FINAL DESIGN PROPOSAL FOR A DIAGNOSTIC KICKER FOR THE KFA

JULICH COSY PROJECT

K.D. Metzmacher
L. Sermeus

SUMMARY

This proposal describes the design and expected performance of a diagnostic kicker system for the KFA Jülich COSY project.

The design is based on a bakeable, single turn, lumped inductance window frame magnet, situated in UHV machine vacuum.

The non-terminated (short-circuited) magnet will be pulsed from a 12.5 Ω cable PFN, resonantly charged to ~33 kV and discharged via appropriately timed main and dump thyatron switches.

Outlined are also the interfaces needed with the different COSY services, timescale, manpower and cost.
LIST OF CONTENTS

SUMMARY

1. INTRODUCTION

2. DESIGN PROPOSAL
   2.1 General description
      2.1.1 Slow time domain – PFN charging
      2.1.2 Fast time domain – Magnet current pulse generation
   2.2 Magnet
   2.3 Switches and related high voltage equipment
   2.4 Electronics

3. Interfaces with COSY services

4. Time scale – Milestone planning

5. Cost estimate – Material, Manpower

LIST OF FIGURES AND TABLES

Fig. 1. Schematic of pulse generator with magnet.
Fig. 2. Simplified pulsed resonant charging power supply.
Fig. 3. Bewley lattice diagram and current at different locations.
Fig. 4. Side view of magnet.
Fig. 5. Sketch of vacuum tank assembly cross-section, connection below tank.
Fig. 6. Sketch of vacuum tank assembly cross-section, connection sideways.
Fig. 7. Magnetic circuit cross-section with POISSON results.
Fig. 8. Equivalent circuit used for SPICE simulations.
Fig. 9. jBd1 and magnet current overlaid.
Fig. 10. Interfaces with COSY services

Table 1 COSY design requirement and parameter list.
Table 2 Magnet design parameter and performance list.
Table 3 Pulse generator parameter list.
1. INTRODUCTION

In April 1988 CERN agreed to a request by KFA Jülich management to design, manufacture and deliver a turn-key diagnostic kicker system for the COSY project.

The main purpose of the kicker is to kick a COSY pencil beam, which will be used as a diagnostic tool to explore the ring aperture. This has to be performed at different beam energies, thus the jBdl and the pulse length must be variable over a wide range.

The kicker system described is largely based on proven designs, existing technology and hardware and experience with similar equipment in use at CERN. This experience fully supports the notion that the kicker magnet, its high voltage power supply and low level electronics should be regarded as a non divisible system.

The following proposal is based on specifications received from KFA¹ and on discussions principally with A. Hardt of COSY.

2. DESIGN PROPOSAL

2.1 General description

A simplified schematic of the proposed system configuration, Fig. 1, shows the principal items responsible for the generation of the fast current pulse needed for the magnet excitation.

It is proposed to package the equipment such that the two thyratron switches together with much of their ancillary equipment and the terminator are in a transformer oil (Shell Diala C) filled housing which is directly mounted on the high voltage bushing of the HT transformer. The assembly will be mounted on wheels and can thus be positioned conveniently.

¹) See an excerpt in Table 1.
The PFN will be standard, high quality, commercially available RG 220 U cable, four cables in parallel providing the system impedance of 12.5 Ω. The cable lengths will be stored, two each on one metallic cable drum, such that all four ends are accessible for at least 10 m. The transmission cable will be identical to the PFN cable. All cable ends will be fitted with LEMO HT 6 series plugs.

The heat generated (principally by the thyratron cathode and reservoir heaters) will be dissipated by an oil-water heat exchanger inside the switch tank with external quick disconnect couplings.

The switch tank will be supplied from 2 racks which contain all other equipment necessary for the operation of the kicker, such as controls, timing, protection and the primary part of resonant power supply.

The magnet will be placed in a vacuum vessel. It will be fully bakeable, as well as its coaxial high voltage feedthrough, to 300°C (at 50°C/hour) in situ. Electrical connections are made via an SF₆ filled connection box, which must be taken off the vacuum tank wall before bake-outs.

The basic operation of the equipment is in two distinct phases and can be described as follows:

2.1.1 Slow Time Domain - PFN Charging

The operation of the commanded resonant PFN charging is well known and described². It suffices here to mention that (see Fig. 2) the continuously charged primary capacitor resonates part of its energy into the secondary capacitor (PFN capacitance) via the stray inductance of the high voltage transformer when the circuit is closed by the commanded SCR switch. The charging current waveform is close to a half sine-wave of a duration of ~4 ms and the PFN is

charged to twice the pulse voltage. The PPN remains charged after the HT diode cuts off the resonance and its voltage will be acquired before it is discharged by the fast thyatron switches. (There are also other transient phenomena after the diode cut-off; it takes ~50 ms before these have settled and the transformer can be re-used). The transformer core is pre-biased by a tertiary d.c. bias circuit to adjust core recovery and improve the use of the magnetic circuit.

2.1.2 Fast Time Domain - Magnet Current Pulse Generation

Referring to Fig. 1, the generation of the fast current pulse can be described with the help of the Bewley lattice diagram in Fig. 3. The PPN is presumed to be charged to twice the pulse voltage and the main-switch is triggered first, at t=0. The forward current wave generated by the main-switch travels towards the magnet and is there fully reflected, thus doubling the magnet current. This wave is then absorbed in the dump-switch terminator, provided the dump-switch is conducting before it arrives.

The current switching-off wave is generated by the closure of the dump-switch. This wave is also fully reflected by the magnet and is, as the previous wave, absorbed by the dump-switch terminating resistor. The PPN is then completely discharged and ready for recharge.

2.2 Magnet

The maximum deflection of 1 mrad at 3.6 GeV/c can be achieved with adequate rise-time using one lumped inductance window frame magnet module. Magnet excitation is with a current of 2.6 kA in a single turn conductor. The conductor is pulsed with positive voltage and one end is grounded inside the vacuum tank. This permits the use of only one high voltage vacuum feedthrough; however, kick reversal is not possible.

The window frame magnetic circuit will be split to reduce the longitudinal beam coupling. To further reduce the beam coupling it is proposed to install a pair of horizontal shielding plates inside
the magnet aperture. Thin ceramic (97% Al₂O₃) plates will be used as substrates for a semiconductive layer of 10 Ω/square resistivity which will act as an image current passage. The conductive layer must then be connected to the vacuum pipe/tank in a suitable way. The proposed solution is to hold the ceramic plates with flexible RF-contacts mounted to the magnet frame such that rigid surfaces are presented for the connection of coupling pieces between the frame and adjacent vacuum chamber walls, as indicated in Fig. 4, which gives a sketch of a side view of the magnet.

The magnet will be loaded into the tank with a special, pre-balanced lifting jig, so that it can be horizontally introduced into the tank and then lowered onto its three support feet. It is common to assure alignment of the vacuum tank with respect to the magnet aperture via tight tolerancing of mechanical dimensions and possibly with shimming. For magnet aperture to beam alignment, the aperture is usually precisely optically referred to targets mounted on top of the vacuum tank. Slight mis-alignments with respect to the adjacent vacuum chambers are absorbed by bellows.

The magnet will be excited from the high voltage pulse generator via four RG 220 U cables in parallel. The interface between transmission cables and high voltage vacuum feedthrough will be a cylindrical enclosure, filled with SF₆ at 3 atm for insulation purposes. This enclosure will contain a peaking capacitor (electrically in parallel with the magnet inductance). The purpose of this capacitor is to obtain the best compromise between kick rise- and fall-time and flat top and after pulse ripple. Furthermore, a precise current transformer (Pearson CT) will be mounted inside this enclosure to permit magnet current measurement and thus will also allow precise kick measurement.

The connection cylinder is directly bolted onto the flange carrying the HT feedthrough and is sealed with a rubber O-ring. Clearly, for every bake-out the transmission cables have to be disconnected from the interface before it is itself taken off the vacuum tank.
We propose two ways in which the connection box could be connected to the vacuum tank:

1. Vertically underneath the tank, as shown in Fig. 5. Possible disadvantages are difficulty of access and the vacuum pump above the tank may obstruct geometrical alignment.

2. Sideways, either radially interior or exterior with respect to the COSY ring centre. This view is sketched in Fig. 6. We prefer this solution because it provides easier access to the electrical connections (including crane access). Another variant of this solution is to put the cable input vertically downwards into the connection box; the radial obstruction (presented by the cable sticking out sideways) can thus be reduced.

The magnetic field calculation was obtained with the POISSON program. The predicted performance of field uniformity across the magnet aperture is shown in Fig. 7, where it can be seen to fall well within the limits requested.

The electrical pulse generator - magnet performance was calculated with the SPICE program, using the equivalent circuit shown in Fig. 8. The magnet current and JBDL waveforms are shown in Fig. 9. It shows that in fact the JBDL is tracking the current very well, confirming that the CT signal will be in good agreement with the kick. This signal will also serve for correct synchronisation between kick and COSY beam.

The materials used for magnet construction proper will all be in the UHV of the COSY ring. They will be compatible with current CERN UHV practice and be bakeable to at least 300°C. Prior to assembly all materials will be pre-treated and the whole magnet assembly will be baked at 300°C during 24 hours in one of the CERN test vacuum tanks.

A maximum temperature gradient of 50°C per hour must not be exceeded.
The following materials will be used in vacuum:

97% Al₂O₃
AlMg₃
Stainless steel 304L or 316LN
Monel
8G11 Philips Ferrite

In case the final vacuum tank is not available at CERN, it is proposed to subject the magnet to its high voltage tests in one of the CERN test tanks, which will be suitably equipped to permit the JBDL performance measurements.

The magnet design parameters and performance are listed in Table 2.

2.3 Switches and related high voltage equipment

Referring to Figs. 1 and 3, we see that the main-switch thyatron operates in a floating cathode mode. This requires the thyatron supplies (heater, reservoir and trigger) to be isolated from ground potential. As the pulse generator is working into an (inductive) short-circuit, this means the voltage at the main-switch cathode with respect to ground can vary between ±40 kV. We propose to use one 220 V/220 V isolating transformer each for the reservoir and the heater. This permits the adjustment of the reservoir voltage from the location of the electronics racks, where the monitoring is also located. The thyatron chosen for the main-switch is an EEV CX 1154 A, a single stage thyatron rated 40 kV and 3 kA.

The dump-switch thyatron works in a grounded cathode mode. In Fig. 3 it is shown that this switch is required to pass full negative current, because of the short-circuited magnet. This calls for a special type of switch. We propose to use an EEV CX 1668 A thyatron, which is the hollow anode version of a CX 1168 A. This thyatron is rated 65 kV and ±3 kA. It will easily pass the reverse current, provided it conducts some positive current immediately before. The reservoir control of this tube will also be located in
the electronics racks.

Because of the requirement to first pass positive current in the dump-switch, we will provide a special trigger facility which will automatically generate a dump-switch trigger after a main-switch trigger such that this condition is fulfilled. It is clearly evident from Fig. 3, that by judicious timing of the two switches the pulse length can be freely adjusted between zero and almost twice the PFN length (there must always be some positive current in the dump-switch and the above mentioned facility will assure that timing manipulations cannot endanger correct operation).

The switches will be mounted in closely fitting, coaxial, low inductance housings as well as the dump-switch terminating resistor. This equipment, likely to require interventions, is readily accessible to enable rapid servicing, even though it is fully oil immersed in the hermetically closed switch tank.

To enable testing at high voltage without the magnet being available (e.g. no vacuum, etc.), CERN will provide convenient dummy loads, which may be used either locally or close to the vacuum tank. They will consist of a 12.5 Ω resistor and a 680 nH inductor.

The parameters for the pulse generator are collected in Table 3.

2.4  Electronics

The following equipment units will comprise the electronics located in the two electronics racks:

Three phase distribution
Module control + 220 V stabiliser
D.C. stabilised power supply
Primary capacitor bank
Low voltage, SCR, Bias, Primary over-voltage protection
Interlock
Voltage measure and secondary protection
Primary current protection
Thyratron protection
Drift stabiliser
Programmable dual fine delay
Quad delay
Dual trigger pulse amplifier
Timing control and protection
Test timing
Local/remote control interface
Monitoring panel
Counter unit
CIM crate (possibly)

3. **INTERFACES WITH COSY SERVICES**

In Fig. 10 we show a synopsis of the different services with which we think the kicker system interfaces.

1. **Electrical Power.** The requirement is for a 220 V 3-phase star supply R,S,T, Neutral and ground with 25 A fusing on each phase. The output must be via a key-lockable circuit breaker.

2. **Cooling Water.** Normal tap water with a flow restrictor or pressure reducer. Flow rate \( \sim 5 \) l/min, \( T \leq 25^\circ C \).

3. **Controls.** The equipment will be fully controllable locally manually or via a remote computer to command and acquire the power status, reset and kick on/off. The fine timing setting of main- and dump-switch will by a programmable dual fine delay unit.

4. **Timing.** Timing pulses are required for Clear, SCR, MS and DS, such that the Clear initialising signal is \(-100 \text{ ms before the SCR pulse; the SCR initiates the PFM charging, which should start \(-7 \text{ ms before Kick. The MS and DS pulses trigger the corresponding thyratrons. If the resolution between these two pulses is not sufficient, only one fast trigger pulse could be used and the relative adjustment be made via the programmable dual fine delay unit. To avoid hardware malfunctioning due to incorrect external}}\)
timing, the timing will be checked for acceptability or otherwise rejected with a timing fault indication. CERN will provide a test timing generator which will be useful for maintenance, testing and internal synchronisation independently of the general timing system.

5. **Signal observation system (SOS).** We consider the magnet current waveform as the most important signal. It is essential for pulse-length and quality control and beam synchronisation. However, in case of malfunctioning of the equipment magnet current may not be available. With no access to the equipment some power supply signals may be useful and will be provided.

6. **Mechanical.** CERN strongly suggests that KFA design and procure the vacuum tank. The interface between magnet, HT vacuum feedthrough, shielding plate connections and HT connection box can be unambiguously defined with a minimum of subsequent interference. This would leave all ancillary equipment related to the vacuum tank, such as adjacent equipment interference, flanges, supports, VAC-ion pump, geometrical alignment fixtures, heating jackets and their electrical controls, manufacture etc. in the hands of KFA. This is clearly desirable.

7. **Beam.** We have proposed in paragraph 2.2 the use of horizontal shielding plates to reduce the longitudinal beam coupling. It is not clear to us, whether these image current passages are really needed in view of the single, very long bunch in COSY. Furthermore, if this fixture is necessary, a compromise must be found between acceptable kick rise- and fall-times as well as flat-top performance and the effect on the beam. This is likely to be seen only with the COSY beam.

8. **Floor Space.** The pulse generator hardware consists basically of two electronics racks, two PFN cable drums (+1.5 m x 1.3 m) and the switch tank. They can be quite arbitrarily positioned, provided there is access to the racks and the switch tank. We estimate a floor surface of ~12 m² is sufficient.
### 4. TIMESCALE - MILESTONE (★) PLANNING

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start</td>
<td></td>
<td>Finish</td>
</tr>
<tr>
<td>Specification</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design proposal published + accepted</td>
<td></td>
<td>★ 16.1.</td>
<td></td>
</tr>
<tr>
<td>Prototype pulse generator HT test</td>
<td></td>
<td>★ 31.5</td>
<td></td>
</tr>
<tr>
<td>Magnet, connection chamber design vacuum tank interference agreed</td>
<td></td>
<td>★ 30.6</td>
<td></td>
</tr>
<tr>
<td>Magnet low voltage test</td>
<td></td>
<td></td>
<td>★ 5.4</td>
</tr>
<tr>
<td>Magnet bake-out</td>
<td></td>
<td>★ 21.5</td>
<td></td>
</tr>
<tr>
<td>Magnet HT test in CERN tank pulsed from final pulse generator</td>
<td></td>
<td>★ 18.6</td>
<td></td>
</tr>
<tr>
<td>Acceptance tests at CERN</td>
<td></td>
<td></td>
<td>★ 17.9</td>
</tr>
<tr>
<td>Ready for shipment</td>
<td></td>
<td></td>
<td>★ 26.11</td>
</tr>
</tbody>
</table>
5. **COST**

<table>
<thead>
<tr>
<th>Materials</th>
<th>kFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switches</td>
<td>14</td>
</tr>
<tr>
<td>HT cables, drums, connectors</td>
<td>60</td>
</tr>
<tr>
<td>HT transfo</td>
<td>10</td>
</tr>
<tr>
<td>HT tank</td>
<td>10</td>
</tr>
<tr>
<td>Ferrites</td>
<td>14</td>
</tr>
<tr>
<td>Shielding plates</td>
<td>10</td>
</tr>
<tr>
<td>Small pieces</td>
<td>10</td>
</tr>
<tr>
<td>Connection box, dummy loads</td>
<td>10</td>
</tr>
<tr>
<td>Electronic racks, cabling</td>
<td>60</td>
</tr>
<tr>
<td>Measuring devices</td>
<td>4</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>230</td>
</tr>
</tbody>
</table>

**Manpower**

| Design study                           | 25  |
| Engineering, supervision               | 40  |
| External labour, drawings etc.         | 100 |
|                                        |    |
|                                        | 165 |

**Materials + Manpower**

| Materials + Manpower                    | 395 kFS |

**Distribution:**

PS/RF Kicker Magnet Section
R. Billinge
D. Blechschmidt
D.C. Fiander
E. Jones
KFA Jülich
Fig. 1  Schematic of pulse generator with magnet

Fig. 2  Simplified pulsed resonant charging power supply
Fig. 3 Bewley lattice diagram and current at different locations
Fig. 4. Side view of magnet

COSY & KICKER PROPOSAL

Scale 1/2

L.S. 22/11/88
Fig. 6 Sketch of vacuum tank assembly cross-section, Connection side-ways

Connection box
SF6 & bars
To take off for bake-out

Ion pump

Weight from here ~ 45 kg

A kicker
COSY Proposal
Scale 1/5
Fig. 7. Magnetic circuit cross-section with POISSON results
Fig. 8 Equivalent circuit used for SPICE simulations
Fig. 9. $\beta d\ell$ and magnet current overlaid
Fig. 10. Interfaces with COSY services
## TABLE 1. COSY design requirement + parameter list

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap height</td>
<td>96</td>
<td>mm</td>
</tr>
<tr>
<td>Magnet gap width</td>
<td>140</td>
<td>mm</td>
</tr>
<tr>
<td>Effective length</td>
<td>&gt; 800</td>
<td>mm</td>
</tr>
<tr>
<td>Max. deflection angle θ</td>
<td>1</td>
<td>mrad horizontal</td>
</tr>
<tr>
<td>Non reversible</td>
<td>3.6</td>
<td>GeV/c</td>
</tr>
<tr>
<td>Corresponding to</td>
<td>120</td>
<td>Gm</td>
</tr>
<tr>
<td>[B_{dl}\max/</td>
<td>B_{dl}\min</td>
<td></td>
</tr>
<tr>
<td>ΔB/B in aperture</td>
<td>-2</td>
<td>%</td>
</tr>
<tr>
<td>Flat top + after pulse ripple</td>
<td>&gt; ±5</td>
<td>%</td>
</tr>
<tr>
<td>Risetime</td>
<td>&lt; 600</td>
<td>ns</td>
</tr>
<tr>
<td>Falltime (5-95)%A</td>
<td>&lt; 200</td>
<td>ns</td>
</tr>
<tr>
<td>Flat-top</td>
<td>0.22 - 1.4</td>
<td>μs</td>
</tr>
<tr>
<td>Timing jitter</td>
<td>&lt; 50</td>
<td>ns</td>
</tr>
<tr>
<td>Pulse repetition rate</td>
<td>&gt; 0.2</td>
<td>Hz</td>
</tr>
<tr>
<td>Transmission cable length</td>
<td>~ 20</td>
<td>m</td>
</tr>
</tbody>
</table>

### No access during machine operation

### Position in COSY ring between 105.24 - 110.14 m

### Signals for observation 50 Ω/10 V

<table>
<thead>
<tr>
<th>No. of timing pulses</th>
<th>4</th>
<th>Cycle, SCR, MS, DS</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Control Commands</td>
<td>5</td>
<td>Power ON - OFF, Kick ON - OFF, Reset</td>
</tr>
<tr>
<td>Number of magnets/section</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Lumped inductance</td>
<td></td>
</tr>
<tr>
<td><strong>Construction</strong></td>
<td>Split window frame, single turn grounded at feedthrough bakeable to 300°C in situ</td>
<td></td>
</tr>
<tr>
<td><strong>w</strong></td>
<td>mm</td>
<td>144</td>
</tr>
<tr>
<td><strong>Aperture h</strong></td>
<td>mm</td>
<td>107</td>
</tr>
<tr>
<td><strong>l</strong></td>
<td>mm</td>
<td>340</td>
</tr>
<tr>
<td><strong>Effective length l_{eff}</strong></td>
<td>mm</td>
<td>400</td>
</tr>
<tr>
<td><strong>Inductance L</strong></td>
<td>nH</td>
<td>676.5</td>
</tr>
<tr>
<td><strong>Z₀ PFN</strong></td>
<td>Ω</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>V_{PFN}</strong></td>
<td>kV</td>
<td>32.6</td>
</tr>
<tr>
<td><strong>I Magnet</strong></td>
<td>kA</td>
<td>2.6</td>
</tr>
<tr>
<td>**|B</td>
<td>d</td>
<td>l</td>
</tr>
<tr>
<td><strong>Kick direction</strong></td>
<td>-</td>
<td>Horizontal, non reversible</td>
</tr>
<tr>
<td><strong>P</strong></td>
<td>GeV/c</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>θ</strong></td>
<td>mrad</td>
<td>1</td>
</tr>
<tr>
<td><strong>τ</strong></td>
<td>ns</td>
<td>54</td>
</tr>
<tr>
<td><strong>B_{air}</strong></td>
<td>mT</td>
<td>30</td>
</tr>
<tr>
<td><strong>B_{ferrite}</strong></td>
<td>mT</td>
<td>150</td>
</tr>
<tr>
<td><strong>w_{ferrite}</strong></td>
<td>mm</td>
<td>15</td>
</tr>
<tr>
<td><strong>V_{ferrite}</strong></td>
<td>cm³</td>
<td>3230</td>
</tr>
<tr>
<td><strong>Ferrite type</strong></td>
<td></td>
<td>8C11 Philips</td>
</tr>
<tr>
<td><strong>M_{ferrite}</strong></td>
<td>kg</td>
<td>16.6</td>
</tr>
<tr>
<td><strong>M_{magnet}</strong></td>
<td>kg</td>
<td>- 45</td>
</tr>
<tr>
<td>**|B</td>
<td>d</td>
<td>l</td>
</tr>
<tr>
<td><strong>Peaking capacitor</strong></td>
<td>pF</td>
<td>2200</td>
</tr>
<tr>
<td><strong>Rise/Fall time (5 - 95)%</strong></td>
<td>ns</td>
<td>165</td>
</tr>
<tr>
<td><strong>Kick ripple</strong></td>
<td>%</td>
<td>± 0.8</td>
</tr>
<tr>
<td><strong>Shielding plates layer resistance</strong></td>
<td>Q/square</td>
<td>10</td>
</tr>
<tr>
<td><strong>PFN</strong></td>
<td><strong>Impedance</strong></td>
<td><strong>Z₀ = 12.5 Ω</strong></td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td><strong>Cable type</strong></td>
<td>RG 220 U 50Ω</td>
</tr>
<tr>
<td></td>
<td><strong>Cable number</strong></td>
<td>4 in parallel</td>
</tr>
<tr>
<td></td>
<td><strong>Length</strong></td>
<td>175 m</td>
</tr>
<tr>
<td><strong>Main switch</strong></td>
<td><strong>Type EEV CX 1154 A (1 gap)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Max. voltage</strong>: 40 kV</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Max. current</strong>: 3000 A</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Risetime</strong>: ~ 30 ns (10-90)%</td>
<td></td>
</tr>
<tr>
<td><strong>Dump switch</strong></td>
<td><strong>Type EEV CX 1668 (hollow anode, 2 gaps)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Max. voltage</strong>: 65 kV</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Max. current</strong>: 3000 A</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Rise time</strong>: 30 ns (10 - 90)%</td>
<td></td>
</tr>
<tr>
<td><strong>Terminator</strong></td>
<td><strong>Construction</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>12.5 Ω Carbon mass resistor disks</strong></td>
<td></td>
</tr>
<tr>
<td><strong>HT pulse transformer</strong></td>
<td><strong>Moser Glaser PAE 35/5</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Insulation cooling</strong></td>
<td><strong>Oil Shell DIALA C</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Heat exchanger oil - water inside the tank</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>5dl/min.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Overall dimensions</strong></td>
<td><strong>of the tank</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>incl. HT transf.</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>l</strong></td>
<td>-.65 m</td>
</tr>
<tr>
<td></td>
<td><strong>w</strong></td>
<td>-.65 m</td>
</tr>
<tr>
<td></td>
<td><strong>h</strong></td>
<td>-1.5 m</td>
</tr>
<tr>
<td><strong>PFN voltage</strong></td>
<td><strong>max.</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>min.</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>40 kV</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>- 2 kV</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Flat top length</strong></td>
<td><strong>Adj. 0 - 1.4 μs</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Rep rate</strong></td>
<td><strong>1 Hz</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td><strong>~ 20 m same as PFN</strong></td>
<td></td>
</tr>
</tbody>
</table>