergency-ventilation on
prim. pump off valves prim. circuit closed
power ≤ 200 kW
γ- monitor
waterlevel cellar
max min pressure prim. circuit
linear-channel
powersupply for control rod drive magnet

Fig. 2

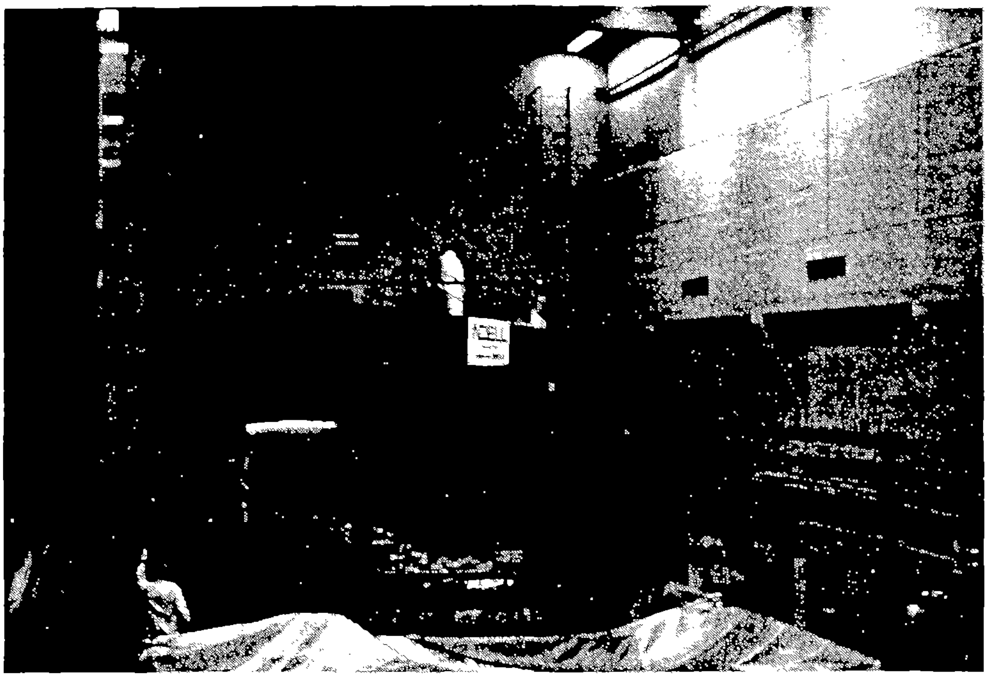


Fig. 3

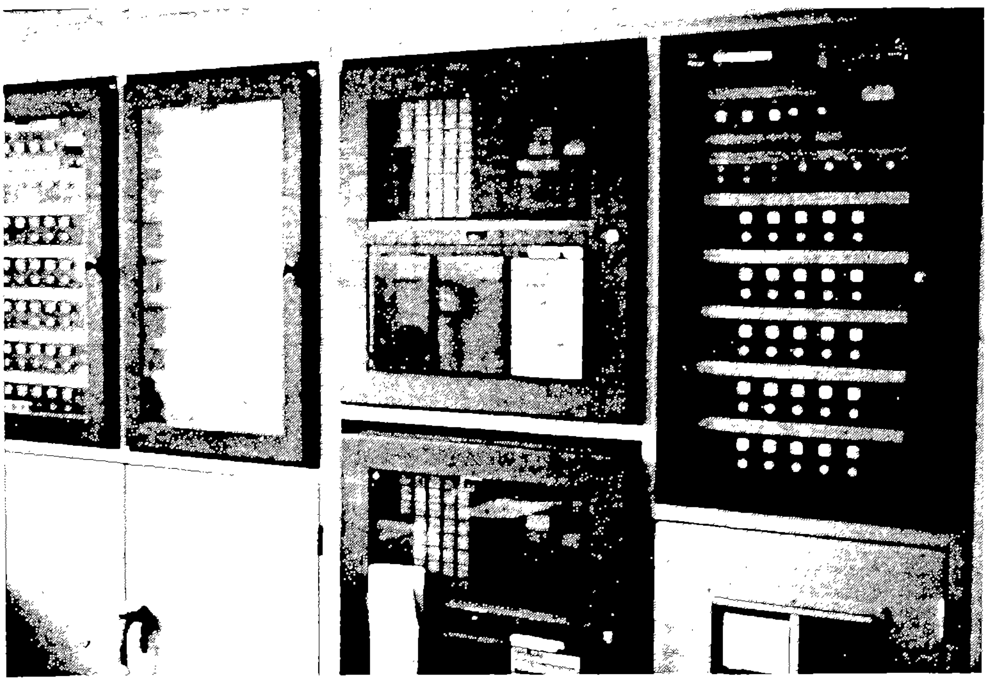


Fig. 4

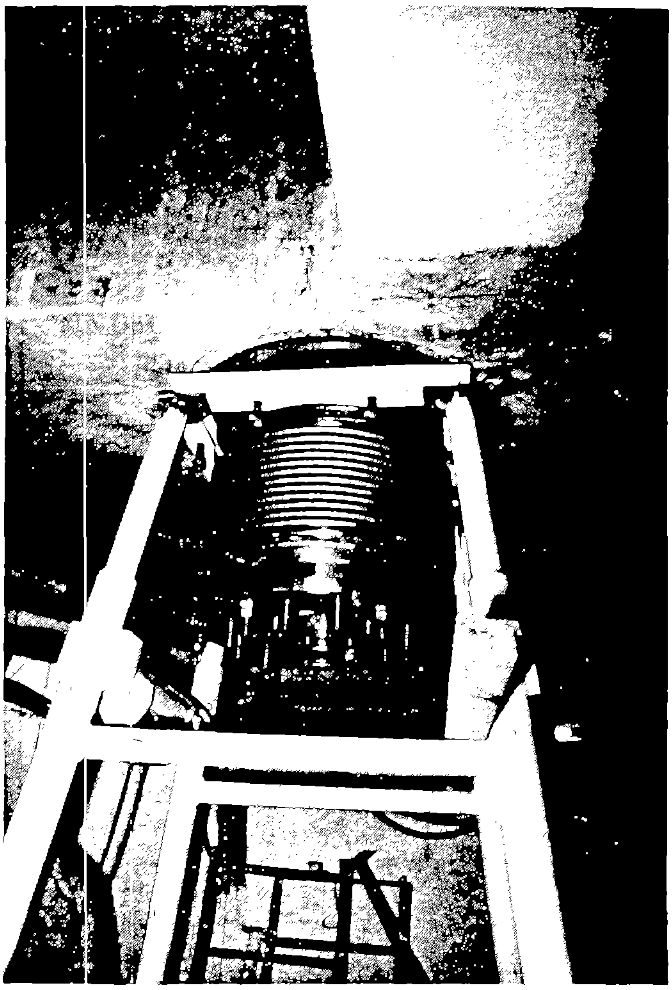


Fig. 5

Fig. 6

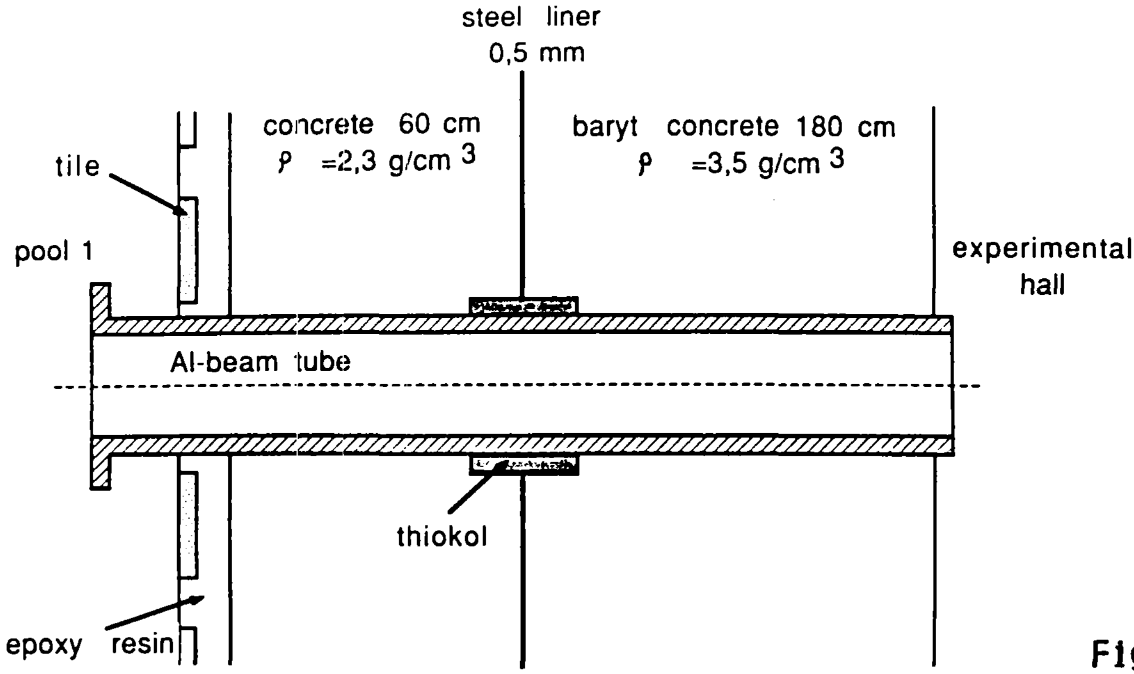

steel liner
0,5 mm
concrete 60 cm
ρ =2,3 g/cm 3
baryt concrete 180 cm
ρ =3,5 g/cm 3
tile
pool 1
experimental
hall
Al-beam tube
thiokol
epoxy resin

Fig. 7

Fig. 8

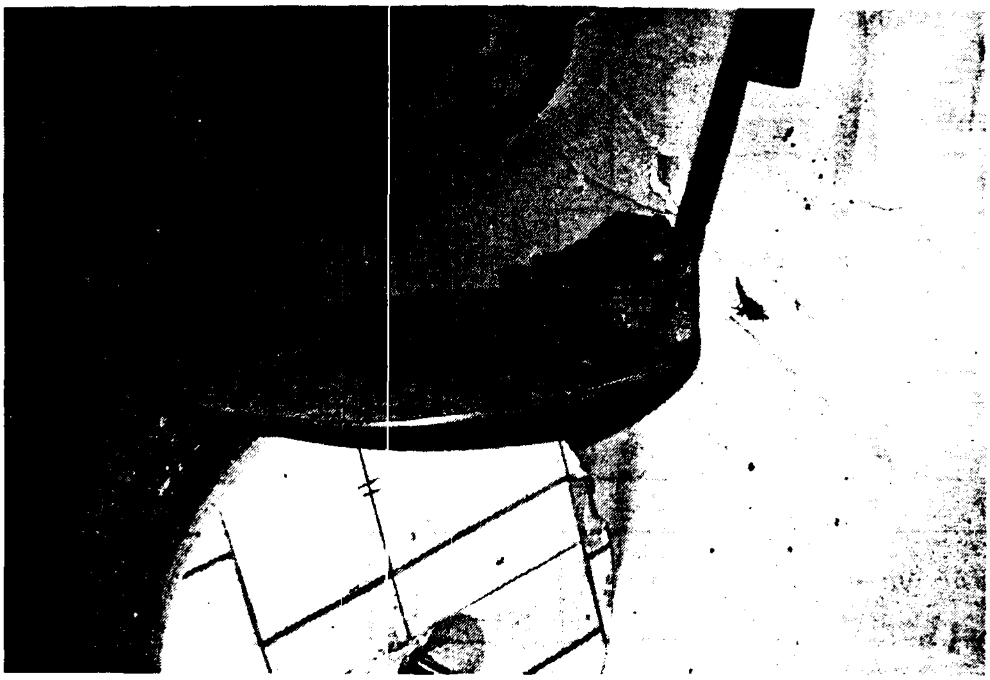


Fig. 9

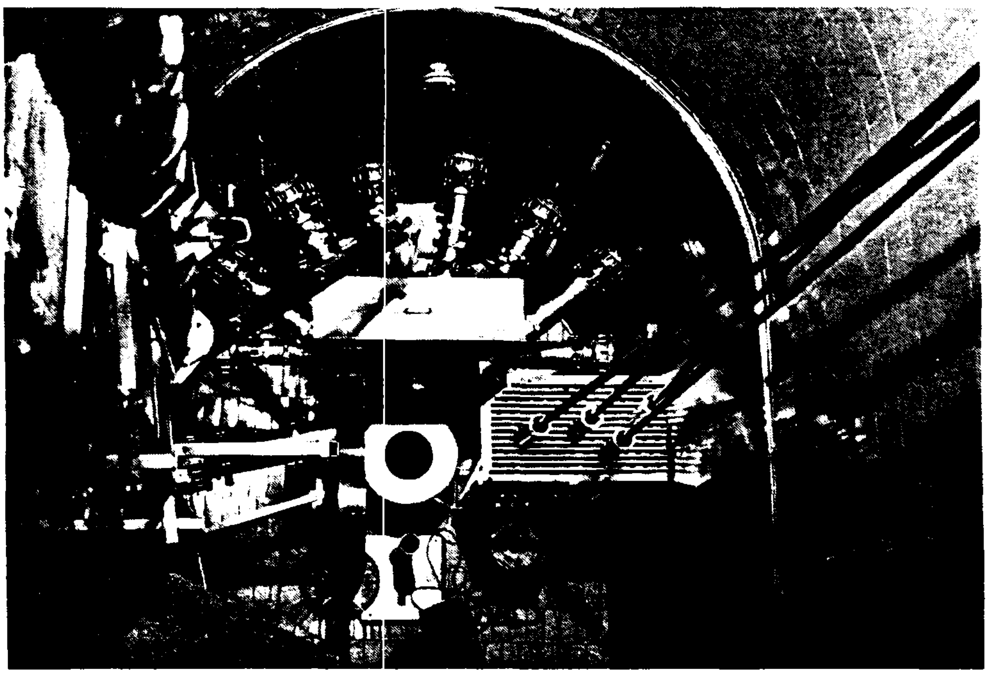


Fig. 10

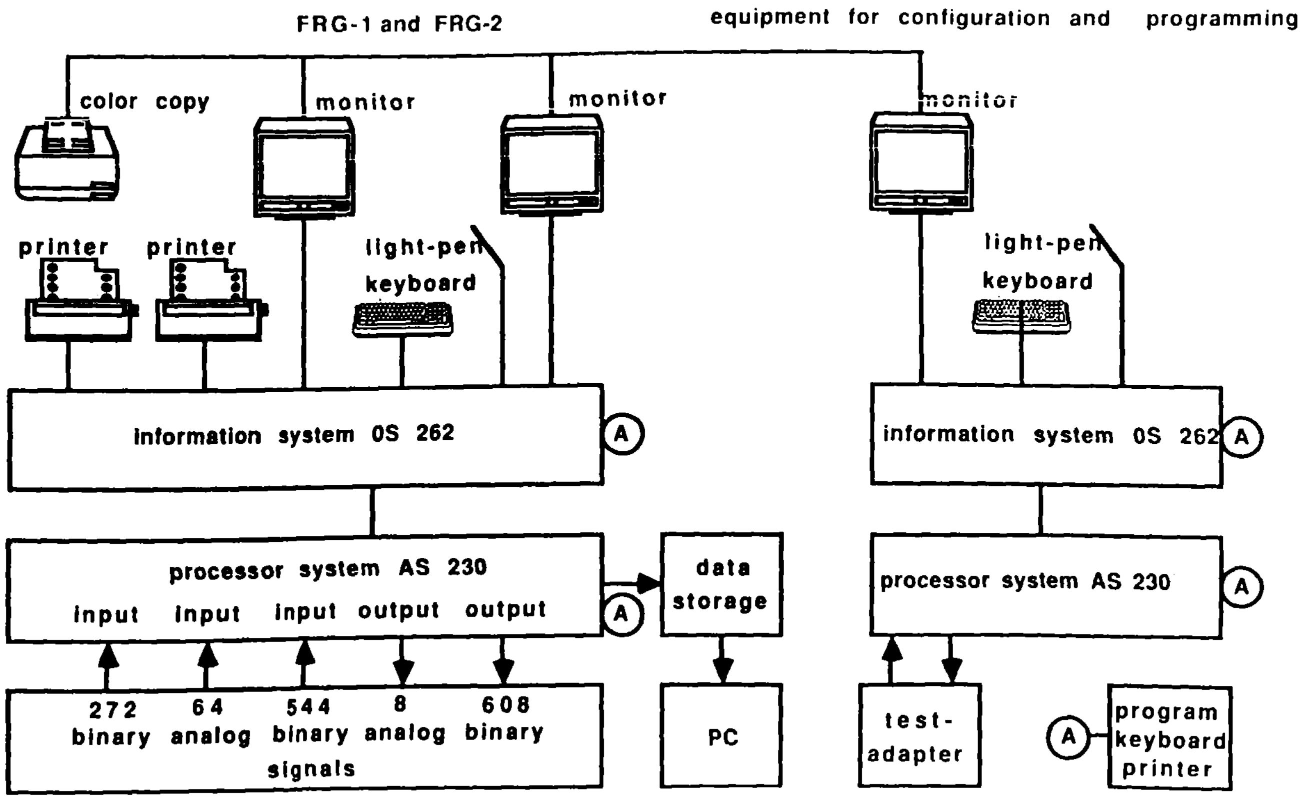
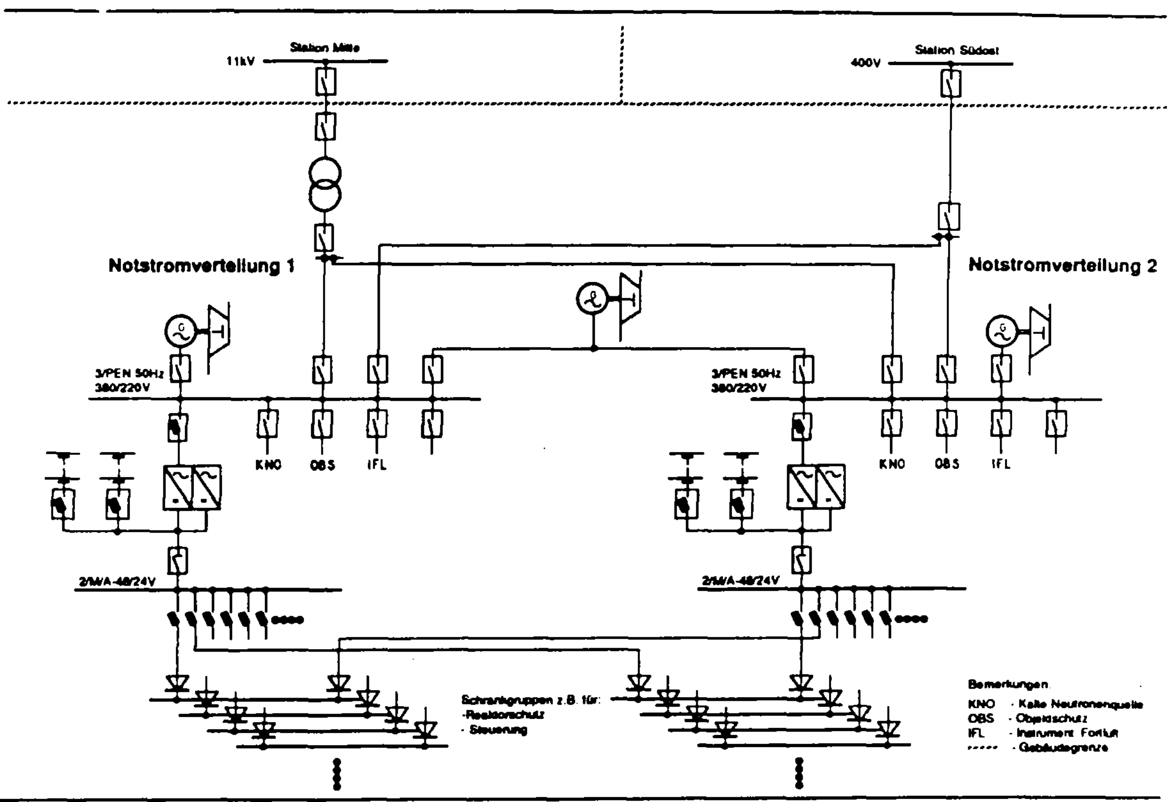

FRG-1 and FRG-2
equipment for configuration and programming
color copy
monitor
monitor
monitor
printer
printer
light-pen
keyboard
light-pen
keyboard
information system OS 262
A
information system OS 262
A
processor system AS 230
input input input output output
A
data storage
processor system AS 230
A
272 binary
64 analog
544 binary
8 analog
608 binary
signals
PC
test-adapter
A
program keyboard printer

Fig. 11



GKSS- Geesthacht, Übersichtsschaltplan-Notstromanlagen

Fig. 12